This study examined the dynamics of student, teaching assistant (TA), and faculty learning in relationship to implementation of a genetic technologies project in a university introductory biology course. Research focused on the types of learning that occurred and the various factors impacting that learning.

Study participants included 25 undergraduate non-science majors, five graduate TAs, and two faculty, including the researcher participant. Qualitative methodologies were employed to address the exploratory nature of the research questions, and included a wide variety of data collection techniques. Variables related to learning were identified and categorized to develop a hypothesis of learning in the studied course.

Students, TAs, and faculty demonstrated developing diverse and remarkably similar cognitive outcomes, learning strategies, and changes within the affective domain. Differences existed in the temporal displacement of learning, as well as breadth and depth of skills and understandings. Similar internal and external factors also impacted student, TA, and faculty learning. Interactions among the three subject groups were frequent, related to common topics of interest and corrections of curricular inadequacies, and were initiated by members of each group.

Emerging categories of data were developed into a hypothesis of learning which incorporated (1) the combination of pre-existing subject and situational conditions with (2) characteristics of innovation, and (3) the resulting learning community. Shifting what was being learned and how it was being taught created opportunities for conflict and uncertainty. Through resolution of these concerns, distinctions between course teachers and learners became blurred. This study suggests that all participants, with their widely varying backgrounds, interests, and abilities, contributed to development of the learning
community when both content and instruction were being altered. Factors such as large
class size, lectures, and TA teaching appeared to add to the diversity of learning
contexts of the course and positively impacted the breadth of overall learning outcomes.

This study suggests that an incredible diversity of learning can occur in a small
subset of subjects over a brief period of time. This complexity of learning sounds a
cautionary note that innovation may not be effectively assessed through the measure of
a few discrete aspects of learning.
STUDENT, TEACHING ASSISTANT, AND FACULTY LEARNING DURING INNOVATION IN AN INTRODUCTORY BIOLOGY COURSE

by
Lesley M. Blair

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APPROVED:

Redacted for privacy

Major Professor, representing Science Education

Redacted for privacy

Chair of Department of Science and Mathematics Education

Redacted for privacy

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Lesley M. Blair, Author
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CHAPTER 1: THE PROBLEM

Introduction

This study seeks to describe student, teaching assistant (TA), and faculty learning occurring in the context of innovation within an undergraduate biology course. Currently there is a growing perception by those with direct stakes in higher education, including university administrators, science faculty, students, and science educators, that introductory science courses have numerous inadequacies. In order to explain the significance of this study, it is important to understand the perceived problems that are driving change in undergraduate science curricula.

Perceived Problem: Introductory University Science Courses Inadequate

Throughout the 1990s there was increasing call for reforming American undergraduate education. For the purposes of this text, focus is placed on the university, as opposed to other institutions of higher education, such as two-year and four-year colleges. The university context has been selected as a more common setting for large introductory science courses staffed by research-oriented faculty and graduate TAs. Within the university setting, national agendas stressing higher education opportunities for all students have coincided with changes in funding and resulting fluxes in staffing, students, and curricula; advancements in science and technology content; fundamental shifts in student needs; and changes in standards for K-12 science education. Following a general overview of change in higher education, emphasis is placed on a review on the role of introductory science courses in K-12 science education.
Adapting to Changes in Higher Education

In 1997, then President William Jefferson Clinton, voiced a fundamental shift occurring in the national view of educational opportunity, that all citizens should have access to higher education.

Today, more than ever before in our history, education is the fault line between those who will prosper in the new economy and those who will not. Most of today's good jobs require more skills and training than a high school diploma affords. Over half the new jobs created in the last three years have been managerial and professional jobs requiring higher-level skills. Fifteen years ago the typical worker with a college degree made 38 percent more than a worker with a high school diploma. Today, that figure is 73 percent. People who finish two years of college earn 20 percent more each year and a quarter of a million dollars more than their high school counterparts over a lifetime. We must make two years of college - the 13th and 14th years of education - as universal for young Americans as the first 12 are today. And, we must make college more affordable for all Americans. (Clinton, 1997 [p.1])

Swenson (1998) discusses this shift as a departure from considering learning as purely "educating," to incorporating the concept of "training."

"We're no longer educating genteel elites; our mandate now is to educate a significant portion of our population, not only for life but to make a living too." (Swenson, 1998 [p. 37])

Although national interest has remained in widening student access to higher education, many universities are faced with inadequate infrastructures, including facilities and student services, to accommodate rapidly expanding freshmen classes (Benjamin, 1998).

Many universities, public and private, have attempted to offset relative decreases in traditional funding with practices modeled from the business community. This has led to increased discussion of cost-effective practices and product-driven outcomes. As recently discussed in an essay from the journal Science, Brown (2000) summarized the potential problems associated with monetarily-based changes to higher education.

To me, they ["privatization" and "business model"] involve an increased dependence on industry and philanthropy for operating the university; an increased amount of our resources being directed to applied or so-called practical subjects, both in teaching and in research; a propriety treatment of research results, with the commercial interest in secrecy overriding the publics' interest in free, shared knowledge; and an attempt to run the university more like a business that treats industry and students as clients.
and ourselves [faculty] as service providers with something to sell. We pay increasing attention to the immediate needs and demands of our "customers" and, as the old saw [saying] goes, "the customer is always right." (Brown, 2000, [p. 1701])

As many forecasters of educational practice predict fundamental changes in higher education, introductory science courses, which are often already working with a large number of students, limited staff, and barely adequate budgets, prepare for accommodating additional curricular constraints.

Burgeoning enrollments in undergraduate biology present colleges and universities with a dilemma: there are simply too many students for all to participate in resource-intensive research programs. (Howard Hughes Medical Institute Undergraduate Biological Sciences Education Program, 1996 [p. 29])

Additionally, science faculty continue to balance research and teaching commitments, in the face of a competitive job market.

As competition stiffens for both available research dollars and tenured faculty positions, junior faculty members feel the pressure most directly. With the tenure clock ticking, they must balance the often competing demands of research and teaching while contributing their share of service, the third traditional element of an academic career. At research-intensive institutions, research accomplishments are perceived as paramount, creating a dilemma for young faculty members who wish to excel at teaching as well as research. (Howard Hughes Medical Institute Undergraduate Biological Sciences Education Program, 1996 [p. 35])

It is commonly junior, non-tenured faculty who staff introductory science courses.

The content taught within introductory university science courses, particularly biological sciences, has increased dramatically within the past few decades. For example, in the widely adopted textbook for non-majors Biology: Life on Earth, topics covered in the 1986 First Edition (Audesirk & Audesirk, 1986) such as cell life, evolution, and botany, persist in the 2002 Sixth Edition (Audesirk & Audesirk, 2002), but have been joined by detailed emphasis on biotechnology and environmental issues.

Changes in content reflect shifting science research emphasis, current citizenry issues, and an increasing emphasis on preparing students for specific careers.

We are also asked to prepare our students more directly with the skills needed in the business world. Training in the pure sciences and humanities is taken to be obviously impractical. (Brown, 2000 [p. 1702])
To address altered content, faculty, many of who learned their introductory science decades earlier, are asked to learn new content and design courses to effectively teach that content. The Society for College Science Teachers (SCST, 1998) proposes that university teaching scholars should have many attributes, including current knowledge of the discipline and educational practice, creative scholarship related to college science teaching, contextual understanding of the discipline, competency in communication and presentation, and the ability to design effective activities. This requires additional preparation to teach in an environment of increased teaching loads and increased reliance on temporary adjunct faculty (Fulton, 2000).

Changes in content focus also have a monetary impact on introductory science courses. Many of the new content areas in the sciences are closely associated with technologies that require more expensive laboratory experiences in those courses that supplement lectures with hands-on activities. In the biological sciences, this includes computer-based ecological modeling and gene mapping techniques (Fox, 1994).

In addition to changing content, the technologies available for teaching have been changing.

For the last decade, higher education has been under attack for failing to produce graduates with skills required for success in the workplace and for active participation in a democratic society. ... The charges have been harsh and inclusive, attacking the leadership, the faculty, and the students; the curriculum; the organizational structure and infrastructure; the models for evaluation of faculty, students, and institutions; the methods of instruction; and the speed and the slowness of integrating technology. (DeZure, 2000 [p.xxii])

As universities increase recruitment efforts, diverse categories of non-traditional students, such as those with learning disabilities, of varying ages, or career expectations, begin their university experiences within large-enrollment, or “freshmen” introductory science courses.

In comparison to their counterparts of the 1960s and 1970s, undergraduates today are more racially diverse and, on average, considerably older. In fact, since the 1980s, the lion's share of college enrollment growth has come from students who might be described as nontraditional. (Levine & Cureton, 1998 [p. 14])

Additionally, undergraduate students are potentially changing due to changes in K-12 education. Many students have been exposed to alternative forms of instruction and
assessments, integrated science, and AP courses (Howard Hughes Medical Institute Precollege Science Education Program, 1993). Faculty are increasingly faced with addressing changing students needs.

Another shift relates to student expectations. Many students now view a university education as a means to a career end (Levine & Cureton, 1998). However, faculty language stresses the value of developing science literacy.

Every college campus and every high school should offer a variety of science courses aimed primarily at the nonscientists who form the great bulk of our student populations. The reason is simple: they vote. An industrialized democracy cannot survive in this scientific age unless the bulk of its population is scientifically literate. The wreckage caused by scientifically illiterate citizenry is all around us in the form of uninformed choices about energy, the environment, education, pseudoscientific pursuits, and much else. There are many other reasons, including competitiveness, jobs, culture, and the health of our own science professions. (Hobson, 2000 [p. 136])

Changes in career paths and expectations have also impacted graduate students. A survey prepared by the Pew Charitable Trust demonstrated a three-way mismatch between graduate student goals, their training, and their careers (Golde & Dore, 2001). This is related to a surplus of science doctorates, relative to full-time university faculty positions. Almost half of U.S. faculty members are part-timers, with approximately one-third working at 2-year colleges, and only one-quarter of full-time faculty members employed at research universities. Many universities are replacing tenured full-time faculty with non-tenured part-time employees. Graduate students indicate that they are not well-prepared for classroom responsibilities (Mervis, 2001). Introductory science courses are often viewed as the training ground for future faculty, as graduate students serve as TAs. However, many of these TA experiences occur with minimal institutional professional development (Gappa, 1993).

Pressures for change in introductory science classes are coming from many directions. Possibly one of the most significant is the call for close coordination between K-12 education and schools of higher education.

Preparing Future K-16 Teachers

In 2001, President George Walker Bush, elaborated on the close association between higher education and K-12 science achievement.
Among the underlying causes for the poor performance of U.S. students in the areas of math and science, three problems must be addressed - too many teachers teaching out-of-field; too few students taking advanced coursework; and too few schools offering a challenging curriculum and textbooks. The Higher Education Community recognizes that it has a vested interest in working to improve elementary and secondary math and science achievement. More than twenty states have begun to form partnerships with colleges and universities for the purpose of raising math and science standards for students, providing math and science training for teachers, and creating innovative ways to reach underserved schools. (Bush, 2001 [p. 6])

This reflected a renewed focus on K-12 science education reform, documented with guidelines for science literacy in the *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), and the *National Science Education Standards* (National Research Council [NRC], 1996a). It is widely believed that in order for these K-12 reforms to be successful, changes in undergraduate science need to occur. As explained by the National Science Foundation (NSF):

> We believe that undergraduate science, mathematics, engineering, and technology (SME&T) education is the linchpin of the entire SME&T education enterprise – for it is at the undergraduate level that prospective K-12 teachers are educated, that most of the technical work force is prepared, and the future educators and practitioners in science, mathematics, and engineering learn their fields and, in many cases, prepare for more specialized work in graduate school. (NSF, 1996a [p. 6])

In the 1990s several organizations, including the Biological Sciences Curriculum Study (BSCS, 1993) and the Coalition for Education in the Life Sciences (CELS, 1993), called for a re-examination of university life science curricula, particularly introductory courses. The urgency of this call accompanies the understanding that students entering university science courses have increasing exposure to aspects of K-12 science education reform.

As K-12 education changes, as a result not only of standards but of new emphasis on inquiry, on active learning, and with new uses of technology, students will come to undergraduate education with new expectations, increasing pressure for reform at this [university] level as well. (NSF, 1996a [p. ii])

In the context of science education reform, many undergraduate science programs are adopting new teaching methodologies, addressing the value of new technologies, and revisiting the content taught to science majors and nonmajors (Fox,
Most of these innovations focus on altering a particular aspect of the introductory course, usually the laboratory (Cooper & Robinson, 1998; Lord, 1994).

Following closely in the wake of the K-12 reform recommendations were publications specifically addressing the role of colleges and universities in K-12 reform efforts. These publications stressed the need for changing undergraduate science education. From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology (NRC, 1996b) noted “from some of the most prestigious institutions... it is possible for students to graduate with not more than six percent of their work in the sciences and technology.” Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Education, and Technology (NSF, 1996a) concluded that the goal for colleges and universities must be that

All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with methods and process of inquiry. (NSF, 1996a [p.65])

However this publication outlined numerous problems with higher education.

Too many students leave SME&T [Science, Mathematics, Engineering, & Technology] courses because they find them dull and unwelcoming. Too many new teachers enter school systems underprepared, without really understanding what science and mathematics are, and lacking the excitement and discovery and the confidence and ability to help children engage SME&T knowledge. Too many graduates go out into the workplace ill-prepared to solve real problems in a cooperative way, lacking the skills and motivation to continue learning. (NSF, 1996a [p. iii])

These publications were subsequently followed by more specific agendas for changing undergraduate science education. Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology (NRC, 1999b) outlined six visions, of which the second specifically addresses introductory science courses.

Science, mathematics, engineering, and technology (SME&T) would become an integral part of the curriculum for all undergraduate students through required introductory courses that engage all students in SME&T and their connections to society and the human condition. (NRC, 1999b [p.3])

These introductory courses were envisioned to cover concepts about the natural and human-constructed worlds, consist of laboratory and original research experiences, and
include applications and hands-on research (NRC, 1999b). Changes such as these to introductory science courses would require faculty to change aspects of their teaching.

Comprehensive improvement will require that faculty in SME&T departments and schools of education collaborate to demonstrate the connection among the disciplines, promote the integration of research and education, and strengthen the pedagogical quality of introductory courses for all undergraduates. (NSF, 1996b [p.3])

NRC (1996b) discussed potential difficulties of implementing reform recommendations.

Innovations are rarely coordinated, so as to build on each other to produce a self-sustaining and expanding community of innovators. Individual programs are continually at a risk from a loss of key personnel or funding. Innovations that could make a difference in other settings remain confined to a single institution, department, or instructor. The contrast with scientific innovation is particularly striking. Scientific knowledge is quickly shared and extended, whereas knowledge about teaching and learning is often neglected or lost. (NRC. 1996b [p. 32])

NRC and other organizations acknowledged that there are numerous factors that threaten successful implementation of science education reform in the university science classroom.

In the context of the various reform recommendations, agencies attempted to compile examples of innovative undergraduate programs at research universities (Howard Hughes Medical Institute, 1996). The Boyer Commission on Educating Undergraduates in the Research University (1998) also provided recommendations for smaller class sizes, interdisciplinary introductory courses, additional faculty to replace teaching assistants, and increased time for curriculum development. As will be discussed, recommendations have frequently exceeded supporting research and available resources.

**Actual Problem: Inadequate Research to Direct Practice**

The first question to ask in the face of the almost overwhelming perception of pending disarray and inadequacy in the undergraduate introductory science classroom is what type of evidence is used to substantiate these concerns. This leads to an immediate, and real-life problem, that to date few empirical studies have been conducted
to study learning dynamics in a successful introductory science classroom. Practice is being altered prior to understanding what, if anything, was working in the first place. Indeed, the indicators of successful learning in higher education are vague and inconsistent—high evaluations, problem-solving skill development, job placement—and these indicators focus on student learning with little consideration of TA and faculty development. Without a clear understanding of the learning that actually occurs in the context of an introductory science course, changes are analogous to “throwing the baby out with the bath water.”

Changing the way undergraduate science courses are structured to address K-12 reform recommendations appears, at least on the surface, to be a well-reasoned and theoretically supported undertaking. However, although often subtle, there are aspects of the current call for reform in undergraduate science classrooms that may undermine the possibility of reform success. These include recommendations focusing on narrow aspects of teaching and learning, suggestions that exceed the research literature, limited understanding of the participants in undergraduate education, minimal coordination between the disciplines researching university science learning, and language that often paints faculty as poor practitioners instead of collaborators.

Current calls for reform of university introductory science courses overlook several components of teaching and learning. First, most reform recommendations for college and university classrooms are focusing on pedagogy, rather than content.

*Science Teaching Reconsidered* is a practical handbook designed for college teachers who want to explore new ways to enhance student learning... *Science Teaching Reconsidered* does not focus on scientific course content. Rather it provides information about successful teaching practices in a variety of science courses. (NRC, 1997 [p. v])

There is a lack of emphasis on content even though K-12 reform documents are calling for changing *what* is taught as well as *how* it is taught. Dramatic changes in scientific research may impact content coverage in university curricula to an even greater degree than K-12 science classrooms. University introductory courses are viewed as presenting content as knowledge to be acquired, with little instructional or assessment emphases on the application of knowledge. Following this thinking, research on university science courses has primarily focused on specific faculty teaching techniques and student outcomes (Menges & Svinicki, 1991; Svinicki, Hagen, & Meyer, 1996).
What is missing from pedagogy-specific research is consideration of the interactions between content and pedagogy. Changing science content, such as increased emphasis on applied aspects of genetic technologies and environmental sciences may be effectively taught with different teaching strategies than Mendelian genetics or ecology. Similarly, changing teaching strategies, such as incorporating research and field trips, may alter the nature of content that can be addressed in a course. Not addressed extensively in research on introductory science courses is whether content should be taught in specific manners to model teaching or encourage thinking about teaching. There may be aspects of the curriculum that assist students in developing pedagogical content knowledge (PCK), or strategies for teaching specific content.

When content is addressed in the context of university science courses, the recommendations focus on interdisciplinary approaches.

Providing incentives for individual faculty and departments in SME&T, the humanities, and social sciences to work together to develop introductory interdisciplinary courses that are meaningful for all students, including both those who are and who are not likely to major in the faculty members’ disciplines. (NRC, 1999b [p. 31])

This recommendation builds on several assumptions including that introductory sciences do not already have a degree of interdisciplinary content coverage, and that there is research supporting undergraduate students building greater conceptual understandings of science within an interdisciplinary program structure.

Many recommendations for change in university classrooms are based upon anecdotal accounts and K-12 research literature. These recommendations such as reducing lecture emphasis are made without adequate research supporting that these changes in pedagogical strategies positively impact the outcomes of older, more educated, and potentially cognitively advanced individuals. These recommendations also often do not take into account that many introductory university science courses already incorporate laboratories, recitations, and out of class activities in addition to lecture. There is also little discussion of effective lectures, particularly in this time of multimedia presentations and distance learning. The NRC handbook *Science Teaching Reconsidered* states

Students taught by lectures, instructor-centered presentations, and student-centered methods achieve similar results on tests that measure
factual knowledge. However, student-centered discussions lead to better retention, better transfer of knowledge to other situations, better motivation for further learning, and better problem-solving (McKeachie, 1994). (from NRC, 1997 [p.3])

The cited source for this recommendation (McKeachie, 1994) is a book of teaching tips, primarily drawn from other anecdotal texts and limited K-12 science education research. The NRC document recommended considering techniques that "help your students learn science better and more efficiently" (p. 9).

Evidence from a number of disciplines suggests that oral presentations to large groups of passive students contribute very little to real learning. In physics, standard lectures do not help most students develop conceptual understanding of fundamental processes in electricity and mechanics. (NRC, 1997 [p. 9])

Only one of the three cited studies involved empirical research, and it is an inappropriately broad implication to extend that study's focus on a single physics concept to all university science courses.

Often, there is an implicit suggestion that a substantial and coherent university teaching and learning research base is driving recommendations. The handbook, *Science Teaching Reconsidered* suggests that

It offers you an overview of current research in undergraduate science education and some practical guidelines for experimenting with and changing the ways you teach. (NRC, 1997 [p. vi])

However, examination of the references for this handbook show that only 17 of the limited references based on empirical research actually focused on undergraduate teaching and learning, and the scope of these few studies is quite broad, ranging from student concepts of specific chemical concepts, to cooperative group instruction in physics classrooms, to visual learning with computer simulations. Clearly the research on any single topic is limited to the point of calling any large-scale implications into question.

The reform recommendations also include suggestions that at times seem to be taken out of the context of university teaching. For example, a suggested strategy for the teaching of introductory science courses is

Encouraging faculty who were not original designers of an innovation to participate in the resulting courses without having to take full responsibility for teaching or maintaining them. (NRC, 1999b [p. 5])
This strategy is based on the concern that faculty do not adequately share classroom ideas and innovations, a concern that is repeated throughout K-12 education. However, the call for a class of faculty that are not full participants in introductory courses, including continued curricular innovation, does not take into account the need for faculty to have a full stake in university reform. The innovation process often appears to be viewed as a one-shot implementation of ideas disseminated from an exemplary research program rather than a long-term learning process that includes continual curricular change.

Leaders in science education have called for additional study of teaching and learning in university courses. In 1993, the Coalition for Education in the Life Sciences (CELS) proposed that

A cadre of leaders will sponsor CELS-like workshops at professional science meetings and urge publication of papers on teaching and learning introductory biology in scientific, society-sponsored journals. (CELS, 1993 [p. 3])

Despite numerous calls for research on undergraduate science learning and teaching and the acknowledgement of the impact of undergraduate courses on future K-12 teachers, the research literature remains limited and fragmented.

This lack of coordination is especially evident in the apparent minimal exchange of information between researchers in science education (as published in the Journal of Research in Science Teaching, Science Education, Journal of College Science Teaching and the International Journal of Science Education) and researchers in higher education (as published in the Research in Higher Education, the Journal of Higher Education, and Innovations in Higher Education). Hearn (1997) explored the "disparate goals" of researchers studying university dynamics.

It seems reasonable to suggest that the controversies surrounding the research emanate in part from fundamental differences in underlying rationales for the research. One difference in rationale is between a goal of immediately practical knowledge versus a goal of expanded theoretical knowledge. For those who see the purpose of higher education research to be a direct contribution to the improvement of policy and practice, research that is historical or philosophical may seem irrelevant at best, and a waste of time at worst. In contrast, for those who see higher education research as meant to enhance our theoretical understanding of the emergence and ongoing adaptation of a central societal institution,
research that focuses “merely” on managerial matters may seem trivial. (Hearn, 1997 [p. 307])

In recent years, science education research on university teaching and learning has focused on practical applications within individual classrooms, whereas higher education research has focused on global institutional factors, such as faculty views and learning communities.

Another concern is the directedness and simplification of specific goals for introductory science courses. Agenda-driven recommendations direct courses to produce students with particular knowledge and skills that may not match with those valued in individual university science classrooms that work within a framework of “academic freedom.”

This is not to say that recommendations from higher education sources are superior to those from other research and teaching traditions. Within the literature on higher education, commonly perused by university administrators and science faculty, there is a tradition of producing summary documents that provide a short list of teaching recommendations that are generic across disciplines, including The Impact of College on Students (Feldman & Newcomb, 1969) and How College Affects Students (Pascarella & Terenzini, 1991). One of the most commonly cited guides to teaching in higher education is Seven Principles for Good Practice in Undergraduate Education (Chickering & Gamson, 1987) which characterizes that a good teacher: (1) encourages student-faculty contact, (2) encourages cooperation among students, (3) encourages active learning, (4) gives prompt feedback, (5) emphasizes time on task, (6) communicates high expectations, and (7) respects diverse talents and ways of knowing. Assumptions are made that teaching can be reduced to a small set of controllable variables, and that those variables directly impact student learning.

Recommendations for practice in higher education publications are often highly contradictory, reflecting the audience the writings are targeting. For example, regarding class sizes, the first of the following quotes is from a book marketed for faculty practitioners, and the second quote is for a journal commonly read by educational researchers.

Class size is the perfect example. As one of the simplest classroom variables that might affect learning, class size is seldom dismissed as irrelevant. Small classes are consistently preferred to larger classes by teaching faculty, and research, with all its faults, appears to support their good judgment in such matters. Glass and Smith (1979) recently brought
the blessings of meta-analysis to bear on the topic and they readily conclude that small classes do indeed contribute to student learning. (Fincher, 1998 [p.59])

We hope that the research provides "right answers" that can be transferred from researcher to practitioner and from teacher to student. Or at the other extreme, we discount research, and insist on personal experience and political expediency – as witness the recent rush to reduce class size, despite conflicting research evidence regarding the efficacy of reduced class size. The question that begs to be answered is not whether small classes result in better learning than large classes, but rather in what teachers could and would do in the context of their own classrooms if class size were reduced. The answer is probably better sought through thoughtful conversations among experienced teachers than it is in the collection of data across large numbers of classrooms categorized by size. (Cross, 1999 [p. 265])

There is also little acknowledgement in the reform literature that there is a history of science reform recommendations prior to the late 1980s (DeBoer, 1991) and that faculty have, to some degree, already adopted teaching strategies and content coverage to address past reforms.

Teaching is much more difficult than most faculty are willing to acknowledge. (NRC, 1997 [p. 1])

There is an apparent disconnect in the language of reform recommendations, which often appears to be highly prescriptive, with researchers from educational programs suggesting large-scale changes.

These problems with current reform recommendations may reflect a process of mandating change from the outside looking in, instead of examining successes within university science courses and building upon those successes. AAAS (1998) states

K-12 reformers must recognize that most faculty are neither lazy nor averse to teaching well, but that they may not know how to do it. (AAAS, 1998 [p. 210])

Although, seemingly conciliatory to faculty intentions, the recommendations are based almost entirely on K-12 science classroom research.

Many of the ideas outlined for K-12 teachers in Science for All Americans and Benchmarks for Science Literacy (AAAS, 1993) can be adapted for higher education faculty. (AAAS, 1998 [p. 217])
This may be an example of "putting the cart before the horse," or drawing conclusions before an adequate research base has been established, a process unlikely to rally the involvement needed from science faculty. As has often been the case of attempting to change K-12 classroom teaching, recommendations from a "critical friend" that is not a colleague or research participant may go unheeded (Hammersley, 1993).

Researchers – the acknowledged authorities of our times – talk about learning with no reference to the experience of teachers who have spent lifetimes accumulating knowledge about learning. And workshops on faculty development encourage faculty exchange with no references to what scholars know through study of matter. (Cross, 1999 [p. 265])

It can be concluded that further research is needed in order to devise recommendations for teaching practices in introductory science courses. The starting point in searching for research focus can be to document what actually occurs in current classrooms.

**Teaching and Learning in the Context of Curricular Innovation**

For the purposes of this text, *learning* is a change in disposition or capability that persists over time, and is not only due to normal processes of growth (Gagne, 1977). *Teaching* refers to helping others to learn more effectively and efficiently than they would on their own (Driscoll, 1994).

The term innovation has different meanings to the various stakeholders in education.

Innovation is a species of the genus "change." Generally speaking, it seems useful to define an innovation as a deliberate, novel, specific change, which is thought to be more efficacious in accomplishing the goals of a system. (Miles, 1964 [p. 14])

Reform recommendations for K-16 schools call for changing what is taught, and how it is taught. *Innovation* encompasses both of these changes to a curriculum. As will be discussed in the next chapter, the limited number of research studies published related to innovation in undergraduate science classrooms have focused on altering existing courses, not studying courses with a history of innovation. Research has focused on altering specific variables without the existence of a theoretical framework demonstrating the importance of those variables in the undergraduate classroom. Little is known about how a model undergraduate science course, one that continually changes to address
changing student and societal needs, looks or functions over time. This study sought to characterize learning in a course with a history of curricular innovation.

Faculty face an enormous number of choices related to planning and instruction including what should be taught, how it should be taught, and how to determine if it has been taught. Only fragmented information on learning can be drawn from the available research on faculty beliefs and professional development programs related to curricular innovation.

Within the university science culture, teaching ability is often perceived as an ability related to research knowledge instead of a pursuit that involves preparation and learning. Although it is widely known that not all good researchers are also necessarily good teachers, researchers are assumed to have the content knowledge necessary to teach undergraduate courses, particularly introductory courses for non-majors. Faculty are called upon to exhibit continual and progressive scholarship as researchers; improving teaching practices is rarely a critical component of promotion and tenure considerations. Possibly as a result, little attention has been given to the degree of learning necessary to teach new content in new ways (Weinstein & Meyer, 1991). Not studied are aspects of knowledge acquisition and application that may be necessary for a faculty member designing or redesigning a curriculum.

Faculty in the biological sciences are often assumed to have a conceptual framework and content knowledge sufficient to teach introductory courses. As previously discussed, changes in general biological knowledge have been dramatic over recent decades. These changes include the emergence of new disciplines, including environmental science and genetic engineering, as well as significant advances in more established disciplines such as physiology and evolutionary biology. As scientific understandings have changed, technology has changed the way scientific knowledge can be accessed. Faculty attempting to provide an overview of the life sciences to non-majors have different concepts and research techniques to teach than they had been themselves previously taught. The Society of College Science Teachers (SCST) defines a teaching scholar "as an individual who keeps abreast of current disciplinary and pedagogical developments" (SCST, 1998 [p. 5]). Faculty are not only being asked to alter how they teach, but also the very substance of what they teach.

Why not directly apply research on teachers' cognition from the 9-12 science education literature? University faculty may differ significantly from secondary school preservice and inservice teachers for a variety of contextual reasons. These reasons
include: educational backgrounds, economic status, teaching responsibility, other commitments (research, service), students, peer group, career expectations, content covered, and physical environment. These are all factors suggested to impact faculty beliefs, and potentially, practice (Banzer, 1997). Due to these potential differences, it may be inappropriate to assume that research on K-12 teacher learning is directly applicable to university faculty.

Graduate TAs play an important role in undergraduate education at many universities. At some of these universities, graduate TAs do a large percentage of the undergraduate teaching, as universities continue to rely on graduate students to cover large enrollment basic science courses (Nyquist, Abbott, Wulff, & Sprague, 1991). In biology, graduate TAs often teach introductory labs and discussion sections. Since these labs and discussion sections are usually smaller than the lectures taught by the faculty, teaching assistants have more direct contact with undergraduates than many faculty (Moore, 1991). Although science graduate students can potentially have a large impact on undergraduate students, first as TAs, and later as teaching faculty, few studies have examined what graduate students learn from their participation in a teaching assistantship (Nyquist, Abbott, & Wulff, 1989).

Many advocated reform changes, including cooperative group learning and "hands-on" activities, largely occur in the discussion/recitation and laboratory sections of a science course. Implementation of reform recommendations such as "development of problem-solving skills" may be more readily accomplished with a small group of students in laboratories and discussion/recitations than in relatively larger lectures. In addition, new trends such as the use of computers in the laboratories, increased diversity in student backgrounds, and emphasis on problem-solving, may increase the demands on TAs teaching within reform-oriented courses. In many higher education classrooms it is the graduate TA who has close contact with the students and the opportunity to understand the learner (Hammrich, 1996). Not known is what TAs learn from teaching students new material and processes.

Similar to faculty, it is often assumed that graduate students in the biological sciences have an adequate, if not ample, grasp of their field to be able to teach an introductory biology course. Based on this philosophy, many programs do not prepare their TAs for teaching specific activities, or focus on specific aspects of content or pedagogy. Little is known about TA content knowledge, or how close interactions with students may influence that knowledge and instruction.
The research on TA learning is extremely limited. Applicable studies are related to TA beliefs and the effectiveness of TA training programs. TAs may differ significantly from K-12 teachers as TAs balance teaching with research and coursework, are pursuing degrees in a science discipline, have little teaching preparation, and may not be involved in curriculum development.

Research on undergraduate student learning is more substantial than that of faculty or TA learning, but is mainly focused on learning outcomes tied to specific teaching behaviors or instructional strategies. These instructional strategies primarily include cooperative group learning, inquiry-oriented laboratory activities, computer technologies, and questioning in lecture halls. In these studies, student learning is frequently assessed by one measure or instrument, including exam scores, evaluation forms, or attitude surveys. Few studies address the impact of a large-scale curricular innovation, altering concepts and instructional strategies, on undergraduate student learning. Studies have not evaluated the role of students in the long-term revision and success of curricular innovation.

Based on reform recommendations, a scientifically literate student has an understanding of biological concepts, principles, theories, processes, and their relationship to technology and society. In addition to the traditional tasks of taking notes, completing labs, and text reading, students will be expected to take over more active control of their own learning. This stress on student involvement in learning echoes the various reforms. However, many students may need to alter their current learning strategies to master the new material and skills (Dunkhase & Penick, 1991; Heady, 1997; Lord, 1994).

Research on university teaching and learning has traditionally been done when no innovation or reform is taking place. Why study teaching and learning in the context of innovation? As discussed, change in K-16 education is already underway, being driven by political, social, and practical considerations. In order to determine what distinguishes an effective course, one that changes over time to address various content and pedagogical changes, from a course that fails in its attempts to change over time, it may be beneficial to study a course with a history of innovation to determine the variables that influence learning. These variables can then be manipulated in subsequent research. Currently in research related to undergraduate science courses, variables are changed without sufficient understanding of whether or not those variables are the same as those observed in K-12 classrooms.
Why has limited research been published on teaching and learning in innovative undergraduate science courses? This may in part be due to the complexity of these courses. Introductory courses often cover a wide range of content, multiple instructional strategies including lecture and laboratory, multiple forms of assessment including exams and laboratory reports, and are staffed by multiple faculty and TAs (Lawson, Rissing, & Faeth, 1990).

There may be many potential problems associated with curricular innovation in the university introductory science classroom. These include time constraints on faculty, minimal preparation of TAs, and limited background preparation for students. Studies have not yet examined the potentially complex dynamics within and between faculty, TA, and student groups as a new curriculum is assembled and implemented, requiring faculty to design a reform-oriented curriculum, TAs to interpret the curriculum for the students, and students to learn new processes and concepts in new ways. Although all three groups may play different, yet critical roles in determining the success of a curricular innovation in the introductory science classroom, research has not been published in this area.

Learning within one group can potentially influence the learning of other groups, and alter curricula (Matthews, Smith, MacGregor, & Gabelnick, 1997). The interactions between students, TAs, and faculty may be a critical component of curricular innovation. These interactions may differ significantly in a course stressing student-centered learning than in the traditional "top-down" idea of a professor having full control over a curriculum.

Questions Guiding Research

Prior to this study, several basic questions remain unanswered in the research literature regarding learning in undergraduate science courses. What types of learning occur in the context of innovation? What are the roles of students, TAs, and faculty in the teaching and learning activities within a curriculum during which innovation is taking place? Without understanding the variables impacting learning in undergraduate introductory science courses, it is premature to make specific recommendations for change. Considering the absence of descriptive studies in the research literature, this study was designed to address two exploratory research questions:
1) In the context of an instructional innovation, what do faculty, TAs, and students learn?

2) What factors limit or augment learning in each of these groups?

**Significance of this Study**

Few studies have examined student, TA, and faculty learning in the context of innovation. This study is intended to fill this gap in the research literature. In the NRC (1999a) publication, *Improving Student Learning: A Strategic Plan for Education Research and its Utilization*, a strategic education research program (SERP) is proposed to organize educational research efforts. Regarding curricular innovations,

Schools and school districts in many parts of the country are engaged in strenuous efforts to transform themselves. There is much that is interesting, and some experiments are exciting... Yet, there is a fragmented quality to all of this activity that the existing research base cannot knit together. Educational research needs to find a new paradigm if it is to produce major advances in our understanding of how schools and school districts function. (NRC, 1999a [p.63])

Although most of the discussion is focused on K-12 schools, it could easily describe the state of research on university learning.

This study identifies variables that impact learning and curricular change. The intent is to contribute to development of a grounded theory of learning and curricular change in an introductory biology classroom. Variables were grouped into categories and themes were sought to develop a hypothesis in the studied course. In addition to informing future practice in the studied course, this hypothesis and the identified variables within may be a guide for inquiry into practice in other introductory biology courses.

This study did not seek to compare learning in traditional versus innovative university classrooms. Instead, the processes of innovation were used as a contemporary context for learning. Aspects of learning seen in this study may also occur in a traditional course. Additional studies may build on the findings of this study to determine whether learning differs in courses undergoing significant curricular changes. This study focused on a course undergoing curricular innovation, to inform future research into changing introductory science courses in the context of science education reform.
In Chapter 2, a review of available research indicates that few studies have examined the interactions among faculty, TAs, and students, particularly in the context of a changing curriculum. The available research literature was used to initiate formulation of the research questions. Due to the limited nature of the existing body of literature, a pilot study was conducted to develop methodologies and is also described in Chapter 2. Chapter 3 outlines the methodologies used in this subsequent study to delineate aspects of learning, including forms of data collection, data analysis, and a detailed description of the researcher-participant.

Gilbert and Watts (1983) described the evolution of data from conceptions, through categories, to frameworks. The results and discussion chapters reflect this lineage. Chapter 4 (research results) describes the variables linked to the research questions, explaining emerging categories through data generated in the study. Chapter 5 (discussion and implications) presents a hypothesis of learning in the studied course, including consideration of the role of the researcher and study methodologies. The results from this study may direct future research. Chapter 5 explores possible lines of research related to the variables impacting learning in the context of innovation generated in this study. A series of appendices follow which provide additional information on study design and results.

As will be discussed, the studied project provided numerous insertion points for diverse individuals to find a context for learning. Similarly, this text has been written with multiple insertion points for different readers. Details on the course structure have been provided for biology faculty. Data collection and analysis methodologies have been elaborated on for higher education researchers. Related studies in undergraduate science have been provided for science education researchers. Finally, elaboration on implications for change has been provided for university administrators.
CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

Curricular innovation, for the purposes of this paper, involves altering what is taught, the way that it is taught, and the assessment of the outcomes. The curricular innovations discussed in the reviewed research focus on altering course content and the manner in which the content is delivered. An attempt was made to focus on recent research conducted within the framework of the new science education reforms (AAAS, 1993; NRC, 1996a). However, several other studies were included as the innovative curricula addressed aspects of science literacy promoted in the current reforms. The primary purposes of the literature review included defining the problem, and exploring methodologies.

A fairly substantial literature base on K-12 teacher change exists, but primarily focuses on teacher beliefs and intentions prior to or following curricular innovation. This study does not focus on stable “top-down” curricular decision-making, but instead focuses on teaching and learning during a period of curricular change. This includes TA and student change, and the interactions between the three groups of students, TAs, and faculty.

Research on university or college faculty learning is extremely limited. Higher education research related to faculty has centered on attitudes toward teaching workshops, and the impact of consultations, grants, and resource availability on faculty motivation (Weimer & Lenze, 1991). Science education research has focused on the impact of specific teaching strategies adopted from K-12 literature on student outcomes. Missing from the literature appears to be research on how some faculty already learn to keep abreast of new science developments, teaching strategies, and student needs, what factors influence this learning, and to what extent learning must occur to adopt reform-based instructional innovations. Limited research is available that focuses on faculty beliefs concerning curricular innovations and the influence of professional development programs on those beliefs.

Research on learning within the university introductory course has focused primarily on university student learning in the context of specific teaching strategies. Far less research has examined alterations of multiple components of a curriculum, including
content and assessment, on student learning. The reviewed studies focused on larger-scale curricular changes.

No studies were found that identified what graduate students actually learn by teaching as a TA, either in a traditional or innovative course. TA research has focused on the influence of training programs on TA attitudes and student evaluations. Research studies have not examined the potential three-way interactions among faculty, TAs, and students, and the influence of these interactions on student learning.

The limited research base revealed three major aspects of curricular innovation in college or university science courses: teacher beliefs, professional development/teacher change, and student outcomes. Due to the narrow breadth of these studies, a pilot study was conducted to develop research questions and test research methodologies. This pilot study is described at the end of this chapter.

Teacher Beliefs and Implementation of Curricular Innovations

Teacher beliefs may play a role in successful (or unsuccessful) implementation of curricular reform (Cuban, 1990). Teachers and their beliefs may lead to specific actions that impact students. The relationship between science teachers’ beliefs, their teaching behaviors, and student outcomes has been researched (Brickhouse, 1990; Gess-Newsome & Lederman, 1995, Lederman, 1992), but remains relatively inconclusive, possibly due to the complexity of factors that may mediate teacher behaviors. The following studies follow the assumption that teacher beliefs influence their intentions, and ultimately, their behaviors in the classroom.

The first study examined “neophyte” and established university science teacher’s beliefs about teaching. Trumbell and Kerr (1993) studied beliefs about science teaching in order to identify possible barriers to curricular change. The authors proposed that science faculty beliefs and practices could directly impact preservice K-12 science teachers enrolled in science courses.

Two separate groups of subjects were interviewed. The selection criteria for the subjects was not discussed. The first group consisted of three doctoral students in biology nearing completion of their degree programs. This group was selected to provide information on the “next generation” of science faculty, all three were TAs in an introductory biology course. The second group consisted of an unspecified number of women scientists (at least ten based on the pseudonyms), who also taught
undergraduate science courses. The open-ended interviews were not explicitly described, but analysis of the article suggests that the interview questions focused on teacher concerns about teaching and undergraduate science education in general. Extensive discussion focused on the development of scientific knowledge, an important aspect of recent science education reforms.

All three of the "neophyte" TAs agreed with the importance of teaching students about the process of developing scientific knowledge. Despite this agreement, the TAs expressed doubt that the current course curricula achieved this learning goal. A primary TA concern was whether students can actually "do" science (as defined by the discrete steps of the scientific method) in a laboratory format, due to artificial nature of hypothesis formation. An additional concern was that students were not ready to understand principles such as the tentativeness of scientific knowledge and that data analysis may not be appropriate for the introductory biology student.

The three TAs discussed the importance of a general "holistic" introduction to biology, with detail to balance the inevitable oversimplifications. They had a limited understanding of multiple forms of learning and assessment, and were reluctant to explore other forms of assessment due to pressures from students desiring good grades.

In borderline cases I guess there is something to be said for going with the tried and true objective [test] – and it's really not that objective – but things a student feels are more objective so they think justice has been done. (Trumbell & Kerr, 1993 [p. 307])

All but one of the faculty stated that they enjoyed teaching, but admitted the constraints of balancing teaching and research commitments. The teachers discussed how students would learn or not learn primarily due to the teacher’s actions, and did not discuss what students bring to the classroom experience. With few exceptions, faculty perceived their role in curriculum development to

...distill the body of knowledge into a few essential points that can be take-home messages and giving some detail, which is, sort of hanging detail off the essential points. (Trumbell & Kerr, 1993 [p. 308])

Primarily, the faculty structured the curriculum to resemble the way they were introduced to the subject, with the idea that students would then possess the same knowledge. Although one subject acknowledged that teaching should not focus on facts,
the faculty repeatedly stressed the amount of content that must be covered in each course.

All of the faculty relied on tests for student assessment. Faculty mentioned other aspects of assessment, such as assessing prior knowledge through questioning and formative assessment immediately following lecture, but these assessments were not being implemented. Regarding scientific controversy, while the faculty believed it was important that students realize controversies exist, they believed that students become frustrated with ambiguity within a science course. Discussions of controversies were introduced and resolved by the faculty, and their curricula did not include activities that encouraged student critical thinking. Somewhat ironically, many of the faculty acknowledged that they themselves often secretly questioned the conventional textbook science, but were reluctant to voice their doubts. They attributed their critical thinking skills to research experiences.

In comparing the two groups, the researchers noted that the TAs were not satisfied with teaching "The Scientific Method," whereas the faculty discussed the method in terms of their own research instead of student learning. The TAs felt pressures from students regarding appropriate grading, and the faculty focused on the need to compare students to one another in order to determine ranking. Although both groups stated that memorization was not the goal of their science courses, they were at a loss for ideas on structuring a learning environment that stressed any other type of learning.

The researchers stated that overall the results of the study supported the idea that faculty would continue to "teach the way they were taught." They were struck by the fact that none of the subjects were familiar with the continuing debate over teaching facts vs. teaching process. Basically, the interviewed subjects were largely unfamiliar with current research or ideas related to science teaching. The authors concluded that although both sets of teachers were displeased with some aspects of their teaching, they were unable to articulate specifically what the problems were. In other words, the teachers were unable to propose alternatives to their current teaching practices. The barrier to curricular innovation elucidated in this study was a lack of awareness of viable curricular alternatives.

The next study examined teacher intentions to implement curricular changes within their courses. Although not specifically focusing on curricular changes within the context of science education reforms, this study addressed a broader issue of faculty
beliefs and curricular change. Stark, Lowther, Sharp, and Arnold (1997) explored university faculty views about curriculum planning within academic programs, including intentions to implement curricular changes within their courses. This study was a continuation of earlier studies that examined factors influencing faculty decisions in course-level academic planning. The general research questions included (1) what beliefs influence faculty perspectives of course sequence? (2) what constitutes a coherent academic plan? (3) how is the curriculum rationale communicated to the students? (4) what steps do faculty take as they construct the curriculum? (5) what change or curriculum planning has occurred in recent years and how? and (6) what provisions are made to assess curriculum effectiveness?

The authors interviewed faculty from a small private college (SPC) and a large public university (LPU) in a mid-western state that had recently mandated a state-wide curriculum and assessment review. These settings were chosen as convenient sites known to differ in size, faculty autonomy, and administrative coordination.

At the SPC, the subjects included program chairs and two randomly chosen faculty from each program. This totaled 36 faculty, approximately half of the faculty. As a result of these interviews, it was noted that few of the faculty were actively engaged in curriculum planning. At LPU the 23 faculty subjects were randomly chosen from eight programs identified by the provost's office to be actively involved in curriculum development (four programs) or less actively involved (other four programs).

The semi-structured interviews were conducted by the senior researchers (Stark & Lowther) with assistance from the other researchers. The authors noted that the interviews varied slightly as they progressed with some questions discarded and new issues raised. The interviews centered around the six previously stated research questions, involved a discussion and card sort activity, and lasted about 90 minutes each. Further details about the interviews were not provided.

Upon completion of the interviews, five of the researchers listened to the tapes and coded answers to the specific questions following the interviewer protocols. The researchers also noted central themes. Two additional researchers, not previously involved in the study, also listened to the tapes, coding responses and seeking support for themes identified by the other researchers. Information on interrater agreement was not provided.

In response to the first three research questions, the researcher hoped to identify the beliefs and assumptions that influence program planning. The researchers found that
faculty mentioned several factors as influencing program planning including discipline, student characteristics, workload, faculty interests, program goals, budget, institutional goals, research developments in the discipline, faculty beliefs about student learning, student goals, class size, enrollment concerns, and facilities. Also mentioned as more modest influences were teaching and learning theory, external examinations, faculty pedagogical training, accreditors, textbooks, traditions, campus politics, and secretarial support. The authors state that disciplinary and educational beliefs provide the structure for program development, modified by contextual factors.

The authors noted that leadership was a pervasive theme of program planning. Leadership at all levels of program planning acted as both an influence on educational assumptions and on contextual filters. The authors were also unable to establish how a "coherent" program is planned due to faculty difficulty in conceptualizing their programs as a whole, instead of examining their own pieces or roles. As a result, faculty were less likely to communicate overall program goals to students than their own specific course goals.

The last three research questions were intended to provide a model of the process of program planning. The researchers defined program planning as making curriculum decisions and choices among alternatives. The faculty subjects viewed planning as something that primarily results in major shifts or innovations, thus taking place very rarely. Almost none of the faculty on both campuses were able to describe the process of "normal" term-to-term or yearly program planning. The researchers believe this reflects heavy personal investment in course planning, less individual control over programs than over courses, and infrequent assessment of program outcomes.

Based on their interviews and subsequent communications with faculty subjects, the researchers designed the hypothesis that in order for program planning to be active, (1) a catalyst must exist, (2) leadership must exist, and (3) a supportive climate or tradition must exist or be developed. The authors described a range of different catalysts including catalysts that stimulate program faculty to respond because they perceive a need for improvement, defensive catalysts that stimulate a response because they threaten a program's existence, and role-related catalysts that are more neutral such as arrival of new faculty or change in activity. Faculty participation in course planning appeared to be strongly influenced by feelings of autonomy in curriculum development and perceptions of the importance administrators attach to the program planning.
Based on their findings and new hypothesized catalyst model of program planning, the researchers suggested several implications for future research including the role and effect of student involvement on curricular change. The researchers suggested that student feedback, through evaluation forms and conversations with faculty, could act as a catalyst for curricular change.

**Professional Development and Implementation**

Reforming university science courses will require teacher change, which has implications for how faculty prepare to teach. Research on curricular innovation includes the influence of professional development programs on teacher beliefs, intentions, and practices. Professional development programs can include classes intended to assist teachers with curricular innovation or a collaborative process of teacher change between science educators and science teachers. Both of these aspects are modeled in the following two studies.

In the first study, science educators and secondary high school science teachers assisted college faculty in developing and implementing an innovative curriculum. Fedock, Zambo, and Cobern (1996) examined the development of community college science faculty as they prepared and taught a summer life science academy for K-12 teachers. Specifically, the researchers sought evidence of changes in faculty views of science education and secondary science teachers.

The four subjects had between 6 and 20 years of experience teaching college biology. They had little knowledge of elementary, secondary, or teacher education, but were concerned about the quality of K-12 education and the resulting knowledge of college freshmen. The four faculty had been chosen in an unspecified manner by the coordinator of an urban Comprehensive Regional Center for Minorities to prepare and teach an in-service summer biology academy for K-12 teachers.

The researchers interviewed the faculty before, during, and after the summer academy. These interviews focused on the subjects' views of science, science education, and teachers. After transcription of the audio-taped interviews, the researchers coded the responses and developed four categories of responses which included: the subjects' views prior to the academy, the subjects' preparation for the academy, events during the academy, and changes of subjects' thought. A narrative
was constructed to summarize the findings. This narrative was read by the four subjects and the final report includes their editorial comments.

Prior to the academy, the four faculty commented that the academy would be a vehicle for learning more about K-12 education, and would assist them in reaching some conclusions about why “…the quality of the students that we’re getting is declining.” (p. 9). The subjects agreed that involvement in teaching the academy may indirectly, positively influence their future students. Also, the faculty had perceptions and concerns about how science was taught (or not taught) in elementary and secondary schools. Generally, the faculty believed that lack of science knowledge impacted teaching in both elementary and secondary schools, and that although science teaching was changing, K-12 science courses primarily consisted of lecture and supplemental laboratories. The faculty were committed to teaching content to the K-12 teachers, using assigned readings and tests. The faculty did not see higher education as a component of science education concerns or deficiencies at this point in the study.

In preparation for the academy, the subjects’ dissatisfaction with K-12 education motivated them to learn more about science education. Prior to this preparation, all four faculty taught their own biology courses, following the traditional lecture and laboratory format. They reviewed science education reform documents, science education research articles, and articles from teacher science education journals. Some of these articles were recommended by a science education professor, particularly articles related to the learning cycle. Other articles were located by the subjects through ERIC (Educational Research Information Clearinghouse) searches. Additionally, the faculty visited K-12 classrooms. Four teacher mentors, considered to be exemplary science teachers by their principals, were hired by the program to assist the faculty as resource consultants and laboratory assistants. One of the mentor teachers had extensive experience using the learning cycle. Based on discussions and their reading, the faculty chose to use the learning cycle as an instructional format (exploration, concept invention, and discovery) instead of the standard college lecture approach. The faculty also decided to incorporate cooperative learning into their instructional strategies.

The subjects were apprehensive about their ability to use these techniques, and relied heavily on the science educator and teacher mentors for planning the curriculum. Their focus had shifted from content to instructional strategies.

The academy was split into two sections, elementary and secondary, each taught by two faculty assisted by two mentor teachers. In the secondary course, the faculty
used a lecture and laboratory format. The researchers noted that elements of the learning cycle were incorporated, although they would have expected a different classroom arrangement. In a typical class, the faculty used a transparency outline to present an overview of the topic, asked questions to identify misconceptions, and encouraged discussion. This was followed by a video, and a small-group activity. The researchers stated that the subjects were not following the learning cycle model.

Throughout the lesson the professors tried to be more indirect in their approach but they could not entirely relinquish old habits. They explained more than they were questioned. What you do not see here are the three phases of the learning cycle. What you do see is the professor doing less lecturing and possibly less prescriptive lab session work and engaging in more discussion with students. (Fedock, Zambo, & Cobern, 1996 [p. 15])

Although the researchers were not satisfied with the instructional strategies, the faculty viewed the changes in their teaching as an improvement. As the five-week academy progressed, the researchers noted that the two faculty teaching the secondary teachers appeared to become more open to indirect, inquiry strategies. The researchers believed that these subjects were limited by the lecture/lab format of the course.

In the elementary course which started after the secondary course, the other two faculty decided to hold classes in a different setting. Instead of taking turns teaching (secondary course), the faculty decided to team-teach a theme-based curriculum in a cooperative group laboratory setting. These instructional decisions were based in part on discussions with the faculty who taught the secondary course, and observation of those classes. In a typical class, the faculty in the elementary course would begin by introducing the topic with a story, and then ask questions to initiate a discussion. The faculty would then ask the teachers to explore the topic with the materials available to them. The class would discuss their findings, have a more detailed discussion, re-explore their materials, and fill out an open-ended worksheet that led to further discussion. The faculty were enthusiastic about this format, and all four faculty discussed altering their teaching practices in their college classrooms.

The subjects all indicated that they changed how they thought science should be taught, favoring the learning cycle and cooperative learning. The subjects subsequently altered their college courses, in some cases dropping the lecture/laboratory format and incorporating activities from the summer academy. The researchers stated that curricular changes were occurring incrementally. The faculty also reported that their college students were answering and asking more questions.
The researchers concluded that change in these four subjects occurred when they were introduced to important science education literature, met K-12 teachers in their classrooms, and when they entered into a serious dialog about effective classroom instruction. Other important factors appeared to be the subjects' ability to prepare and “practice” their new instructional strategies with the support and guidance of mentors. The researchers noted that these faculty did not have research commitments and were interested in K-12 education. Additionally, the subjects received financial and professional support to research science education.

Although the researchers believed that the subjects' teaching styles became more indicative of the learning cycle, it was not determined if the differences impacted K-12 teacher learning. Information on student achievement in the summer academy or the subsequent college courses was not provided.

In the next study, a self-assessment program was developed to enhance the quality of post-secondary instruction. Prather (1995) investigated the impact of the program on faculty desire and ability to improve science courses. The Instructor Self-Assessment Program (ISAP) was developed for use by faculty and TAs. ISAP involves using a videotape review procedure for improving aspects of instruction. The authors noted that videotaped self-assessment could be perceived as less obtrusive than external observation and evaluation. Instructional videos introduced a variety of instructional strategies based in the literature of effective K-12 teaching. The ISAP assessment instrument consists of 30 items related to instructional techniques, and a Likert-type or yes/no scale for each item. An additional student assessment of lesson form was developed to allow the teachers to correlate their findings with student perceptions of their teaching. No information on the validity or reliability of these instruments was provided.

An unspecified number of faculty using ISAP volunteered information about their teaching. The authors noted that this was a small percentage of the overall number of faculty using the program, and simply reported a summary of the faculty comments, instead of generalizing to the entire population of faculty using ISAP.

The most frequently discussed teaching insights focused on the issues discussed in the instructional videos, which included equal treatment of students and wait-time. One instructor stated:
I thought that business about wait-time was a bunch of malarkey, but I tried it in the second lesson. It makes a difference. (Prather, 1995 [p. 414])

The researchers summarized the self-reported data and identified three trends. First, the ISAP led the subjects to examine a broad spectrum of factors that influenced their teaching. Next, the faculty reported that the self-assessment process allowed them to make substantive changes in their teaching behaviors. Finally, the faculty had a positive attitude toward the self-assessment process.

The authors concluded that guided self-assessment could potentially enable faculty to make significant changes in their own teaching. This study did not address those faculty who might not be motivated to participate in a self-evaluation program. Instead, this study suggested that an organized self-assessment program may assist those faculty already interested in altering aspects of instruction. The authors state that they are extending this project to include counseling on content coverage and student outcomes. Student outcomes, in the context of curricular innovation, are the focus of the next four studies.

**Curricular Innovations and Student Outcomes**

The primary reform rationale for altering current university curricula is to produce scientifically literate students. The following set of studies sought to evaluate the effectiveness of a variety of curricular innovations on altering aspects of student content and process knowledge.

The first study examined the influence of a Science-Technology-Society (STS)-based curriculum on university students' knowledge of STS issues. Bradford, Rubba, and Harkness (1995) compared university student views of STS after taking an introductory physics course or an STS course. The goal was to determine whether and to what extent these courses promoted student understanding of interactions between science, technology, and society.

Subjects were 138 students enrolled in the STS general education course and 122 students enrolled in a general education physics course at an eastern land grant university. Each course met three times per week for 50 minutes over a 15-week semester. The classes were taught in large lecture halls and both courses fulfilled university general education requirements. The physics course covered fundamental concepts of physics, technological aspects of physics, and occasional historical
The STS course focused on four major themes: (1) STS foundations, (2) resources and their utilization, (3) human needs and aspirations, and (4) decisions and actions.

Subjects were pre-tested and post-tested with 16 multiple-choice items selected from the 114 items in the Views on Science-Technology-Society (VOSTS) item pool. The researchers assumed inherent validity and reliability to the questions. To determine whether VOSTS items were appropriate for university students, the researchers and a former STS professor chose 37 items, added an opportunity for write-in responses, and administered the pilot questionnaire to summer session students. Students only added write-in responses to 10% of the questions, which researchers considered an indicator that the VOSTS items represented possible views of STS items. However, the form was too long for the allotted testing time, and the researchers chose 16 questions they believed to be representative of various reform recommendations.

The researchers suggest that the VOSTS items do not lend themselves to inferential statistical analysis unless choices are collapsed into categories. A panel of five expert judges were charged with classifying the choices under each of the 16 VOSTS items as realistic (R), has merit (HM), or naïve (N). Numeric values of 3, 2, and 1 were assigned to these classifications. The first statistical analysis was used to determine if students' views of STS had changed. A mean change score was calculated from individual subjects pre- and post-tests, the changes were summed, and analyzed with a t-test (alpha = 0.05) for dependent samples. To focus on each of the 16 items, a McNemar analysis (alpha = 0.05) was conducted for each item in the pre-test and post-test samples. A total of 32 tests were performed.

Results of the two-tailed t-tests did not show a significant difference in change between the STS and physics courses (\( p > 0.05 \)). The McNemar statistic was significant for the STS subjects for seven of the 16 items (\( p < 0.05 \)), indicating that statistically different numbers of respondents in the STS course scored higher or lower than the physics respondents. The McNemar statistic was significant for the physics subject on one of the 16 items.

Students in the STS course moved towards more realistic views on the influence of politics on scientists, the influence of special interest groups on science and technology, trade-offs of science and technology, and technology control. However, the STS students moved towards more naïve views on the definition of science, the
connection between science and technology and the quality of life, and the contribution of science to the solution of social and practical problems.

The researchers concluded that the findings suggest that the STS course did not have an impact on students' views about STS interactions as measured by the VOSTS items. Although the course appeared to provide students with more realistic views of some aspects of STS, students also developed unanticipated misunderstandings. The researchers suggest that conceptual conflicts were not resolved in the STS course, and that the physics course had virtually no impact on students' views of STS interactions. As STS courses are currently offered at about 2000 colleges and universities, this study suggests that the impact of these curricula on student learning may warrant more extensive study.

Also researching the effects of implementing an STS curriculum in a higher education course, Gregory (1992) investigated the effectiveness of a new university curriculum intended to instill nonmajors with an appreciation for science. The new curriculum focused on the theme of science in the news, particularly the print media, as a way to introduce the relevance of the subject matter. The study objective was to determine whether this type of curriculum was effective in altering student attitudes towards science.

Subjects consisted of the university professor (the researcher) and an unspecified number of students. The course ran 10 hours each week (in- and out-of-class time), for four weeks. The students read two newspapers each day and were instructed to place all science articles in a notebook with a written summary of each article. Class time was spent discussing articles and the scientific principles underlying the topics. Assigned readings assisted students in critiquing the science articles.

Data included notes from in-class discussions, the student journals, and comments on course evaluation forms. Information on data analysis was not provided. Early class discussions focused on determining what constitutes science, as students attempted to determine what types of articles qualified as "science" for their journals. The researcher noted that this illustrated the diversity of roles science plays in student lives. Since the professor was not able to expand on all of the topics covered in the newspaper articles, the professor/researcher noted that students shifted their discussions to how science information is obtained and developed a clearer view of the role of a scientist.
Student comments on the course evaluations indicated that student attitudes toward science and the media altered due to their involvement in the course. Although there was no pretest, students attributed their own changes in attitudes to aspects of the course.

It really opened my eyes. Before this class I would believe anything in the papers. ...The course made the students more aware of the popular press’ effect on society’s opinion of science. (Gregory, 1992 [p. 224])

The researcher stated that although students’ attitudes toward science had changed, it was difficult to determine the scientific knowledge gained in the course. A year later, an unspecified number of the students filled out a questionnaire regarding the course, no validity information was provided. All of the students stated that they were reading science news articles more frequently than they had prior to the course.

Following this study, an attempt was made to incorporate the analysis of current news articles into a large-enrollment introductory microbiology course for non-science majors. Students read three articles weekly, kept summaries in a journal, and used these summaries to participate in classroom discussions. Based on preliminary analysis of student evaluations and in-class observations, the researcher concluded that the students’ attitudes toward science did change, but not as dramatically as those students in the intensive four-week course.

The researcher concluded that courses that focus on students actively practicing science literacy are more effective than traditional nonmajor science courses. However, the primary goal of this curriculum was improving student attitudes, which would represent a dramatic curricular departure for most undergraduate science courses.

In another university study, Jensen and Finley (1996) assessed student learning of evolution in an introductory biology course. Four different sections of the course combined traditional or historically rich curricular materials with problem solving or traditional lecture instruction. The research questions were (1) What are the effects of each instructional strategy paired with each curriculum on student conceptions and alternative conceptions of evolution? (2) What are the effects of the different curricula on student conceptions and alternative conceptions of evolution?, and (3) What are the effects of the different instructional techniques on student conceptions and alternative conceptions of evolution? The authors anticipated that the section utilizing the historically rich curriculum and problem-solving instruction would be more effective in altering student conceptions of evolution.
The subjects were 155 university students enrolled in a general biology course for students not considered to be prepared for regular university courses. Students in the course were used as subjects if they attended the four intervention lectures and completed both the pre- and post-test.

The evolution unit was covered in six 50-minute lectures, approximately two weeks of a ten-week course. The varied instruction and curriculum occurred in the lecture portion of the course, no information was provided on the content of the weekly two 2-hour laboratories that accompany the lectures. Two lecturers taught in their usual lecture modes, one using lecture, the other using lecture interspersed with problem-solving activities. The curriculum varied in the way content was presented in lecture. The traditional curriculum began with evidence for evolution, and Darwin's contribution and concluded with variation and evolutionary adaptations. The historically rich curriculum began with theories pre-dating Darwin, discussed Darwin's life and contributions, and concluded with adaptations.

The assessment instrument used was a modified form of two previously designed tests. The final form consisted of five types of questions. The first two types, seven Likert-type questions and five multiple-choice questions were used to elicit responses to the other questions, and were not included in data analysis. The third group of questions were one-sentence justifications of the answers provided to the first twelve questions. The forth section asked students to explain the evolutionary mechanism of three different events. The fifth section asked students to define evolution, adaptation and fitness. Content validity was determined by a panel of experts and construct validity was assessed with pilot study interviews. Pre-tests were administered five weeks prior to instruction and post-tests were administered two weeks following instruction. No reliability information was provided.

Student written responses were coded as Darwinian (variation, inheritance, survival of the fittest, changing percentages, identifying inconsistencies, etc.) or alternative conceptions (teleology, Lamarckian, natural theology, etc.). Points were assigned for each type of response (Darwinian or alternative conception) and totaled. Nonparametric statistical analyses were used including the Wilcoxon matched-pairs signed-ranks test for comparing pretest to posttest scores, and the Kruskal-Wallis one-way analysis of variance test was used to compare the four different treatments.

In all four different sections, student Darwinian scores increased, and alternative conceptions decreased between the pre-test and post-test ($p < 0.05$). The Kruskal-
Wallis analysis of variance tests for the total Darwinian ($p = 0.027$) and alternative conceptions ($p = 0.021$) scores showed a statistically significant difference between the sections. Results from Mann-Whitney comparison tests indicated no significant difference ($p = 0.124$) in Darwin scores between the different curricular treatments, but suggested statistical significance in alternative conception scores ($p = 0.005$) in favor of the historically rich curriculum. Mann-Whitney analyses also showed a significant ($p = 0.030$) difference in Darwin scores between the instructional strategy treatments, favoring problem-solving instruction. No discussion was provided as to whether these numbers, reflecting small changes in pre- and post-test scores, indicated practical significance.

Examination of mean rank scores revealed the largest differences in Darwin scores between the historically rich problem-solving lecture and the traditional lecture, suggesting higher student achievement with the historically rich problem-solving lecture. The authors concluded that changes could occur within the curricular framework of a traditional university science course if curricular changes incorporated alterations in content and instructional strategies. However, additional research would be needed to describe the effectiveness of larger-scale curricular changes.

The next study focused on student response to an innovative chemistry curriculum. Nakhleh, Bunce, and Schwartz (1995) examined the impact of a new chemistry curriculum *Chemistry in Context: Applying Chemistry to Society* (CiC) on student attitudes. The CiC curriculum, produced by the American Chemical Association, consists of a text and supporting instructional materials (handouts, overheads) that stress the relevance of chemistry in students' daily lives. Units such as "The Air We Breath" are intended to link fundamental chemistry concepts to social and environmental issues. The researchers were attempting to determine whether students responded positively to this type of curriculum, with the assumption that students who have positive attitudes will exhibit improved learning outcomes.

The sample consisted of students from 9 of 18 colleges and universities that had adopted the textbook. Although the selection criteria for these nine schools was not discussed, the authors noted that the selected schools included small schools, large schools, historically black institutions, and a community college. Two of the nine schools did not administer the instrument correctly, resulting in a sample of 222 students from seven schools. The percentage of students volunteering to participate in the study was not provided, although 222 appears to be a relatively low percentage of non-majors,
particularly if at least one of the schools was “large.” At two of the seven schools, students exposed to CiC were compared with students taking “traditional” chemistry courses. The number of students in this comparison group and the selection criteria were not provided.

The instrument was an opinion survey with 20 statements, to which the students would respond on a scale of 1 point (agree strongly) to 5 points (disagree strongly). The statements ranged from “I like science” to “Chemists are friends of mine” and “Chemists aren’t interested in how research affects lives.” Despite the simplicity and generality of these statements, the researchers stated that the instrument had been designed for university students and piloted with students enrolled in previous CiC courses. Although the authors stated that they had calculated internal consistency reliability (Cronbach’s Alpha), no reliability coefficients were provided. Additionally, no information on instrument administration was provided, although it can be deduced that the same instrument was administered at the beginning and end of the studied chemistry courses. Additional demographic information was collected on the subjects that included information on school size, race, and gender.

The statements were analyzed by calculating the difference in scores on the pre-test and post-test, and applying a t-test to assess the change. The researchers displayed “significant” results with $p$-value ranges of 0.01 to 0.05 and “highly significant” $p$-values of 0.000 to 0.009. Generally, the statistical results showed students providing more positive responses towards chemistry in the post-tests. Students showed more agreement with statements such as “I talk about chemistry issues with my roommates” and more disagreement with statements such as “Chemistry doesn’t have much to do with politics.” However, due to the large number of students (222) taking the pre- and post-tests, small shifts in their answers (less than 0.5 on the 5 point scale) would be statistically significant. No discussion was provided as to whether the statistically significant results also represented practical significance. Few differences were seen between students of different size schools.

The researchers concluded that the CiC curriculum had a positive effect on student attitudes towards chemistry. They stated that any shifts toward positive attitudes would potentially impact enrollment in elective introductory chemistry courses. The researchers also suggested that the curriculum challenged students’ preconceived ideas about chemistry, particularly those relating chemistry to social issues. This may suggest
that the curriculum altered student views of science-society interactions, an aspect of the science education reforms.

The next study relating an innovative curriculum to student outcomes involves a science learning community. Morgan, Carter, Lemons, Grumbling, and Saboski (1995) developed an introductory science program intended to actively engage students in the learning process. The theme of "Change, Constancy, and Change" ties biology to other disciplines. One of the central goals of the learning community was to develop students' thinking skills.

Beginning in 1989, all first year life science students at the University of New England were required to enroll in five courses that constituted the learning community: Biology I and II, Introduction to Environmental Issues, a literature course entitled Literature, Nature, and Biology, and Introduction to Learning Community. The courses were designed around four modules associated with the unifying theme. The courses encouraged students to explore issues and direct instruction by selecting questions for further study. Discussion sections, laboratories, and field trips typified the instruction, with an emphasis on peer teaching.

Subjects in this study were all students enrolled in the year-long learning community for four consecutive years. The total population included 134 students. In order to determine the influence of the learning community on student learning, an instrument was administered to students in the program. The Measure of Intellectual Development (MID) was developed for use with high school students engaged in learning communities. Subjects respond to general information statements, using a five-point Likert-type scale. No new validity or reliability information was provided for the administration of the instrument with the new group of students. The MID was administered as a pre-test and post-test each year.

A series of t-tests were used to detect differences between the pre-tests and post-tests of each year. Statistically significant differences ($p = 0.001$) were seen between the pre-tests and post-tests administered in the third (pre = 2.60/5, post = 3.02/5) and fourth years (pre = 2.95, post = 3.08/5). No mention was made of the practical significance to these small improvements in MID scores. A Scheffe multi comparison analysis was used to determine if there was greater improvement during any given year. The data showed that the increase in scores was significantly greater for the third year ($p = 0.05$) than for any other year.
Students also completed evaluation forms that had them rank achievement of course goals on a Likert-type scale of one (low agreement) to five (high agreement). The majority of students responded that there was a sense of community emphasizing cooperation and purpose (69%), that they had actively participated in the learning process (68%) and that they thought they had gained critical thinking skills (69%).

Based on these results, the authors concluded that a reduction in class size (40-44 to 22) resulted in the higher MID scores in the third and fourth year. The smaller class sizes fostered a greater sense of community, resulted in more discussions, and facilitated interactions between students and faculty. Despite the enormous time commitment involved in team-implementing the learning community, the authors stated that this approach addressed many aspects of science education reform. The researchers and faculty perceived gains in critical thinking skills, based on the exchange of ideas within the learning community.

The final study examined the influence of portfolio development on student outcomes. Barrow (1993) implemented portfolio assessment in a general chemistry course, with the intent of supplementing constructivist teaching strategies and desired outcomes. The assessment permeated all aspects of the curriculum, including planning and instruction, revealing the critical role assessment plays in reform success.

The instructor/researcher invited students to participate in an alternative assessment plan, worth 20 percent of their grade (80% traditional exams). Forty-six of the 122 students agreed to participate. The portfolio was defined as a container of evidence containing knowledge, skills, several categories of evidence, a statement of portfolio goals, and artifacts. Students began their portfolios by submitting a statement of their goals and intentions related to developing the portfolio. This was intended to have students take more responsibility for their learning. Several students mentioned including the work they did preparing for exams.

... I view this portfolio as an opportunity to not only show my instructor my efforts to prepare for exams, and learn material, but also if properly done, serve as a reference for me in the future. (Barrow, 1993 [p. 150])

Other students viewed the portfolios as journals to keep track of learning. The purpose of my portfolio is to demonstrate the daily learning processes of the topic. By keeping a portfolio, hopefully it will enable me to go back to previous assignments and enlighten myself further. (Barrow, 1993 [p. 150])
Many of the students stated that they wanted to use their portfolios to develop a better understanding of general chemistry.

...I want to use my portfolio to foster a deeper understanding of the principles of chemistry. (Barrow, 1993 [p. 151])

The instructor/researcher met with each student to assist them in constructing their portfolios. During these meetings the researcher realized that many of the problems the predominantly African-American student subjects had with learning the science content was due to with job and family commitments. Once the portfolios were submitted, the researcher determined that students using portfolios had higher course grades than students who just took exams. This may have been due to more motivated student participating in the portfolio assessment, or due to overall higher grades on the portfolios than on the exams. Many of the students were intrinsically motivated to complete the portfolios.

I had taken this course before and had failed it. I really had problems seeing how chemistry related to what I was doing as a person in landscape design. The portfolio helped me to make the critical link. (Barrow, 1993 [p. 153])

Additionally, the portfolios may have helped students organize and structure their own learning of chemistry, as well as spending more time studying chemistry in general. The researcher stated that the portfolios extended the learning environment, developing student reflective processes and a context where the learner in the center of the course. The curricular innovation also led to increased faculty-student contact and increased faculty awareness of student issues.
Summary of Research Literature

The reviewed studies all examined aspects of curricular innovation in science courses. These innovations involved altering both the content being taught and the accompanying instructional strategies. Even if the studies preceded the current reforms, they all promoted aspects of science literacy advocated by AAAS (1993) and NRC (1996a). These aspects included STS (Bradford, Rubba, & Harkness, 1995; Gregory, 1992), critical thinking (Barrow, 1993; Morgan, Carter, Lemmons, Grumbling, & Saboski, 1995), nature of science (Jensen & Finley, 1996), and multiple components of science literacy (Nakhleh, Bruce, & Schwartz, 1995) Table 2.1.

The duration of the new curricula lasted from four lectures (Jensen & Finley, 1996) to a full year (Morgan, Carter, Lemons, Grumbling, & Saboski, 1995). Some of the curricula were designed to address the current reform measures (Bradford, Rubba, & Harkness, 1995; Fedock, Zambo, & Coburn, 1996; Jensen & Finley, 1996). Two of the studies also included a form of professional development or training for the teachers implementing the curriculum (Fedock, Zambo, & Coburn, 1996; Prather, 1995).

Table 2.1: Curricular Innovations Addressed in the Reviewed Studies.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Authors</th>
<th>Curricular Innovation</th>
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<tbody>
<tr>
<td>Teacher Beliefs</td>
<td>Trumbell, Kerr</td>
<td>General faculty beliefs and biology innovation</td>
</tr>
<tr>
<td></td>
<td>Stark, Lowther, Sharp, &amp; Arnold</td>
<td>General faculty beliefs and curricular change</td>
</tr>
<tr>
<td>Professional Development</td>
<td>Fedock, Zambo, &amp; Cobern</td>
<td>Learning cycle</td>
</tr>
<tr>
<td></td>
<td>Prather</td>
<td>Instructor assessment</td>
</tr>
<tr>
<td>Student Outcomes</td>
<td>Bradford, Rubba, &amp; Harkness</td>
<td>STS Introductory physics course</td>
</tr>
<tr>
<td></td>
<td>Gregory</td>
<td>STS curriculum</td>
</tr>
<tr>
<td></td>
<td>Jensen &amp; Finley</td>
<td>Historically-rich problem-solving curriculum</td>
</tr>
<tr>
<td></td>
<td>Nakhleh, Bruce, &amp; Schwartz</td>
<td>Social/Environment focus</td>
</tr>
<tr>
<td></td>
<td>Morgan, Carter, Lemons, Grumbling, &amp; Saboski</td>
<td>Science learning community</td>
</tr>
<tr>
<td></td>
<td>Barrow</td>
<td>Portfolio instruction and assessment</td>
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</table>
Research questions in the reviewed studies were fairly general, due to the limited quantity of research in the area of curricular innovation. All of the reviewed papers related to faculty involvement in innovative curricular design and implementation focused on teacher beliefs. None of the studies centered on research questions related to teacher knowledge and learning.

Two studies examined teacher beliefs related to their intentions to design and/or implement innovative curricula. Stark, Lowther, Sharp, and Arnold (1997) asked university faculty what factors influenced their decisions to alter a curriculum. The faculty included numerous factors, including beliefs about their disciplines, overall curriculum goals, budget and enrollment concerns, student learning, and student characteristics. The researchers concluded that faculty need a catalyst such as student feedback to believe that a curriculum needs to be altered. For that change to succeed, the researchers suggest that faculty need some form of leadership and support from their disciplinary programs. Trumbell and Kerr (1993) studied TA and faculty beliefs to identify factors that would limit curricular innovation. They concluded that faculty are largely unfamiliar with alternative instructional strategies, and were likely to continue teaching as they were taught.

Two studies examined the role of professional development in altering teacher beliefs regarding curricular innovation. Fedock, Zambo, and Cobern (1996) examined the beliefs and practices of college professors as they developed a science course for K-12 teachers. Assistance from science educators and K-12 science teachers, as well as financial support appeared to play key roles in shifting faculty beliefs about instruction and course content. Additionally, data suggested that these belief changes translated to altered classroom practices. Prather (1995) investigated the role of a self-assessment program on faculty teaching. The researcher concluded that guided self-assessment could potentially enable faculty to make significant changes in their own teaching. The study suggested that an organized self-assessment program may assist those faculty already interested in altering aspects of instruction.

The studies related to student outcomes primarily focused on student performance on specific exams or instruments, and did not discuss the practical significance of these results. Also, the research questions related to student outcomes tended to focus on specific outcomes (attitude toward science, specific understandings of relationships between society and science) instead of taking a broader look at the impact of a curricular innovation on the acquisition of a variety of concepts and skills.
Few of the studies addressed whether student performance on the assessments had meaning beyond the scope of the specific courses, although Gregory (1992) suggested students studying science “in-the-news” continued practicing those skills after completion of the course.

The five studies investigating the links between innovative curricula and student outcomes, came to different conclusions concerning the effectiveness of these curricular changes. Bradford, Rubba, and Harkness (1995) studied the effects of an STS-based curriculum on university students’ ideas related to STS. They concluded that the STS curriculum was not effective because many students developed misconceptions from participation in the course. Conversely, Gregory (1992) simply wanted to improve college students’ attitudes toward science with a short course focused on “science in the news” and found that students developed an appreciation for science and the influence of media on scientific knowledge. Jensen and Finley (1996) studied the effects of a short unit on the history of science on college students’ ideas of science. The researchers concluded that historically rich problem-solving lectures were more effective than traditional “history-free” lectures in altering students’ ideas of evolution.

Nakhleh, Bunce, and Schwartz (1995) examined the impact of a new chemistry curriculum on student attitudes. The researchers concluded that the curriculum had a positive effect on student attitudes towards chemistry. The curriculum may have challenged students’ preconceived ideas about chemistry, particularly those relating chemistry to social issues. This may suggest that the curriculum altered student views of science-society interactions, an aspect of the science education reforms. Morgan, Carter, Lemons, Grumbling, and Saboski (1995) developed an introductory science program to actively engage students in the learning process. The researchers and students perceived gains in critical thinking skills, based on the exchange of ideas within the learning community. The researchers noted that a small class size was an important component related to perceived student gains.

Barrow (1993) implemented portfolio assessment in a general chemistry course. The portfolios enabled some of the students to organize and retrieve information. The researcher noted the importance of increased interactions with the students. Two of the studies found that teachers’ perceptions of student abilities may influence decisions to alter a curriculum (Prather, 1995; Stark, Lowther, Sharp, & Arnold, 1997). The studies did not determine whether actual student expectations matched the teachers’ conceptions.
The methodologies in the reviewed studies varied from Likert-Type questionnaires to extensive classroom observations and interviews (Table 2.2).

**Table 2.2: Summary of Research Designs of Reviewed Studies.**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Authors</th>
<th>Year</th>
<th>Subjects</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Beliefs</td>
<td>Trumbell, Kerr</td>
<td>1993</td>
<td>University TAs and Faculty</td>
<td>Open-ended Interviews</td>
</tr>
<tr>
<td></td>
<td>Stark, Lowther, Sharp, &amp; Arnold</td>
<td>1997</td>
<td>College and University Faculty</td>
<td>Semi-structured Interviews</td>
</tr>
<tr>
<td>Professional Development</td>
<td>Fedock, Zambo, &amp; Cobern</td>
<td>1996</td>
<td>College Faculty</td>
<td>Structured Interviews</td>
</tr>
<tr>
<td></td>
<td>Prather</td>
<td>1995</td>
<td>University Faculty</td>
<td>Survey Form</td>
</tr>
<tr>
<td>Student Outcomes</td>
<td>Bradford, Rubba, &amp; Harkness</td>
<td>1995</td>
<td>University Students</td>
<td>Open-ended Questionnaire</td>
</tr>
<tr>
<td></td>
<td>Gregory</td>
<td>1992</td>
<td>University Students</td>
<td>Evaluation Forms</td>
</tr>
<tr>
<td></td>
<td>Jensen &amp; Finley</td>
<td>1996</td>
<td>University Students</td>
<td>Open-ended Questionnaires</td>
</tr>
<tr>
<td></td>
<td>Nakhleh, Bruce, &amp; Schwartz</td>
<td>1995</td>
<td>University and College Students</td>
<td>Survey Form</td>
</tr>
<tr>
<td></td>
<td>Morgan, Carter, Lemons, Grumbling, &amp; Saboski</td>
<td>1995</td>
<td>University Students</td>
<td>Pre- and Post-tests</td>
</tr>
<tr>
<td></td>
<td>Barrow</td>
<td>1993</td>
<td>University Students</td>
<td>Unstructured Interviews</td>
</tr>
</tbody>
</table>

Few of the studies addressed the advantages and limitations of their methodologies, although the descriptive studies (Fedock, Zambo, & Cobern, 1996; Stark, Lowther, Sharp, & Arnold, 1997) generated lists of factors related to curricular innovations and teacher beliefs. Considering the exploratory nature of the research questions, the open-ended interviews and observations in these studies generated information for future studies. Conversely, four of the student outcomes studies attempted to fit specific close-ended analyses on broad research questions (Bradford, Rubba, & Harkness, 1995; Gregory, 1992; Morgan, Carter, Lemons, Grumbling, & Saboski, 1995; Nakhleh, Bruce, & Schwartz, 1995).

None of the reviewed studies explicitly studied teacher knowledge. However, interesting trends emerged in the studies regarding teacher knowledge and learning.
Trumbell & Kerr (1993) and Stark, Lowther, Sharp, & Arnold. (1997) noted that teachers’ beliefs about the importance of a topic influenced whether they taught the topic. Additionally, both studies suggested that the teachers had limited knowledge about some of the topics covered in the curricula, influencing their decisions on whether to include the topics. Neither study mentioned whether the teachers attempted to learn more about the topics prior to excluding them from the curriculum.

Stark, Lowther, Sharp, and Arnold (1997) suggested that faculty beliefs concerning their disciplines and recent research within the disciplines could influence their decisions to alter their curricula. Additional information on what this process entails was not addressed in the study. Fedock, Zambo, and Cobern (1996) suggested that support from science educators and experienced K-12 science teachers helped college teachers in learning about the current ideas and research in science education. Additionally, the researchers noted that time for preparation and “practice” implementation contributed to shifts in faculty beliefs regarding content coverage and instructional practices.

**Implications of Research Literature**

Based on a review of the literature, it was apparent that most aspects of curricular innovation and learning in university science classrooms had not been studied. Prior research focused on verification of theory, although that theory was not derived from detailed descriptions of classroom phenomena. Studies also focused on short-term practices and not curricular change over time. Based on the available studies, primarily related to teacher beliefs and student outcomes, there were a number of implications that were considered in the formulation of the research questions driving the study described in this thesis.

**Faculty Learning and Curricular Design**

Although not specifically addressed in the reviewed papers, two of the papers included data that suggested teacher knowledge and on-going learning may be critical components of the success of curricular design and implementation (Fedock, Zambo, & Cobern, 1996; Trumbell & Kerr, 1993). The research described in subsequent chapters attempted to determine the type of faculty learning that occurs in the design, implementation, and revision of an innovative curriculum. The reviewed research suggested that faculty decisions to learn new material may be influenced by their beliefs,
including their attitudes toward the importance of curricular change (Fedock, Zambo, & Cobern, 1996).

A missing factor in the literature was a link between teacher change and student outcomes. Faculty learning may influence student learning through the development of curricular objectives, instructional strategies, and assessments. The reviewed studies focused on “teacher-proof” instructional strategies, although individual teacher behaviors such as time spent preparing for lecture may have a significant impact on student learning. This led to developing methodologies for this study that documented beliefs and behaviors related to faculty learning, and the influence these factors on curriculum design.

**Teaching Assistant Learning and Curricular Interpretation**

Although the reviewed studies had not addressed the influence of TA learning on student outcomes, TA beliefs and time constraints may influence the time spent learning new material, and preparing strategies to interpret curricular changes for “student consumption.” Three of the reviewed studies mentioned that a variety of factors such as frustration with students and limited time could limit the implementation of a curriculum (Prather, 1995; Stark, Lowther, Sharp, & Arnold, 1997; Trumbell & Kerr, 1993). The study described in this paper attempted to identify factors influencing TA teaching and learning within the context of an innovative curriculum.

TAs interact directly with students, and may have views about student abilities. Trumbell and Kerr (1993) suggested that TA views of student abilities may influence TA instructional decisions. This research study was designed to document TAs views about student abilities, and determine if this influences aspects of TA learning, including preparation and organization of course activities.

**Student Learning in the Context of Innovation**

The reviewed studies on curricular innovation and student outcomes focused on specific student outcomes, instead of providing an overview of the range and types of learning (knowledge acquisition and decision-making) that students engage in when asked to learn new content in entirely new ways. This led to a research study design using a variety of methodologies to construct a hypothesis of the types of student learning that occur in the context of a curricular innovation, including the factors that influence the learning.
Only one of the studies (Gregory, 1992) examined whether student learning transferred to activities beyond the original science course. This led to development research methodologies to examine how subjects related what they had learned to other scenarios.

**Influence of TA and Student Feedback on Curricular Design**

In addition to student outcomes, an important factor is the ability to sustain a curricular innovation for future courses. Oral and written feedback from students may influence curricular revisions and future implementation. Two of the reviewed studies suggested that teachers' perceptions of student abilities and expectations may influence what they decide to include in the curriculum (Stark, Lowther, Sharp, & Arnold, 1997; Trumbell & Kerr, 1993). The research in this thesis examined the extent and means by which TA and student feedback influenced curricular revisions.

**Need for Additional Information on Methodologies**

The available literature presented a clear and wide gap in the understanding of the complexity of student, TA, and faculty learning within courses undergoing curricular innovation. This led to the development of expansive research questions to document learning in an undergraduate science classroom. However, the limited number and unrelated nature of available studies did not suggest a clear type of methodology to address the emerging research questions. A pilot study was conducted to develop and test methodologies that would enable the researcher to collect and manage extensive information about simultaneous learning in three subject groups.

**Pilot Study**

As mentioned, few of the reviewed studies addressed the advantages and limitations of their methodologies. Due to the limited research base, a pilot study was conducted Spring Term, 1998. The primary objectives of the pilot study were to (1) develop and practice research methodologies to describe learning in an introductory biology course, and (2) design strategies to manage and analyze the data collected.

This pilot study was conducted within the same series of undergraduate biology courses as the subsequent study discussed in this thesis. Although the course content and innovative project differed, as will be discussed, the basic design of the course was almost identical. For this reason, a detailed description of the pilot study is provided.
Pilot Study Setting

The pilot study was conducted at an American West Coast public university. The introductory biology course had 436 undergraduate students with declared majors in subjects other than biology. The course partially fulfilled university baccalaureate core laboratory science requirements. This course was the third (coded BI 103) of three introductory biology courses in a series (coded BI 10X), each lasting 10 weeks, worth four credits, covering different topics, and designed to be taken in any sequence. Many of the students enrolled in the pilot study's course had not taken either of the first two courses. Conceptual themes that ran throughout the three courses included the history of biological knowledge development, scientific process, and links between science and society. The diverse topics covered in the course studied included botany, human physiology, and disease.

The course consisted of lecture, activities (recitation and laboratory), and assigned textbook readings. An additional student project will be described below. Two 50-minute lectures were taught by the faculty per week. Faculty and TAs attended two hours of weekly preparation for the recitation and laboratory activities. TAs taught one or two groups of 40 students for a recitation (50 minutes) and laboratory (1 hour, 50 minutes) each week. During these activities, students worked in cooperative groups and received group grades.

The course was managed by a course coordinator (one of the teaching faculty in the pilot study) and was team-taught by three faculty. The course coordinator oversaw all aspects of the course, including TA preparation and student assessment. The lecturing faculty designed activities, wrote exams, and attended TA preparatory sessions. Historically, a close link had been maintained between the lecture, activities, and textbook reading assignments. The textbook used was written by faculty who had lectured in the course. Additionally, each of the biology courses were continually updated with new activities, new lectures, or improvements on existing instruction. These improvements were initiated by the course faculty, often with input from TAs and student feedback (evaluations and word-of-mouth).

The program facilities had been recently up-dated with computers in laboratory and lecture, a Learning Center with tutors and resources available to students, and a faculty development facility with multimedia equipment. A limited amount of technical and financial support, primarily related to computer technologies, were available to faculty interested in curriculum design and implementation.
Pilot Study Curriculum

The course studied in the pilot study began with a three-week unit on botany, followed by a seven-week unit that covered human physiology and diseases. Upon examination of the curriculum, two of the lecturers (the same two participating in the later study), including the researcher, decided to re-design the seven-week physiology/disease unit. The decision to alter the curriculum was based on many factors (see results section below) including the results of a survey conducted the previous year. The results suggested that many students: (1) were unaware of the biological basis of many health-related behaviors such as taking vitamins or aerobic exercise, and (2) generally made health-related decisions based on family traditions or information heard from a single source (generally TV).

The new physiology/disease unit included a student-centered project that incorporated aspects of lecture, activities, textbook readings, and independent research intended to (1) have students learn how behaviors can lead to the onset of diseases and (2) engage students in searching for information, critically reviewing that information, and applying that information to health-related decisions.

An attempt was made to address science education reform recommendations included in various reform documents (AAAS, 1993; NRC, 1996a). The new curricular changes addressed reform recommendations related to science content, instruction, and assessment (see Appendix A). The curriculum had been validated by matching instructional goals and assessment with the overall reform-based curricular goals (see Appendix B). An important caveat is that the reform recommendations were made for K-12 instruction, and that an on-going attempt was being made by the course instructors to determine how these recommendations related to the university classroom. Conditions of learning within the curriculum are designed to facilitate the instructional learning goals of reasoning, critical thinking, and use of knowledge (Driscoll, 1994).

Within the BI 103 course, the learning goals included students understanding how their behaviors can relate to the onset of disease (factual information) and how to critically review research and formulate health decisions (procedural information). In addition to the traditional tasks of taking notes, completing activities, and reading textbook readings, the students in the study were asked to take over more active control of their own learning. This stress on student involvement in learning echoes the various reforms.
The curriculum outline for the new seven-week unit is provided in Table 2.3, and the new unit is outlined in Table 2.4. Students were asked to examine their own risk factors for a variety of diseases, select and research a disease, and write a paper about that disease. To provide a more detailed picture of the degree of innovation in the new course unit, objectives and assessments are provided for the sub-unit “A Case Study: Cancer” (Appendix B).

Pilot Study Subjects

The faculty subjects were two of the three instructors who taught the course. The third instructor taught the initial botany unit that was not integrated with the seven-week unit on physiology and disease taught by the two instructor subjects. One of the two subjects was an experienced teacher who had taught the course for over 20 years, and was the course coordinator. The other subject, the researcher, was a relative novice with three years teaching experience in the course (see researcher description in Chapter 3). Both subjects had taught together in other courses, although this was the first joint restructuring of significant portions of a curriculum.

The subjects were responsible for curriculum development, lecturing, student assessment, TA preparation, and facilities management. Both subjects also taught one other course and spent significant time addressing TA and student questions and concerns.

The TA subjects were four volunteers from the group of seven TAs assigned to teach within the course. All four subjects had been TAs in the two previous courses (coded BI 101 and BI 102) of this biology series. The researcher solicited TA volunteers at the first weekly preparation session by describing the study and distributing informed consent forms.

As were required to teach laboratory and recitation activities, attend two hours of weekly preparation for these activities, grade student laboratory/recitation papers, proctor exams, attend lectures, participate in TA educational activities, and write exam questions from the activities they teach. Within the laboratory and recitation activities, TAs were strongly encouraged to not lecture, but instead spend their time assisting the students in working through the activities in their cooperative groups (single activity grade assigned to group of five students). The primary role of the TAs in the course was to respond to student questions.
### Table 2.3: Original Course Unit on Physiology and Disease.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Botany</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cells and Tissues</td>
<td>Human Organ Systems I</td>
<td>Animal Structures</td>
<td>Invertebrate Structure</td>
</tr>
<tr>
<td>5</td>
<td>Human Organ Systems II</td>
<td>The Endocrine System</td>
<td>Homeostasis</td>
<td>Hematology</td>
</tr>
<tr>
<td>6</td>
<td>The Nervous System I</td>
<td>The Nervous System II</td>
<td>Textbook Integration</td>
<td>Human Olfaction</td>
</tr>
<tr>
<td>7</td>
<td>Research and Development I</td>
<td>Reproduction and Development II</td>
<td>Reproduction</td>
<td>Contraception</td>
</tr>
<tr>
<td>8</td>
<td>Defense Systems I</td>
<td>Defense Systems II</td>
<td>Disease</td>
<td>Immunity</td>
</tr>
<tr>
<td>9</td>
<td>Cancer</td>
<td>HIV and AIDS</td>
<td>Cancer</td>
<td>Cancer</td>
</tr>
<tr>
<td>10</td>
<td>Other Human Diseases</td>
<td>Biology and the Future</td>
<td>Computer Search on Disease</td>
<td>No Lab (release time)</td>
</tr>
</tbody>
</table>

### Table 2.4: Revised Course Unit on Physiology and Disease.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Botany</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cells and Tissues</td>
<td>Human Organ Systems I</td>
<td>Life Style Analysis</td>
<td>Invertebrate Structure</td>
</tr>
<tr>
<td>5</td>
<td>Human Organ Systems II</td>
<td>Human Organ Systems III</td>
<td>Nutrition and Exercise I</td>
<td>Hematology</td>
</tr>
<tr>
<td>6</td>
<td>Healthy Life Styles</td>
<td>Nutrition: Science vs. Pseudoscience</td>
<td>Nutrition and Exercise II</td>
<td>Computer Models: Diet, Weight, Vitamins</td>
</tr>
<tr>
<td>7</td>
<td>Human Reproduction</td>
<td>A Case Study: Cancer</td>
<td>A Case Study: Cancer</td>
<td>A Case Study: Cancer</td>
</tr>
<tr>
<td>8</td>
<td>Our Senses</td>
<td>The Human Brain</td>
<td>Human Vision</td>
<td>Human Olfaction</td>
</tr>
<tr>
<td>9</td>
<td>Defense Systems</td>
<td>Immunity and Disease</td>
<td>Disease Transmission</td>
<td>Computer Health Quizzes</td>
</tr>
<tr>
<td>10</td>
<td>Infectious Diseases</td>
<td>Diseases for the New Millennia</td>
<td>Project Research Analysis</td>
<td>No Lab (release time)</td>
</tr>
</tbody>
</table>
There were 436 students enrolled in the course and all were asked to volunteer for the study. Of the 436 students, 296 agreed to participate. The final course grades of those students who volunteered were representative of the grades for the entire class. Of the students who volunteered to be in the study and turn in projects on time, 25 were selected to participate in interviews over a two-week period. Volunteer student code numbers were sorted into four groups by performance on the second midterm (A/A-, B+/B/ B-, C+/C/C-, D+/D/D-/F). Students were randomly selected from each of the four groups and contacted by phone or e-mail. The first 25 that were successfully contacted (of 32 selected prospects), were asked in for interviews. These 25 represented at least four students from each of the grade groups. This stratified sampling was intended to identify a wide range of students with a variety of course experiences.

Since students in the course came from almost every other discipline offered at this university to fulfill the baccalaureate life science requirement, student subjects represented diverse backgrounds and interests, and many would not have enrolled in a life science course if it was not required. Within the class, students were expected to attend lecture and take notes as necessary, attend and fully participate in laboratory and recitation activities, complete the assigned project, read assigned textbook chapters, take exams (two midterms and a final), and seek assistance from faculty, TAs, or other students as needed.

Pilot Study Data Collection and Analyses

In order to test the research methodologies intended to describe learning, a variety of data collection techniques were utilized. Each technique was developed to address components of faculty, TA, and student teaching and learning within the course.

Faculty Curriculum Artifacts

During curriculum development, the faculty generated a great deal of paperwork, including journal articles, Internet print-outs, tentative schedules, and rough drafts of the activities. These artifacts, combined with the researcher journal and interviews were used to reconstruct the process of curriculum development and the types of knowledge and processes involved in the development.

The finished student activity manual and textbook were also important artifacts used within the course. The course manual contained the syllabus, activity handouts,
Teaching Assistant and Student Pre-Project Activity

Prior to the project, students completed an activity that required them to evaluate various aspects of their lifestyle and introduced the project. This pre-project activity included questions about diet, exercise, stress, risky behaviors (drug use, etc.), and family history that were not used in this study. Five additional questions were included to provide information on student behavior relative to the project goals, and the answers to these questions were included in the pilot study.

1. What behaviors, if any, do you currently engage in with the intent of reducing your risk for disease(s)?
2. If behaviors are listed for #1, how did you learn about the benefits of these behaviors?
3. Most of your health information comes from:
   (rank with 1 = most information, 6 = least information)
   __________ coursework __________ television
   __________ magazines/books __________ doctors
   __________ family __________ computers/Internet
4. How do you judge whether a source of health information is reliable?
5. Of all of the behaviors listed in the previous sections, which one are you interested in studying for your project? __________ Why are you interested in studying this topic?

The TAs also completed this activity prior to teaching as a component of their preparation. The faculty had worked through the questions and answers during earlier planning sessions (see faculty artifacts). These activities were collected from subject TAs and students as background information for the post-project interviews.

Preparatory Session Observations

Faculty and TAs attended two one-hour prep sessions each Monday to review the laboratory and recitation activities. The primary goal of these preparatory sessions was to address procedural concerns (exam times, room changes), introduce the activities (instructional strategies and assessment), and address TA concerns and suggestions for improving prior activities. The TAs were expected to complete the activities on their own to become more familiar with the material and procedures. Other interactions between faculty and TAs, included TAs attending lectures, holding office
hours in the building, and holding casual conversations with the faculty which were less frequent.

The researcher took notes during all of the preparatory meetings. These data provided information on the questions being asked, problems with the curriculum, TA perceptions of student learning, and the work TAs were putting into interpreting the curriculum.

Lecture Observations

Students and TAs attended the two weekly lectures. Additionally, the non-lecturing faculty member also attended to insure unity between the material covered in the “team-taught” lecture. Due to the large number of students and limited lecture space, each lecture was repeated at a later hour. Generally between 65 and 75 percent of the students attended the lectures, with some students missing most, and others only missing occasionally. Lecture attendance (as measured by occasional lecture puzzles) positively correlated with exam grades. Lectures were designed to provide an overview of the curriculum, historical perspectives, and material not covered in other components of the course.

Although most of the lecturers asked the students questions 10 or more times during the lectures, most of the time was spent with the lecturers telling stories and the students listening or taking notes. Exceptions occurred on topics such as “cancer,” when student interest and concern lead to more of a discussion format. Overall, students generally rated the lecture component of the course higher than the activities on their student evaluation forms. The experienced faculty lecturer added lectures on aspects of the tentative nature of scientific knowledge to the first three weeks of the unit. The researcher/lecturer added lectures on the historical basis of scientific knowledge to the last four weeks of the unit. The curriculum objectives were used in the organization and presentation of the lecture topics.

All of the researcher's lectures were videotaped and notes were taken on the other lectures to attempt to record student responses to questions within the large lecture hall. The videotaping was varied using different camera positions and microphones, and different note-taking strategies included global scan and selective verbatim. Different data collection techniques were later compared to determine complexity of data recorded and time efficiency.
Activity Observations

Much of the curricular innovation was occurring in the activity portion of the course. Students worked in eight groups of five, turning in a single activity report to the TAs. Due to the nature of the unit, students did much of the work on their individual projects outside of the classroom, and worked with one another to master the group activities. The activities were far less structured than traditional biology activities. One week the students were simply given several Internet addresses and asked to develop a thorough profile of their diet, including any health implications associated with excesses and deficiencies.

The researcher already habitually attended several of the activities to assist the TAs with the large number of students, and was fairly unobtrusive while making observations. Observations focused on the introductory lecture presented by the TAs, conversations between TAs and students, and interactions within student groups. The researcher moved to different locations in the room to focus on different subjects, and take notes.

Due to the large number of activities each week (22 activities, 33 hours), the researcher was unable to attend every activity. Instead observations focused on the eight laboratory and recitation sections taught by the four subject TAs.

Teaching Assistant Artifacts

Teaching artifacts include overhead transparencies, classroom notes, handouts, and exam questions. These artifacts were collected as part of the course's TA education program, and provided information on TA preparation.

Formative Interviews

Relatively unstructured, informal interviews were carried out with faculty, TAs and students. The subjects were reminded that conversations were a component of the research study, and were asked to reflect and elaborate on a particular teaching or learning event observed by the researcher, or to comment on their progress.

Formative interviews were brief, often consisting of a single question and answer, and occurred throughout the project. The two faculty subjects already met three or more times a week to briefly discuss course concerns. TA and student formative interviews primarily occurred before and after classroom observations. The researcher took notes for all of the formative interviews that were placed in files organized by subject TA class.
Projects

Students turned in their projects during the ninth week of the course (week six of the unit). The project consisted of independent research on a topic of each student's choice, the pre-project activity, other activities related to disease prevention, and student summaries of what was learned in the unit. The researcher collected and photocopied projects completed by all 296 of the student subjects from the TAs and immediately returned them to the TAs for grading.

Student Post-Project Interviews

Student interviews were scheduled for one hour each, with 30 to 45 minutes of actual interview, and 15-30 minutes for researcher notes and reflection. Interviews were held in the researcher's office, conveniently located close to the course facilities. With the student's permission, the interviews were audiotaped and later transcribed.

The semi-structured interview began with the researcher asking generally if the student felt he/she learned anything from the project. The student then was asked to expand on that answer. More specific questions followed, usually including:

1. Why did you select this particular topic for your class project?
2. In this project, you discussed __________. Can you explain this a bit to me?
3. (Show student his/her project) When initially asked what you knew about this topic, this is what you wrote (Give student a chance to review). Did you later find that any of these things were wrong or incomplete? Please explain.
4. How did you research your topic? How did you judge whether a source was reliable?
5. If you were asked whether or not it was a good idea to take calcium supplements (new topic), how would you respond? Where would you go for additional information?
6. Recall the activities from this unit (show copy of syllabus for clarification). In which one do you think you learned the most? the least? Please explain.
7. Did you find yourself studying, or doing anything different during this unit compared to what you have previously done in your courses?
8. How did your TA help you with the activity or the projects?
9. Did anything from lecture relate to your project? If so, what, and how?
10. Overall, what do you think you learned from the physiology/disease unit?

Follow-up questioning was used to clarify student answers. Additional questions pertaining to individual students' projects and exam responses were used to clarify what
they learned in the course. Following the interviews, the researcher reflected on the interview and wrote down any notes that summarized the interview.

Teaching Assistant Post-Project Interviews

Interviews were scheduled for one hour each, with 15 minutes of that time set aside for researcher reflection. The interviews centered on giving the TAs an opportunity to reflect on the unit and verbalize aspects of their own learning experience.

The interviews began with the TAs overall impression of the unit in order to elicit general responses. A series of ten questions followed:

1. What was your overall impression of the physiology/disease unit?
2. Which, if any, of the topics covered in the unit were new to you?
3. How did you prepare for teaching the computer-based activities? Did this preparation differ in any way from how you prepared to teach other activities?
4. (Show copy of syllabus) Which of these activities was the most successful? The least successful? Please explain.
5. What did students appear to have the most trouble with during this unit? What do you think students learned by participating in this unit?
6. In what ways were you able to assist students with their projects?
7. Which, if any, of the material covered in lecture related directly to the activities and/or project in this unit?
8. How well did the preparatory sessions prepare you for teaching the material? What improvements would you suggest?
9. In the last week you designed and led your own activity, what kind of preparation did this involve?
10. Overall, what do you think you learned from the physiology/disease unit?

Follow-up questions were used to clarify TA answers. Following the interviews, the researcher reflected on the interview and wrote down any notes that may facilitate subsequent interviews.

Faculty Post-Project Interviews

The two faculty subjects met and discussed the curricular innovation, including changes that might improve the curriculum for the following year. Prior to the interview, the researcher generated a series of questions for the other faculty member, and answered the questions herself prior to hearing the other subjects' responses. These questions were:
1. What was your overall impression of the physiology/disease unit?
2. What aspects of this curriculum took the most preparation?
3. What did students appear to have the most trouble with during this unit? What do you think students learned by participating in this unit?
4. (Show copy of syllabus) Which of these activities was the most successful? The least successful? Please explain.
5. What role did the TAs have in the implementation of the curriculum?
6. Were preparatory sessions different in any way? How could TAs have been better prepared to discuss this unit?
7. Describe the process of constructing the new lectures for this unit. How familiar were you with this material prior to this new curriculum? What new content, if any, did you learn while preparing the lectures?
8. How did lecture tie in with the activities and the projects? What aspects of lecture can be improved?
9. What changes can be made to improve the curriculum?
10. Do you believe the two major objectives of the project, disease prevention and critical analysis of information, are topics that should be covered in an introductory biology course for nonmajors? Explain.
11. Overall, what do you think you learned from teaching the physiology/disease unit?

Follow-up questions were used to clarify the subject's responses (the researcher wrote detailed responses for each question). Following the interview, the researcher reflected on the answers and wrote additional notes.

Exam Scores

Student subjects took a midterm exam and final exam covering material in the new physiology/disease unit. Exam data from study subjects was compared with the project grade and laboratory section. Additionally, the specific exam questions were broken into groups based on the source of information (lecture, activity, textbook, mixed) to see if students had difficulty with material from particular parts of the course.

Summary of Pilot Study Data Collection

Table 2.5 summarizes the types of data collected during the pilot study. Data collection focused on learning within the three groups (faculty, TAs, and students). Additionally, the influences of interactions on learning was examined for faculty/TAs (preparatory session observations, post-project interviews), TAs/students (activity observations, post-project interviews), and faculty/students (lecture observations, post-project interviews).
Table 2.5: Pilot Study Data Collection Matrix.

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Type of Data</th>
<th>Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty Knowledge and Skills</td>
<td>Curriculum Development Paperwork, Information Presented to Students</td>
<td>Faculty Curriculum Artifacts</td>
</tr>
<tr>
<td></td>
<td>Lecture Information Presented to Students</td>
<td>Lecture Observations</td>
</tr>
<tr>
<td></td>
<td>Faculty Reflection on Teaching</td>
<td>Formative Interviews</td>
</tr>
<tr>
<td></td>
<td>Faculty Reflection on Curriculum and Personal Knowledge</td>
<td>Post-Project Interviews</td>
</tr>
<tr>
<td>TA Knowledge and Skills</td>
<td>Questionnaire on Pre-Project Behaviors and Knowledge</td>
<td>TA Pre-Project Activity</td>
</tr>
<tr>
<td></td>
<td>Interactions Between TAs and Faculty</td>
<td>Preparatory Session Observations</td>
</tr>
<tr>
<td></td>
<td>Interactions Between TAs and Students</td>
<td>Activity Observations</td>
</tr>
<tr>
<td></td>
<td>TA Preparation for Teaching</td>
<td>TA Artifacts</td>
</tr>
<tr>
<td></td>
<td>TA Reflection on Teaching</td>
<td>Formative Interviews</td>
</tr>
<tr>
<td></td>
<td>TA Reflection on Curriculum and Personal Knowledge</td>
<td>Post-Project Interviews</td>
</tr>
<tr>
<td>Student Knowledge and Skills</td>
<td>Questionnaire on Pre-Project Behaviors and Knowledge</td>
<td>Pre-Project Activity</td>
</tr>
<tr>
<td></td>
<td>Interactions Between Students and TAs</td>
<td>Activity Observations</td>
</tr>
<tr>
<td></td>
<td>Lecture Material and Attendance</td>
<td>Lecture Observations</td>
</tr>
<tr>
<td></td>
<td>Student Reflection on Activities</td>
<td>Formative Interviews</td>
</tr>
<tr>
<td></td>
<td>Knowledge About Specific Topic</td>
<td>Projects</td>
</tr>
<tr>
<td></td>
<td>Knowledge About General Topics</td>
<td>Exam Scores</td>
</tr>
<tr>
<td></td>
<td>Student Reflection on Curriculum and Personal Knowledge</td>
<td>Post-Project Interviews</td>
</tr>
<tr>
<td></td>
<td>Student Reflection on Impact of Curriculum on Personal Behaviors</td>
<td>Follow-up Interviews</td>
</tr>
</tbody>
</table>

Pilot Study Results

The primary objectives of the pilot study were to (1) develop and practice research methodologies that illuminated aspects of learning in an introductory biology course, (2) design strategies to manage and analyze the data collected. Results pertaining to these questions and additional insights into the proposed study questions are provided.
Research Methodologies

The data collected painted a rich picture of university classroom teaching and learning dynamics. However, several modifications were designed to improve on the methodologies used in the pilot study.

Although the faculty curriculum artifacts were useful for determining curriculum development tasks, more detailed descriptions of the early curriculum planning meetings would have provided important information about faculty learning. A researcher journal would have more completely documented early planning as well as subsequent data collection. This was added to the ensuing study.

Students and TAs answered the pre-project activity questions with brief responses. Formative interviews in conjunction with the pre-project activity would enable the researcher to ask follow-up questions. The formative interviews in the pilot study were short and relatively unstructured. Asking specific questions related to other data would assist in building a more complete picture of faculty, TA and student learning.

In the post-project interviews, subjects often repeated questions in their answers. This suggested the need to improve interview prompts (Southerland, Smith, & Cummins, 2000). The researcher focused on improving interview skills through practice interviews.

Communication between faculty and TAs primarily occurred during the preparatory sessions. Participants often discussed key components of teaching and learning. As the researcher participated in these discussions, information was often not recorded until after the fact, leading to disjointed, incomplete data. Concurrent verbatim note-taking would provide more detailed information.

Many of the goals of the course were embedded in the lectures, which provided the only forum for interaction between faculty, TAs, and students. Videotapes of the researchers' lectures provided a clearer view of lecture dynamics, particularly questions/answers than note-taking. In addition, the tone of discussion and responses to the lectures (such as laughing or groaning) was captured more effectively on video. The videotape could be transcribed and maintained as a supplemental data source.

Activity observations included videotaping and note-taking. The video was useful for providing coverage of the five-ten minute TA introduction to the activity, but provided little useful data about the remainder of the class, as students worked in groups, and the TA circulated throughout the classroom answering questions. The note-taking provided more detailed information on the topic of conversations that the researcher could overhear at numerous points throughout the classroom. Part of the difficulty of this
"hunt-and-peck" method of data collection was that attention focused on different students and different student groups in each class. A more focused look at a few specific groups each week would have provided more information on the teaching and learning occurring within those specific groups.

Activity artifacts from the TAs provided hints about planning, but often painted an incomplete picture of the amount of TA preparation necessary to teach. Structured formative interviews prior to and/or following the activities would provide additional information about TA planning.

The projects included narratives in which students described their process of learning about their specific health-related topics. This data could be supplemented with observations of the oral presentations in which the students further elaborate on what they have learned. Also, collection of information on the projects prior to the post-project student interviews would enable the researcher to ask more specific questions about the projects.

Student post-project interviews allowed the researcher to ask specific questions about tasks the students completed as part of the course project. The interview questions generated discussion on many facets of learning, from using computer programs to organizing lecture notes. However, many students had difficulty recalling what they did several weeks earlier. Sequential, formative interviews would have provided more complete information on student project-related learning as it occurred, and a foundation for the final interviews.

A concern prior to the pilot study was that students would respond to written questions in a uniformly positive manner, reminiscent of the Halo Error (Thorndike, 1920). Pike (1999) showed that the halo effect (error) was a component of university students' ratings of their learning and development on survey forms with Likert-type scales. This reflected students responses on evaluation forms in previous BI 10X terms. During the post-project interviews, students appeared to vary responses, from critical of particular project requirements to enthusiastic about learning outcomes.

Analysis of the final exam provided information about student achievement on specific topics related to the lecture, activity, and textbook portions of the course. Additionally, many students cited the importance of the second midterm exam in motivating them to work harder on their projects.
At the end of the pilot study it was unclear how feedback from students and TAs would influence revisions in the curriculum. Written notes from the faculty curriculum planning meeting following each term would provide this information.

Possibly most significantly, the pilot study demonstrated that different data collection techniques elucidated different variables associated with learning. Methodologies needed to remain relatively general in order to generate variables associated with student, TA, and faculty learning.

Data Analysis

In the pilot study, data analysis primarily occurred after all of the data were collected. This was problematic for several reasons. First, problems with data collection were not always recognized until a bulk of the data was collected. For example, the activity artifacts were not providing sufficient information about TA planning, a problem that was not identified until the TA post-project interviews. A data analysis journal could have been kept as a component of the researcher journal, to record design problems, shifts in data collection, and trends in the observed data. Additionally, the researcher journal would have provided a view of researcher thoughts and biases as data collection progressed.

Another problem with delaying data analysis until the end of the study was loss of opportunities to discuss the data with the faculty, TAs, and students in the formative and post-project interviews. Responses and behaviors could have been clarified by the participants if the data had been analyzed prior to these interviews. The development of a grounded theory of teaching and learning within the course would have been enriched by this opportunity for feedback from the studies' subjects.

Another, more logistical, concern was the build-up of massive quantities of data for a single final analysis. The interaction within and between the different subject groups were very complex, and organization of data throughout the study would have facilitated final data analysis.

During data analysis, it became clear that it would be difficult to report the findings without repeating results under multiple headings. For example, when discussing TA preparation, data related to TA beliefs, faculty comments in the preparatory sessions and student comments during activities. This thread can be carried on to show that TA comments in the preparatory sessions influence faculty adjustment of the curriculum, and TA preparation influences student motivation. It is
difficult to represent all of these overlapping interactions with words alone. Due to the complexity of the interactions that occurred within this course, a more complex graphical model may better represent the myriad of interactions, as well as the data that supports these interactions.

Faculty/Student/Teaching Assistant Teaching and Learning

Although not a primary goal of the pilot study, preliminary information provides tantalizing hints as to the complexity of faculty, TA, and student teaching and learning. Faculty learning occurred prior to, during, and after the course. Prior to the course, the faculty spent considerable time learning how to utilize computer technologies in the activities and lectures. The stress on computer technologies limited time spent on developing other aspects of the curriculum, such as the student activity manual and support materials for the TAs. Although both faculty had previously taught introductory biology, design of the new curriculum involved learning basic science content, and finding current information on a variety of science topics. Time constraints related to research, service, and other teaching obligations limited the time available to design the curriculum. Communication between the faculty was critical in sharing information pertaining to the curriculum goals, science content, and course technologies. During the course, faculty focused on their lectures and modifying lecture instruction and assessment based on feedback from TAs during the preparatory sessions. This feedback also contributed to curriculum revisions following the course, which was only briefly addressed by the pilot study methodologies.

The TAs had more direct contact with the students and have a clearer idea of what doesn't work (in the activities). Now we need to figure out what will work. (faculty, post-project interview)

Although all of the TAs had previously taught within the course, they were unfamiliar with the new activities, projects, and science content. The TAs primarily focused on developing classroom management strategies to address student concerns and complaints associated with the new curriculum.

The students are annoyed about all of the things that aren't working and the mistakes in the manual. We should do things a little differently, with them (the students) handing in a little of the project each week. (TA, preparatory session)
The TAs utilized a new TA office to share teaching strategies with other TAs in the course. Additionally, the TAs sought assistance and support from the course faculty at the weekly preparatory meetings. The TAs spent more time planning for each class than they had in previous courses due to the open-ended nature of the activities. Interviews at the completion of the course revealed that the TAs had not learned all of the science content that they were teaching or assessing, but had instead focused on the form and delivery of the student projects.

The students developed a variety of techniques to research and produce their disease projects. Many of the students had not critically reviewed science papers in previous courses, and sought assistance for this process from other students in their collaborative groups, and less frequently, their TAs.

___ (student name) showed me a good site on the web (World Wide Web) that I'm using for my report. Its easier than having to go to the library and start from scratch. (student, formative interview)

Students also helped each other with computer searches and word processing. In the final interviews, students suggested that they learned different skills and science content from their individual projects than from other aspects of the course, such as lecture and activities. Analysis of the projects, activity, and exam scores suggested that the projects may have been a valuable learning experience for those students having difficulty with the course activities and exams.

None of the previously reviewed research studies focused on the potential interactions among the three groups (students, TAs, and faculty), and the impact of those interactions on learning and curricular success. The interactions between faculty, TAs, and students played a critical role in mediating curricular problems. Due to limited direct interactions with students, faculty were dependent on information from TAs for course modifications. Additionally, TA and student learning were directly impacted by faculty curricular decisions. The time spent on various learning tasks of the three groups could be directly attributed to feedback from other course participants.

Pilot Study Implications

The pilot study suggested (1) several methodologies that could provide data pertaining to faculty, TA, and student teaching and learning, including formative interviews and a researcher journal, (2) benefits of data analysis throughout the study to generate more information from the subjects, and (3) a need to develop a theory of learning that can explain the complexities of interactions within the university classroom.
Additionally, the pilot study elucidated researcher emphasis on assessing subject knowledge and the transfer of that knowledge. This enabled reformulation of data collection to encompass a broader definition of learning.

Formulation of Research Questions

In order to develop a theory of learning in the introductory science classroom, three major components need to be addressed: (1) the learning results, or changes in performance, that can be explained by theory, and (2) the means, or processes that impact learning, and (3) the inputs, or triggers, that facilitate the processes of learning. (Driscoll, 1994). Due to the limited research base examining the general characteristics of student, TA, and faculty learning, the research questions guiding this study were intended to address all three components of theory development. The first research question examined what the subjects were actually learning, and the second question asked which factors were the means and inputs for that learning.

Two additional research questions were studied in conjunction with this research project: the degree of impact of interactions between subjects on learning, and the effect of learning on subsequent curricular change. Due to the methodological differences associated with studying these two questions, their results will be addressed further in subsequent publications. Focus for this study will be on describing the characteristics of learning.

Initial questions for the research came from real-world observations and perceived problems that emerged from the researcher's experiences and research interests (Marshall & Rossman, 1995). The researcher's background is covered in greater detail in Chapter 3.

Summary

Analysis of the reviewed research, including the pilot study, suggested research questions and methodologies related to curricular innovation and teaching and learning in the university classroom. The study described in the remaining chapters was grounded in the reviewed research, practice (the current science education reforms and researcher experiences), and generalized theories of learning. *A priori* assumptions were limited, resulting in a research design intended to describe and explore learning in the context of innovation. This design is described in detail in the next chapter.
CHAPTER 3: DESIGN AND METHOD

Introduction

Based on the research implications discussed in the previous chapters, this study incorporated descriptive and exploratory methodologies to document teaching and learning in an introductory biology course and identified important variables to generate hypotheses for future research. This chapter begins with a general description of methodologies, followed by an overview of the setting, curriculum, and subjects involved in the research. Next is a detailed description of the phases of data collection and brief overviews of the concurrent data analysis. This is followed by a more thorough discussion of data analysis that is broadly described in the context of the research questions:

1. In the context of an instructional innovation, what do faculty, TAs, and students learn?
2. What factors limit or augment learning in each of these groups?

General Description of Methodologies

Due to the limited research base on student, TA, and faculty learning in the context of curricular innovation, and the resulting lack of substantiated a priori assumptions, a qualitative design was utilized. Methodologies adopted for this study were selected to describe events, identify variables, and generate theory. Grounded theory data collection and analysis methodologies were used in tandem with narrative inquiry and ethnographic approaches. Grounded theory is used when the purpose of research is to construct conceptual frameworks that can be used to generate theory.

The first major strength of grounded theory lies in its possibilities for redirecting higher education research away from an exclusive emphasis on verification and toward the development of theory. Since many of our paradigms and theoretical frameworks (almost all of them borrowed from the social sciences) do not appear to fit the data, it seems a propitious time to redirect our energies. (Conrad, 1982 [p. 285])
This research also drew upon ethnographic techniques to provide a rich
description of the context for learning (Wolcott, 1988) and narrative inquiry (Clandinin &
Connelly, 2000). Focus shifted frequently between describing the fine detail of what the
subjects were doing to the wider perspective of the context of the observed behavior.
Data collection and data analyses were tightly interwoven, including constant
comparison and theoretical sampling of data. This study centers on observation of a
selected case; an undergraduate biology course undergoing curricular innovation
(Merriam, 1988).

Qualitative data, including participant observation, in-depth interviewing, and
document analysis, were used to describe this case. This practitioner research design
enabled long-term study and access to subjects as well as direct application of research
results. A narrative description was developed from the data, placing learning in a
spatial and temporal context. Concepts were then inductively delineated from the
observed phenomena and grouped into interrelated categories. These categories were
used to link data to existing social science theories (McMillan & Schumacher, 1997).
Results provide an extension of understanding about conditions for change in
undergraduate introductory biology classrooms.

Constraints to conducting this research included complexity of the research
problem, methodological difficulties, and ethical considerations. Specific aspects of
these constraints were continually analyzed and addressed by the researcher, as
discussed further in the data analysis section.

As with any story, this research involves a particular setting, drama (learning in
the context of a curricular innovation), and actors (the subjects). Following are detailed
descriptions of the setting, curriculum, and subjects, to establish both the unique and
typical natures of this study's observed phenomena.

Setting

This study was set within the same series of introductory biology courses (BI
101, 102, and 103) described in the pilot study. However, some differences existed
between the course described in the pilot study (BI 103), and the course used in this
study (BI 102). These differences will be noted in this chapter. BI 102 (1999) consisted
of 519 undergraduate students with declared majors in subjects other than biology. The
topics covered included genetics, evolution, and animal behavior. Conceptual themes
running throughout the course included the history of biological knowledge development, scientific process, and links between science and society.

This BI 102 course was selected for three reasons. First, the course had a long history of successful curricular innovation. The lecture and activity sections of the course had been revised every term for 28 years, addressing changing student needs, new teaching faculty, new technologies, and changes in biological research. Students had worked in collaborative groups for 19 years, lecture time had been decreased to increase activity time, and the curriculum incorporated numerous aspects of scientific inquiry and the nature of science. At least one faculty member revised aspects of the course each term. The series of courses were popular with students, and without grade inflation (average grades in C+ average), less than 1% of students dropped the courses, evaluation scores were extremely high, and BI 10X courses typically had to turn away interested students due to limited capacity.

Additionally, the course not only had a history of innovation, it was in the process actively adapting to accommodate changes in content, student demographics, institutional structure, information technologies, and state-wide K-12 science standards. In the previous year, advances in animal cloning, potential evidence of ancient life on Mars, and the rising awareness of genetically engineered crops had taken media literacy of genetics well beyond the content taught within university genetics courses in the early 1990's. Students were also changing, consisting of a larger number of older than average students, underrepresented students of color, and students with learning disabilities. Changes in institutional focus, including discussion of students as “clients” and learning as a commodity was leading to recruitment of student groups not previously serviced by the university system, such as students with learning disabilities and older-than-average students. As with the case of many undergraduate institutions, adequate funding was an increasing concern, and the studied course was seated within a college facing a seven-figure budget deficit. Access to information of all kinds was rapidly shifting to computer technologies, including on-line journals, Internet use, electronic card catalogs, and e-mail contact. The state was also in the process of implementing new K-12 science standards with increased emphasis on experimentation and portfolio assessment. Faculty were attempting to adapt to all of these changes in the studied course.

Finally, the researcher had been involved with the course for five years, as a TA for four years and as a lecturer the previous year. This included two years of research on
student and TA learning within the BI 10X series. The course offered the unique opportunity for the researcher to be a participant-observer and directly apply results to further curricular change. Faculty and TAs spent significant time interacting with one another and students, minimizing the potential impact of research interactions on altering participant behaviors.

Similar to the pilot study, a new project was added to the curriculum. Two faculty designed the project and accompanying lectures, and seven TAs taught the activity sections. Technological support included computers for the classroom (two for every group of five students, and one for each lecturer), a digital projector for lecture, and limited assistance from campus information services. Support to the faculty for curriculum design and implementation was provided by the department in the form of budget flexibility to purchase needed laboratory or recitation supplies, as well as books and other written materials.

Curriculum

The course began with a six-week unit on genetics, followed by a two-week unit on evolution, and a two-week unit on animal behavior. A new six-week genetic technologies project, culminating in a debate was added to the genetics unit. The decision to alter the curriculum was based on many factors (see Pilot Study, Chapter 2) including faculty use of the Internet as a source of information, previous success with instructional innovation, familiarity with state and national science education reforms, and most importantly, familiarity with changing student needs.

The new project incorporated aspects of activities, lecture, textbook readings, and independent research intended to (1) have students explore the underlying concepts of a biological issue in-depth and (2) engage students in searching for information, critically reviewing that information, and utilize that information for decision-making. Students were challenged to thoroughly research an assigned genetics technology topic (genetic engineering or gene therapy) and participate in a class oral debate on the issues associated with that technology. As this was the first time the project would be implemented, the point-value in the overall course grade assessment was limited to less than five percent.

In order to accommodate the new project, various aspects of planning, instruction, and assessment were modified by the faculty prior to the beginning of the
course. These modifications included new activities, new lectures, and new assessment protocols.

An attempt was made to address science education reform recommendations included in various reform documents (AAAS, 1993; NRC, 1996). The new curricular changes addressed reform recommendations related to science content, instruction, and assessment (Appendix C). Instructional objectives included four major aspects of science learning, including science inquiry (communicating, skepticism), scientific knowledge (broad themes, concept interrelatedness), conditions for learning science (cooperative learning, independent research), and applications for science learning (current issues, daily life decisions). The new curriculum was validated by matching instructional goals and assessment with the overall reform-based curricular goals (Appendix D). An important caveat is that the reform recommendations were made for K-12 instruction, and that an on-going attempt was made by the course faculty to extend those recommendations to the university classroom.

Within this course, the primary learning goals were to have students understand the complexity and integrated nature of biological issues (factual information) and how to critically review research and formulate decisions (procedural information). In addition to the traditional tasks of taking notes, completing labs, and reading the textbook, the students in this study were asked to take more active control of their own learning. This stress on student involvement in learning echoes the various reforms. Other course goals not primarily addressed in the new project included (1) introducing students to the historical development of scientific knowledge, (2) incorporating “hands-on” laboratories that give students the opportunity to use biology equipment, and (3) providing students an opportunity to develop an aesthetic appreciation for the sciences. Although the new project reduced some of the course time dedicated to these additional course goals, they still permeated the entire course.

The curriculum outline for the original course is provided in Table 3.1, and the new course with highlighted genetic technology activities is outlined in Table 3.2. To provide a more detailed picture of the degree of innovation in the new course unit, the introductory activity to the genetics technology project is included (Appendix E).
Table 3.1: Original Course.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Process of Science</td>
<td>Early and Mendelian Inheritance</td>
<td>Scientific Processes</td>
<td>Life Cycles</td>
</tr>
<tr>
<td>2</td>
<td>Meiosis</td>
<td>The Chromosome Theory</td>
<td>Meiosis</td>
<td>Inheritance in Corn</td>
</tr>
<tr>
<td>3</td>
<td>Fruit Flies and Other Models</td>
<td>Non-Mendelian Genetics</td>
<td>Fruit Fly Genetics</td>
<td>Fruit Fly Computer Simulation</td>
</tr>
<tr>
<td>4</td>
<td>Birth of Molecular Genetics</td>
<td>Nature of Genetic Information</td>
<td>DNA Structure and Replication</td>
<td>Chromosomes and Crossover Problems</td>
</tr>
<tr>
<td>5</td>
<td>Human Genetics</td>
<td>Human Genetic Disorders</td>
<td>Mendelian Inheritance in Humans</td>
<td>Protein Synthesis</td>
</tr>
<tr>
<td>6</td>
<td>Humans and Genetic Technologies</td>
<td>Case Study: Breast Cancer</td>
<td>Genetics and Society</td>
<td>Human Pedigrees</td>
</tr>
<tr>
<td>7-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2: New Course Unit with Genetic Technologies Project.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Setting the Stage: BI 102</td>
<td>Early and Mendelian Genetics</td>
<td>Introduction to the Genetic Technologies Project</td>
<td>Inheritance and Corn</td>
</tr>
<tr>
<td>2</td>
<td>Meiosis</td>
<td>The Chromosome Theory</td>
<td>Meiosis</td>
<td>Life Cycles</td>
</tr>
<tr>
<td>3</td>
<td>Non-Mendelian Genetics</td>
<td>Changes in Chromosomes</td>
<td>Project Update</td>
<td>Fruit Fly Genetics</td>
</tr>
<tr>
<td>4</td>
<td>The Discovery of DNA</td>
<td>Protein Structure and Function</td>
<td>DNA Structure</td>
<td>Protein Synthesis</td>
</tr>
<tr>
<td>5</td>
<td>Human inheritance</td>
<td>The Human Genome Project</td>
<td>Human Pedigrees</td>
<td>Genetic Technologies Project</td>
</tr>
<tr>
<td>6</td>
<td>Biotechnologies</td>
<td>The Future of Genetics</td>
<td>Genetics and Society</td>
<td>Genetic Technologies Debate</td>
</tr>
<tr>
<td>7-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Evolution and Behavior
Within the new project, students researched and debated whether the U.S. government should limit the development of genetically engineered organisms or human gene therapy. Students initially researched the assigned topics independently, generating individual annotated references (due the third week). Groups of students then coalesced their individual research to produce a group summary paper (due the fifth week). Each group of five students then merged with another group to form a debating “supergroup” assigned to either a “pro” or “con” argument (Appendix F). The debate rules were distributed in the fifth-week laboratory (Appendix G). On the day of the debates, students submitted individual notecards and questions for the other debating groups (Appendix H). Detailed summaries of each of the lectures, activities, and textbook readings in weeks one through six, related to the project, are provided in Appendix I.

Subjects

Selection of subjects reflected the open-ended nature of the research questions. Due to uncertainty over which concepts would be theoretically relevant, the subjects were volunteers from each of the major categories of project participants: faculty who designed the activity, lectured on related material, and interacted with TAs and students, TAs who led the project activities and had direct contact with students, and student groups who worked together to complete the new project. The sampling strategy was to comprehensively sample as many student groups and TAs as could be accommodated without compromising the descriptive methodologies. Subjects were asked to participate in a study examining teaching and learning within the course. Further details were not provided until the conclusion of the post-project interviews.

Faculty

The faculty subjects were two instructors involved in teaching the course. A third faculty lecturer, not directly involved in the genetic technologies project design or implementation, was not included in the study. The role of lecturing faculty is described in more depth in relationship to curricular innovation in the results chapter. One of the two faculty subjects, the researcher (F1), was a relative novice with one year of lecturing
and curriculum design experience in the course (see researcher description later in this chapter). The other faculty subject (F2) was an experienced teacher who had taught in all aspects of the course for 28 years, and was the course coordinator. On a student-generated website evaluating faculty, F2 was repeatedly and publicly acknowledged as an exceptional teacher. Both faculty had taught together in other courses, including the course discussed in the pilot study (Chapter 2). The faculty were responsible for curriculum development, lecturing, student assessment, TA preparation, and facilities management. Both faculty also spent significant time addressing TA and student questions and concerns.

Teaching Assistants

The researcher solicited TA volunteers from the seven TAs assigned to teach the course prior to the start of the term by describing the study and distributing informed consent forms (see Appendices J and K for script and TA informed consent form). Six of the seven TAs volunteered to participate, with the single declining TA citing a full research and course schedule. One of the six volunteers was excluded since the activity times overlapped with the lecture times, limiting the researcher's ability to conduct activity observations and formative interviews in that TA's sections. The five TA subjects were assigned codes (T1, T2, T3, T4, T5) based on order in which they volunteered to participate in the study. These code names were used in data collection and analysis to enhance anonymity.

Four of the five subjects had previously taught as TAs in the previous term's biology course (BI 101), and it was the first teaching experience for one of the TAs. Two of the four TAs had also taught in the BI 10X courses the previous year and had previously been TAs for this course (BI 102). However, none of the TAs had taught a unit on genetic technologies, or activities involving student research and debate. All five TAs were pursuing masters degrees in science, including environmental science, botany, and science education. One of the TAs had 12 years of experience working as a field technician. The other four TAs had continually been in school since their undergraduate degrees. Two of the five subjects planned on teaching biology in a community college or private university, the other three planned on being university faculty.

All TAs in the course were required to teach laboratory and recitation activities, attend two hours of weekly preparation for these activities, grade student
laboratory/recitation papers, proctor exams, attend lectures, and submit exam questions from the activities they taught. Within the laboratory and recitation activities, TAs were instructed to not lecture, but instead spend their time in assisting the students in working through the activities in their cooperative groups. A single activity grade was given to a group of five students. A typical activity began with a brief introduction by the TAs that included safety procedures, objectives, and other announcements. This was immediately followed by the activity in which students followed written procedures and assisted one another in completing the activity. TAs addressed problems and questions and debriefed groups of students at the completion of many of the activities. The primary role of the TAs in the course was to respond to student needs.

Students

There were 519 students enrolled in the course. The researcher sought one collaborative group of five students from the 16 groups (8 in each section) taught by each of the subject TAs. Unlike the pilot study’s disease project, the genetic technology project was a group effort. Interviewing intact groups provided information on group dynamics. The 40 students in each TA’s section had been randomly assigned to their groups of five students by their TAs on the first week of the course. During the second week of the course, after lecturing, the researcher solicited volunteers by attending the laboratories of the five subject TAs, describing the study, and distributing informed consent forms (see Appendices J and L for script and student informed consent form). One group of five students that volunteered in each of the five sections was included in the study, for a total of 25 student participants. These subject groups were selected from the volunteer groups in each class by simply selecting the group closest in proximity to the researcher, as no student selection criteria were being utilized. Students were coded by which section and group they attended. For example, subject S2E was a student subject in TA subject T2’s section. Other members of the group were S2A, S2B, S2C, and S2D. The order of the coded names (A-E) was based on the order in which subject students participated in the first formative interviews. To summarize, S = student, T = TA, a number indicates which of the five TAs, and letter A-E indicates which students in a particular group (Table 3.3).

Student groups were chosen based on their willingness to participate and no attempt was made to select a sample that was representative of the entire course, as it was unclear which variables would be appropriate to utilize as criteria for selection. The
student subjects had a wide range of characteristics, including declared major (agriculture, business, three areas of engineering, computer science, physical sciences, education, health and human performance, art, and music), year in school (30% freshman thru seniors), final grade in course (A through F, with average grade B-), gender (11 men, 14 women), age (average of 20, range of 18-36), and ethnicity (primarily American with two subjects from other countries).

Students in the course were not biology majors and took the course to fulfill the baccalaureate life science requirement. This resulted in a very diverse group of students, many of who would not have enrolled in a life science course if it were not
required. Within the class, students were expected to attend lecture and take notes as necessary, attend and fully participate in laboratory and recitation activities, complete the assigned project, read assigned textbook chapters, take exams (two midterms and a final), and seek assistance from faculty, TAs, or other students as needed. After recruiting the volunteers, the researcher collected background information on previous classroom and work experiences through written assignments and interviews to determine whether previous experiences influenced subsequent learning.

Data Collection and Analysis

Data collection was broken into three phases based on the timing of the project (Table 3.4). Pre-project data collection began when the faculty started to design the course curriculum and ended with TAs and students completing the pre-project activity. Project data collection began as TAs and students started the activities related to the genetic technologies projects (week 2 of the term) and ended with students turning in their projects (week 6). Post-project data collection began immediately following the date the projects were due, through completion of the final interview (week 10), and ended two years later when impacts of the project on curricular change were no longer evident. Data analysis began with data collection in the Pre-project phase, and continued throughout the study.

With general, variable-seeking, research questions a concern was balancing appropriately general data collection techniques with the time available. The design of this study involved limiting selection of the course level (introductory, subject (biology), size (large), curriculum (process of change, innovation, addressing standards), subjects (faculty, TAs, and students working together), content (new unit on genetic technologies), and researcher access. Within the selected course, time constraints, especially student and researcher schedules, limited the number of student subjects and amount of formative interviews that could be conducted. A large assortment of data collection techniques was selected to enable the researcher to broadly study learning dynamics within the subjects.
Table 3.4: Overview of Three Stages of Data Collection.

<table>
<thead>
<tr>
<th>Week</th>
<th>Stage</th>
<th>Course Activities</th>
<th>Data Collection and Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior to Course</td>
<td>Pre-Project</td>
<td>IRB Approval, Recruit Faculty Volunteers, Faculty Artifacts, Researcher Journal</td>
</tr>
<tr>
<td>1</td>
<td>Pre-Project</td>
<td><strong>Recitation</strong>: Introduction to the Genetic Technologies Project</td>
<td>Recruit TA and Student Volunteers, Faculty Artifacts, Researcher Journal</td>
</tr>
<tr>
<td>2</td>
<td>Project</td>
<td>Students begin independently researching topics</td>
<td>Collect Pre-Project Activity, Researcher Journal, Begin Formative Interviews</td>
</tr>
<tr>
<td>3</td>
<td>Project</td>
<td><strong>Recitation</strong>: Project Update (students share information with their groups)</td>
<td>Preparatory Session Observations, Activity Observations, Activity Artifacts, Formative Interviews, Lecture Observations, Researcher Journal</td>
</tr>
<tr>
<td>4</td>
<td>Project</td>
<td><strong>Lecture</strong>: The Discovery of DNA <strong>Recitation</strong>: DNA Structure (students work with group members on researching related issues)</td>
<td>Preparatory Session Observations, Activity Observations, Activity Artifacts, Lecture Observations, Researcher Journal</td>
</tr>
<tr>
<td>5</td>
<td>Project</td>
<td><strong>Laboratory</strong>: Genetic Technologies Project <strong>Lecture</strong>: The Human Genome Project (students prepare to debate issues)</td>
<td>Preparatory Session Observations, Activity Observations, Activity Artifacts, Formative Interviews, Lecture Observations, Researcher Journal</td>
</tr>
<tr>
<td>6</td>
<td>Project</td>
<td><strong>Laboratory</strong>: Genetic Technologies Debate <strong>Lectures</strong>: Biotechnologies, The Future of Genetics (Students debate issues)</td>
<td>Preparatory Session Observations, Activity Observations, Activity Artifacts, Formative Interviews, Lecture Observations, Researcher Journal</td>
</tr>
<tr>
<td>7+</td>
<td>Post-Project</td>
<td>Midterm Exam and Final Exam (students prepare for exams)</td>
<td>Midterm and Final Exam, Post-Project Interviews, Researcher Journal</td>
</tr>
<tr>
<td></td>
<td>After Course</td>
<td>Post-Project Faculty design curricula</td>
<td>Curriculum Planning Observations, Researcher Journal</td>
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</tbody>
</table>
Specific aspects of data collection and analysis, such as use of recording devices, were altered as the research evolved (Marshall & Rossman, 1995). However, the following forms of data collection and analyses, developed in the pilot study, allowed for researcher flexibility in addressing the research questions.

**Pre-Project Data Collection**

The initial faculty discussion on implementing changes in the course curriculum began in July of 1998 (Table 3.5). In order to document the process of curriculum design, all artifacts (notes and charts) were kept from each of the meetings. Additionally, the researcher began keeping an electronic journal (see researcher journal) with notes of each curriculum meeting and other events related to the course curriculum. The new student activities and project requirements were completed in January 1999.

**Table 3.5: Timeline of Data Collection for This Study.**

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<tr>
<td>Pre-project data collection and analysis</td>
<td>Project data collection and analysis</td>
<td>Post-project data collection and analysis</td>
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**Researcher Journal**

The faculty met frequently to work on the course curriculum. A digital researcher journal was maintained to record summaries of these meetings, including individual contributions and concerns. For extended meetings, audiotapes were made, with permission of the other faculty member, to keep an accurate account of the conversation. These audio recordings were transcribed and added to the journal.

The researcher also recorded daily entries throughout this research project. These entries included thoughts and ideas pertaining to the project that influenced data collection and interpretation. One aspect of these notes focuses on existential, outward
notes, and the other aspect focused on inner responses. An attempt was made to
distinguish between these two categories. Entries were made after observations or
interviews to provide a record of researcher ideas separate from the recorded
interview/observation data.

Analysis of data in the researcher journal began immediately upon entry, by
reviewing former researcher comments, searching for trends and "hot spots" or potential
directions of interest, and recording ideas and insights. The journal later provided a
chronological and situational context for data analysis.

Faculty Curriculum Artifacts

During curriculum development, the faculty generated a large number of artifacts,
including course schedules, journal articles, Internet printouts, tentative schedules, and
rough drafts of the activities. These artifacts, when combined with the researcher journal
and interviews, were used to reconstruct the process of curriculum development and the
types of knowledge and processes involved in the development.

The finished student activity manual and textbook were also important artifacts
used within the course. The activity manual contained the syllabus, activity handouts,
and the new project assignment. Students were assigned specific readings out of the
textbook. Faculty design and use of these artifacts were examined and led to further
questions in the formative and post-project interviews.

Faculty, TA, and Student Pre-Project Activity

Prior to the project, students completed an activity that introduced the genetics
technology project (Appendix E) as a component of the new curriculum. The faculty and
TAs also completed this activity prior to teaching as a component of their preparation.
The faculty completed the activity together (as a group of 2) prior to the TA preparatory
session. Three of the TAs completed the activity with the researcher prior to the first
week's preparatory session, and the other two TAs completed the activity with the
researcher after the first preparatory session. These activities were collected as
background information for the formative and post-project interviews.

1. List as much as you know about your topic, and share this information
   with your other group members.
2. The first part of this project involves finding information about your topic.
   Where can you go to find this information (list as many specific sources
as possible). You may want to assign specific group members to examine these sources and compare notes the next time you meet.

3. Once you have found sources of information about your topic, you will be asked to comment on each source (brief summary and critical analysis of whether it is a reliable source of information). These "annotated references" are due at the beginning of recitation, week 3. How will you judge whether a source of information is reliable? (Week One Recitation Activity)

Responses to these questions were analyzed for the faculty, TAs, and the 25 student subjects as quickly as possible. Follow-up questions were asked during the formative interviews conducted week six. Additionally, the data were re-visited by the researcher prior to the post-project interviews to be able to detect and explore any changes in responses.

Project Data Collection

Project Data collection began in the first week of the course. This data provided information on learning as faculty lectured and managed TA preparation, TAs interpreted the curriculum for students, and students attempted to succeed in the course. During this period of time the researcher collected a variety of data on lectures, preparatory sessions, and activities. This data collection included faculty and TA artifacts (described later), interviews, transcripts of preparatory sessions, and student work. Notes were continued in the researcher journal to record thoughts on data collection and interpretation.

All observations were guided by fundamental contextual questions including: Who is in the scene? Which behaviors are repetitive or irregular? How do the subjects interact? What content is discussed in the interactions? Where and when is the scene located? And what conditions influence the observed behaviors? (McMillan & Schumacher, 1997).

Preparatory Session Observations

Faculty and TAs attended two one-hour prep sessions each Monday to review the laboratory and recitation activities. The primary goal of these preparatory sessions was to address procedural concerns (exam times, room changes), introduce the activities (instructional strategies and assessment), and address TA concerns and suggestions for improving prior activities. The TAs were expected to work through the activities on their own to become more familiar with the material and procedures. Other
interactions between faculty and TAs, including TAs attending lectures, holding office
hours in the building, and holding casual conversations with the faculty were noted.

The researcher took notes during all of the preparatory meetings. The notes
were analyzed as soon as possible in order to ask TAs follow-up questions regarding
issues discussed in the preparatory sessions. These data provided information on the
questions being asked, problems with the curriculum, TA perceptions of student
learning, and the work TAs put into interpreting the curriculum.

Lecture Observations

Students and TAs attended the two weekly lectures. Additionally, the non-
lecturing faculty member also attended lecture to insure unity between the material
covered in the “team-taught” lecture. The lectures related to the project focused on
abnormal inheritance, the human genome project, biotechnologies, and the future of
genetics research.

All of F1’s lectures were videotaped and transcribed. Lecture observations
focused on the content presented and questioning between the lecturer and the
students. Transcriptions of the lectures were used to ask student subjects about
aspects of their involvement in the course, TAs about content matter related to genetic
technology, and faculty about preparation for and response to lecturing.

Activity Observations

Much of the curricular innovation occurred in the activity portion of this course.
The genetic technologies project required group cooperation and collaboration. The
activities were far less structured than traditional biology activities. One week the
students were simply asked to share Internet addresses with one another in order to
augment their development of the project. The open-ended nature of these
investigations put increased curriculum design and management responsibility on the
TAs. Students also had to learn how to work within a relatively unstructured classroom
environment.

The researcher routinely attended the course activities to assist TAs with the
large number of students and continued this practice during this study to habituate
students to an observer presence. However, this also resulted in students asking
questions of the researcher, in her role as course instructor, making data collection more
complex. Occasionally the researcher moved about the classroom to assist a group if
problems arose during the activity. Whenever possible, the researcher tried to remain fairly unobtrusive while engaging in overt observation (Stark & Roberts, 1996). Observations focused on the introductory lecture presented by the TAs, conversations between students within the group being studied, and interactions between the TA and the study group. The researcher sat off to the side taking notes during the TA introductory comments and frequently scanned the room to remove perceived focus from the study group. In order to supplement the note-taking, a fixed video camera was placed in the corner of the room to provide additional information about the classroom interactions.

The notes were used to ask the TAs and the students in the study groups questions immediately following the activities. The videotapes were primarily used to record the TAs' short introductory lectures, and other classroom activities that may have been missed by the researcher. Due to the large number of activities each week (34 activities, 51 hours), the researcher was unable to attend every activity. Instead, observations focused on sections taught by the volunteer subject TAs, with observations of other sections as time permitted.

Teaching Assistant Artifacts

Teaching artifacts included overhead transparencies, classroom notes (TA's versions of "lesson plans"), handouts, and exam questions. These artifacts were collected as part of the course's TA education program, and revealed additional information about TA content knowledge and perceptions of teaching.

The researcher amassed the TA artifacts and formulated questions related to the artifacts to ask in the post-instruction interview. In addition to formal, planned, data collection, the researcher and the subject TAs had short formative, interviews throughout the unit. These interviews occurred if (1) the researcher had questions about the data, (2) wished to collect additional data, or (3) the TA initiated a discussion about his/her teaching (a common occurrence). Notes from these interviews were kept, coded, and analyzed with the other data collected during the study, as discussed in the summary data analysis section later in this chapter.

Student Artifacts

During the project students generated a large number of artifacts, including research notes, annotated references, group summaries, debate notes, debate
questions, critiques of other debate groups, and written impressions of the debate. These artifacts, when combined with the researcher journal and formative interviews, were used to reconstruct the process of student research of genetic technologies and the types of knowledge and processes that occurred during this process.

Student artifacts were also used to generate a list of topics that guided the pre-planned questions on conceptual knowledge, changes in knowledge, and research results (closure). Additionally, the researcher used this list of topics to generate follow-up questions.

Formative Interviews

These interviews were labeled formative due to the potential to alter behaviors of the participants, including the researcher, these relatively unstructured, informal interviews were carried out with faculty, TAs, and students. The subjects were reminded that conversations were a component of the research study, and were asked to reflect and elaborate on a particular teaching or learning event observed by the researcher. The questions asked in these interviews were based on data collected from all aspects of the course. For example, following a lecture, faculty were asked to reflect on their responses to student questions.

The faculty met repeatedly to discuss lectures, activities, and TA preparation. During these discussions, the researcher documented lessons learned as well as the rationale for changes in the curriculum, and the influence of TAs and students on these decisions.

Two types of formative interviews were conducted with the TAs: prior to, and immediately following teaching. The formative interviews conducted prior to teaching focused on TA preparation and incorporate questions regarding TA artifacts and the preparatory sessions. For example, the researcher asked a TA why he/she designed a particular overhead transparency for use in the class. In order to determine what TAs were learning from their interactions with their students, TAs were interviewed immediately following teaching about particular interactions with students observed by the researcher. This type of structured interview elicited information about TA perceptions and judgments.

Students worked on their projects in laboratory and recitation, and outside of the classroom. Formative interviews were conducted with "subject group" individuals prior to the activity (as they arrive) concerning project activities conducted outside the
classroom. The entire subject group was interviewed following activities to monitor any changes in ideas or strategies resulting from activity participation, and the sources of these changes. Interviews focused on (1) what students were doing outside of class times related to the project, (2) why they had chosen to focus on specific areas of their topic, (3) how they were locating resources, (4) how they were reviewing their resources, (5) what they thought they have learned about their topic, (6) how they were organizing tasks within the groups, and (7) whether they had used information from lecture, the textbook, or their TAs.

Formative interviews were brief, often consisting of only a few questions and answers, and occurred throughout the project. Notes were taken or the conversations were audiotaped and transcribed, depending on the location and duration of the interview. Shorthand notation was used whenever possible to enable use of a selective verbatim data collection technique. The formative interview data was analyzed as quickly as possible in order to direct other formative interviews and the post-project interviews.

The researcher attempted to identify examples of impact of the interviewing process on subject cognition, recording thoughts in the researcher journal (Welzel & Roth, 1998). One component of the formative interviews (and the research design in general) was an attempt to minimize student focus on the research questions by varying the language used throughout the study. Subjects were asked about what they were "doing" or what they "knew." Variations of "learning" were avoided until the final interviews, and the research questions were not discussed until the end of the study. Changes to the format and substance of the formative interviews are described at length within the results section.

Post-Project Data Collection

The prior two stages of data collection provided a context for the interviews in the Post-Project phase of data collection. At this point the researcher had collected and analyzed data on various aspects of the faculty, TA, and student learning, and used the interviews to provide more detailed information on content knowledge acquisition and decision-making. Validation of the post-project interview protocols and interview questions were accomplished by submitting the procedures to a panel of five experts (science education and biology faculty) along with a written description of the study. These experts were asked to determine whether the interviews would adequately elicit
the desired responses. The Post-Project phase included the project presentations, interviews, the final exam, and curriculum revisions.

Projects and Presentations

Students finished their projects during the sixth week of the course. The project consisted of note cards and an oral presentation (project assignment sheet in Appendix E). After students turned their note cards into their TAs, the researcher collected and copied the note cards completed by the 25 student subjects and immediately returned them to the TAs for grading.

Students debated the role of government regulation related to the assigned topics of either gene therapy or genetic engineering. Using their note cards and any other visual artifact, students addressed the genetic technology issue, provided a group response, and defended their position in an oral debate observed by their classmates and TA. Other students and the TA were given the opportunity to ask questions. The researcher attended each of the subject TAs' debates and took notes which were used for the TA and student post-project interviews. The researcher reviewed this data prior to interviewing the students to formulate questions and scenarios related to each group's presentation.

Post-Project Interviews

The interviews were conducted during the seventh, eighth, and ninth, week of the course in the researcher's office. Interviews lasted from 30 minutes to three hours, depending on the subject's interest and schedule. Most of the participants discussed multiple facets of the project, and the course in general, with a few remaining focused on addressing the specific questions. Responses provided in the results chapter in part indicate subject emphasis during interviews.

Interviews were held in the researcher's office, conveniently located close to the course facilities. The door was kept closed and the interviews were audiotaped with student permission. As with all other aspects of data collection, audiotapes, their transcripts, and notes were coded for confidentiality.

The interviews were semi-structured around general questions related to learning during the project. Each of these questions was followed by a series of follow-up questions, both planned and unplanned. Planned follow-up questions were subject-specific, and were used to clarify discrepancies between the participant's formative interview comments and other sources of data collected by the researcher.
Prior to the post-project interviews, the researcher limited questioning to topics raised by the subjects, to minimize research-related changes in subject learning. However, during the post-project interviews, subjects were asked a broader range of knowledge questions. During the post-project interviews, questions focused on aspects of subject learning, including descriptions, selections, representations, and inferences (Donald, 1993) to paint a clearer picture of what had occurred during the project. Interview techniques were refined as the interviews progressed, and these changes were examined to note impact on data analysis (Weiss, 1994).

Notes pertaining to formative interviews and projects were prepared ahead of time for each subject, as well as any questions pertaining to the curriculum that were asked in each student interview. The researcher compiled a list of “points of clarification” for each subject, to listen for in the question responses and/or to specifically ask about in follow-up questioning during the interviews. These points primarily focused on areas of data conflict, where two sources of data were suggesting different things.

Another important aspect of the final interviews was to ascertain subject feedback regarding the researcher's preliminary interpretations of the data, particularly the categories of learning, categories of factors impacting learning, and the extent of impact of participant interactions on learning. If these topics were not discussed by subjects in response to the general questioning, the researcher asked specifically about the categories with follow-up questions. Following the interviews, the researcher reflected on the conversations and made notes that would facilitate subsequent interviews.

All of the 25 student subjects in the studied groups were asked to complete individual interviews conducted prior to the last week of class. These interviews were conducted with individual students instead of with the groups to permit each student adequate time to reflect on his/her own learning. This format elicited candid responses about the contributions of group members to the project. Interviews were scheduled for one hour each, with 30 to 45 minutes of actual interview, and 15-30 minutes for researcher notes and reflection.

The student interviews began with the researcher asking the student to discuss the project and asking generally if the student felt he/she learned anything from the project (the students already knew their grades from the projects and the midterm exams). The student was then asked to expand on that answer. More specific
questions followed, tailored to the student's project. The researcher asked the following questions of all student subjects:

1. (Overall Impression) What was your overall impression of the genetic technologies project?
2. (Perception of Learning) What do you think you learned, if anything, from the genetic technologies project?
3. (Individual Preparation) How did you research your topic? How did you judge whether a source was reliable?
4. (Conceptual Knowledge) In this project, you discussed __________. Can you explain this topic to me?
5. (Change in Knowledge) When initially asked what you knew about this topic, this is what you said/ wrote (Give student a chance to review notes). Did you later find that any of these things were wrong or incomplete? Please explain.
6. (Transfer of Knowledge) If you were asked to vote on whether human cloning should be permitted, how would you make your decision?
7. (Learning Skills) Did you find yourself studying, or doing anything different during this unit compared to what you have previously done in your courses?
8. (Group Work) How did your group prepare to debate this topic?
9. (Talking about Teaching) Recall the activities from this unit (show copy of syllabus for clarification). In which one do you think you learned the most? the least? Did anything from lecture relate to your project? If so, what, and how?
10. (Interaction with TA) How did your TA help you with the activity or the projects?
11. (Interaction with Researcher) How do you think participating in this study may have impacted you during the project?
12. (Closure) Do you agree that you learned ____ because of ____ (multiple examples). Please elaborate.

Follow-up questioning was used to clarify student answers. Additional questions pertaining to individual student's projects and exam responses were used to clarify what they learned in the course. Students were also given a current news article on a genetic technology topic not covered in the course, but related to the material (for example genetic screening and cloning) and asked how they would review the article and whether the would use it to make decisions about the genetic technology. Questioning explored the underlying content related to the course project, the strategies the students would use to complete a similar project, and the source of these behaviors.

Notes on activity observations and TA interviews were reviewed and follow-up interview questions were customized for each subject TA. Interviews were scheduled for two hours each, with 30 minutes of that time set aside for researcher reflection. The interviews were longer than those set for students due to the close working relationship
of the TAs and researcher, and discussion of other course-related topics. The interviews centered on giving the TAs an opportunity to reflect on the unit and verbalize their learning experience.

The interviews began with the TA’s overall impression of the unit in order to elicit general responses. More specific questions followed, tailored to the TAs’ teaching experiences. All of the subject TAs were asked the following questions:

1. (Overall Impression) What was your overall impression of the genetic technology project?
2. (Perception of Learning) What do you think you learned, if anything, from the genetic technologies project?
3. (Individual Preparation) How did you prepare for teaching the genetic technology activities? Did this preparation differ in any way from how you prepared to teach other activities?
4. (Conceptual Knowledge) In this project, the students discussed genetic engineering and gene therapy. Can you explain these topics to me?
5. (Change in Knowledge) When initially asked what you knew about this topic, this is what you said/ wrote (Give student a chance to review notes). Did you later find that any of these things were wrong or incomplete? Please explain.
6. (Transfer of Knowledge) If you were asked to vote on whether human cloning should be permitted, how would you make your decision?
7. (Learning Skills) Did you find yourself doing anything different during this unit compared to what you have previously done?
8. (Talking about Teaching) Which of these genetic technologies project activities was the most successful? The least successful? What was your impression of the lectures? Did the prep sessions adequately prepare you to teach? Please explain.
9. (Working with Students) What did students appear to have the most trouble with during this unit? What do you think students learned by participating in this unit? In what ways were you able to assist students with their projects?
10. (Interaction with TAs) Did any other TAs influence your teaching?
11. (Interaction with Researcher) How do you think participating in this study may have impacted you during the project?
12. (Closure) Do you agree that you learned _____ because of _____ (multiple examples). Please elaborate.

Follow-up questioning was used to clarify answers and the TAs were asked to expand on their answers regarding what they learned about genetic technologies. For example, the researcher asked the TAs to discuss the “pros” and “cons” related to genetically engineered organisms, with additional follow-up questions derived from prior formative interviews. This was followed by asking the TAs where they learned the information, and specifically whether they learned any of it from their own research, their
students, or the faculty-designed aspects of the course (lecture, preparatory sessions, textbook readings).

In the follow-up questions related to teaching (specifically question 12), the TAs were asked to review a short activity on a genetic technology not previously covered in the course (genetic screening or animal cloning). The TAs were asked how they would teach the topic. Additional questions focused on preparation, instruction, and assessment, and/or any specific aspects of teaching that appeared during earlier data collection. The TAs were asked to reflect on the sources of their teaching techniques.

The two faculty subjects met and discussed the curricular innovation, including changes that may improve the curriculum for the following year. Prior to the interview, the researcher generated a series of questions for the other faculty member, and answered the questions herself prior to hearing the other subject's responses. Questions included the following:

1. (Overall Impression) What was your overall impression of the genetic technology project?
2. (Perception of Learning) What do you think you learned, if anything, from the genetic technologies project?
3. (Individual Preparation) How did you prepare for teaching the genetic technology activities? Did this preparation differ in any way from how you prepared to teach other activities?
4. (Conceptual Knowledge) In this project, the students discussed genetic engineering and gene therapy. Please explain these topics?
5. (Change in Knowledge) When initially asked what you knew about this topic, this is what you said/ wrote (Provide chance to review notes). Did you later find that any of these things were wrong or incomplete? Please explain.
6. (Transfer of Knowledge) If you were asked to vote on whether human cloning should be permitted, how would you make your decision?
7. (Learning Skills) Did you find yourself doing anything different during this unit compared to what you have previously done?
8. (Talking about Teaching) Which of these genetic technologies project activities was the most successful? The least successful? What was your impression of the lectures? Please explain.
9. (Working with Students) What did students appear to have the most trouble with during this unit? What do you think students learned by participating in this unit? In what ways were you able to assist students with their projects?
10. (Interaction with TAs) Did the prep sessions adequately prepare the TAs to teach? Did any of the TAs influence your teaching?
11. (Interaction with Researcher) How do you think participating in this study may have impacted you during the project? (question for F1)
12. (Closure) Do you agree that you learned ____ because of ____ (multiple examples). Please elaborate.
Follow-up questioning was used to clarify the subject’s responses (the researcher wrote detailed responses for each question). The faculty discussed the answers regarding what they learned about genetic technologies. These questions were derived from what the students presented during their debates, and the key points they generated on their note cards. For example, the researcher asked the other faculty to discuss the “pros” and “cons” related to gene therapy, with additional follow-up questions derived from prior formative interviews. This was followed by discussing where they learned the information, and specifically whether they learned any of it from their own research, the students, or the TAs. The faculty also discussed the activities, text readings, and F1’s lectures.

In the follow-up questions related to teaching (specifically question 13), the faculty reviewed and discussed a brief activity on a genetic technology not previously covered in the course (animal cloning). The faculty discussed whether and/or how the topic could be transformed into an aspect of the curriculum. Additional questions focused on preparation, instruction, and assessment, and/or any specific aspects of teaching that appeared during earlier data collection. The faculty also discussed the sources of their teaching techniques. Following the interviews, the researcher reflected on the conversation and wrote down any notes that would potentially facilitate data analysis.

In addition to the general questions listed for each subject group, subjects were asked specific content-related questions, such as to describe aspects of germline and somatic cell gene therapy, including as a follow-up question, why germline gene therapy is generally more controversial. Subjects also were asked to provide four possible reasons for why plants were genetically engineered. In the follow-up questioning, most subjects were asked versions of the following four questions, selected based on their appearance during the project and relevance to the debate topics:

1. Describe the process of gene cloning. Include bacteria, vectors, genes, restriction enzymes, plasmids, and bacteriophages.
2. Describe protein synthesis. Include mRNA, tRNA, rRNA, DNA, nucleus, cytoplasm, translation, transcription, and amino acids.
3. What was the eugenics movement? Describe what happened and what ended the movement in the United States.
4. What is something that you believe will happen related to genetics in the future?

Subjects were shown a paper in a plastic cover with the questions written on them as they were verbally read aloud by the researcher, so they did not have to memorize the
questions. Several students referred back to this paper as they answered the questions. Students were also directed to the paper and pencils at the table in case they wanted to sketch their responses.

Exam Questions and Scores

Student subjects took a midterm exam and final exam covering material in the genetics unit. The exams were designed by the course faculty, with several activity questions from the TAs, and contained questions that specifically addressed the genetics project. The exam was validated by matching questions to their project objectives using a table of specifications and was reviewed by three faculty who had taught introductory biology.

Exam data from the study subjects was compared with the project grade and laboratory section. Additionally, the specific exam questions were broken into groups based on the source of information (lecture, activity, textbook, mixed) to see if students had difficulty with material from particular parts of the course.

Despite often-discussed limitations, multiple choice exams can reveal aspects of student’s conceptual understandings and changes in those conceptions from one exam to the next (Sadler, 2000).

Revised Curriculum

Following completion of the course (and the faculty Post-Project Interview), the faculty met to revise the curriculum for the following terms. As a participant, the researcher took notes during the curriculum conversations, and collected any written documents to record the factors that influenced changes in the curriculum. Revisions covered all aspects of the curriculum, including project objectives, lectures, activities, the student manual, assigned textbook readings, assessment, TA preparation, and faculty planning.

Although the curricular innovations may have had an immediate influence on the students participating in the study, it was critical to determine the factors that influenced curricular revision. The revised curriculum and meeting transcripts were analyzed to determine the influences, if any, of TA and student learning on the curriculum re-design process.
Summary of Data Collection

Table 3.6 summarizes the various types of data collected in each phase of data collection. In order to provide a variety of information pertaining to faculty, TA, and student learning, multiple types of data collection techniques were utilized. The data collection planning matrix is provided in Table 3.7.

Table 3.6: Phases of Data Collection.

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<th>Data Collection Phase</th>
<th>Types of Data Collected</th>
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</tr>
<tr>
<td>Project Data Collection</td>
<td>Lecture Observations, Preparatory Session Observations, Activity Observations, TA Artifacts, Formative Interviews, Researcher Journal</td>
</tr>
<tr>
<td>Post-Project Data Collection</td>
<td>Post-Project Interviews, Project Presentations, Exam Scores, Revised Curriculum, Researcher Journal</td>
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The Researcher

This section seeks to explain the researcher’s motivation and beliefs prior to the study and how these factors related to formulation of the research questions and subsequent data analysis. The researcher was both a participant-observer and the primary instrument of data collection. The typical role of the researcher as teacher in the studied course involved lecturing, TA preparation, and curriculum design enabling her to interact with all participants in the course. This involvement in the research setting could be characterized as both intensive and extensive. Prior to the study, the researcher spent approximately two-three hours daily interacting with other faculty, TAs, and students, and frequently participated in all aspects of the course. As a result, data collection for this study did not require a significantly more obtrusive presence in the classroom setting. All subjects were aware of the researcher’s role and the researcher did not evaluate the TAs or students, to avoid possible ethical conflicts.
As a component of the qualitative design of this study, the researcher brought ideas, perceptions, and biases, which directed and enriched the processes of data collection and analysis. Following is a description of the researcher's teaching and research background, perception of teaching, relationship to the research subjects, and pre-study predictions regarding the research questions.

The researcher was a doctoral student in science education holding a Bachelors of Science degree and a Masters of Science degree in biology, and additional graduate work in ecology. Biology research experiences ranged from history of biology (undergraduate), to oncology (graduate), and aquatic ecology (graduate). For the past
five years, research interests had focused on undergraduate science teaching/learning and study of vascular epiphytes (particularly species in the genus *Hoya*).

Teaching experiences included seven years as a TA in introductory biology and chemistry courses, and one year as a TA in upper-division biology courses. The researcher had taught high school physics and chemistry, numerous science short courses, tutored undergraduate biology and chemistry, and taught as a biology and chemistry instructor at a small private university. Within the studied course, the researcher shifted from being a lecturing TA (through the project) to course coordinator (during post-project data analysis).

At the time of the study, the researcher’s primary teaching duties included lecturing, curriculum design, coordinating TA activities, assisting in activity preparation, and interacting with the then course coordinator (F2) on a near-daily basis. In this position, the researcher had more responsibility for and work within the course than additional lecturing faculty who participated in the course on a term-by-term basis. On becoming the course coordinator and primary lecturer the following term, the researcher experienced only a minor increase in course responsibilities. Similar to the TAs who participated as subjects in this study, the researcher was attempting to balance teaching responsibilities with research interests and continued studies.

Since the researcher was the TA coordinator, she came in contact with the TAs during the weekly preparation sessions, lecture, and activity observations. The researcher had four years of similar experience as a TA within the course, before changing to lecture and curriculum design responsibilities. The researcher’s office was next to the TA office and down the hall from the classrooms and F2’s office, and was available to address questions and problems most of the day, each weekday and most weekends. The researcher did not play a role in hiring decisions pertaining to the TAs involved in this study, and, in order to protect TA anonymity, did not discuss specific TAs with others involved in the course unless specifically requested by the TA.

As a lecturer in the course of over 500 students, the researcher only had the opportunity to have extensive conversations with those students who attended office hours, lingered after class, or were involved in a research study. Most interactions referred to specific questions related to lecture materials or course policies asked following lecture. However, students frequently stopped by to provide feedback on the course, to ask about course content, or to engage in non-course related conversation. These discussions had been valuable in previous terms, especially when students
offered suggestions for improving the course. The researcher spent approximately one hour each day interacting with individual students, in addition to time spent with students in this study.

The motivation for this study was generated by a number of factors, related to a desire to develop practical applications and to generate theory for a long-term research agenda. The researcher had been spending significant time with students and TAs in the context of teaching and other research projects and wanted to find ways to assist these groups in learning. Additionally, the researcher was taking on increasing levels of teaching responsibility and wanted to learn how F2 and others had been able to sustain a course with a long history of high student retention and extremely high student evaluation ratings while continually updating the curriculum. A review of the research (Chapter 2) indicated that students, TAs, and faculty were studied separately and the researcher had noted that interactions between these three groups occurred very frequently in the BI 10X courses. A final motivator to conduct this study occurred at a national science education conference in which the researcher repeatedly heard fellow science educators discuss faculty teaching capabilities in a highly negative manner, with little empirical data supporting the alternative teaching recommendations.

In the initial stages of design, this study was focused on learning within a single group, the TAs. The researcher's rationale was that in her earlier smaller-scale studies on TA learning, it appeared that TAs often did not adequately learn the content that they were teaching. However, continued questions as to whether there was evidence that TA content knowledge impacted student learning, clearly indicated that it would be important to study learning in both groups. At that point the researcher was transitioning from a TA role to that of faculty, leading to the researcher questioning whether the most complete study would examine learning in all three groups. This decision was finalized when attending a session at a science education meeting in which a presenter discussing analogies presented the idea of a chemical "triple point" in which the three states of matter coexisted in time and space. The researcher extended this analogy to the three participant groups in an introductory science course and decided that, as in the chemical analogy, study of this congruence of participants could be fruitful.

At the onset of this study, the researcher had a generalist view of cognition and learning, believing that the behaviorist, cognitive, and situative perspectives all contribute to an intricate portrait of learning. This included believing that the nature of knowing and transfer of learning consisted of acquiring and applying associations,
cognitive structures, and participatory abilities. Reflecting this generalized concept of learning, the researcher viewed teaching as presenting connections and building conceptual understanding in a larger social context (Greeno et al. 1996), or even more extensive environmental context. In a schematic sense, these views could be represented by a multi-dimensional continuum in which different aspects of learning blended into one another, with different degrees of emphasis and location on the continuum varying between individual learners. This growing lack of allegiance to a particular learning theory influenced the formulation of the general research questions, and the desire to search for a wider description on university teaching and learning.

Based on past experiences, the researcher had formed strong personal views about teaching and learning prior to this study, but acknowledged that there could be numerous ways to effectively teach university biology to a diverse group of learners. The researcher believed that a university education should build upon the education received during students' K-12 years, not merely repeat concepts that were not learned during earlier schooling. Ideally, the university would challenge students to see familiar content in new ways, and place emphasis on establishing skills that would promote scholarly life-long learning. The researcher believed that undergraduate students should be provided with skills for effective learning (note-taking, communication skills, research) and be challenged to take responsibility for their own learning early in their undergraduate education. This indicated that in addition to the concepts and processes covered in an introductory biology course, students should be assisted in learning information gathering, interpretation, and reporting. These views on the role of undergraduate education shaped in part the overall BI 10X course goals and the more specific objectives of the studied project.

The researcher believed that teaching has an artistic dimension, in addition to basic skills like classroom management. Following Banner and Cannon's (1997) principal elements of teaching, the researcher believed that learning, authority, ethics, order, imagination, compassion, patience, character, and pleasure all significantly impact teaching. This belief promoted to search for aspects of motivation in this study's data.

The researcher's conception of biology related to its historical context, involved process in addition to context, influences, and was influenced by other disciplines, and emphasized the relevance of the material to student lives. This structure was not new, but had been modified by recent coursework in science education and increased biology teaching responsibilities. Due to responsibilities in course curriculum design in previous
years, the researcher's views of biology were reflected in some aspects of the studied course's philosophy and design.

Based on the available research literature on university learning and the results of the pilot study, the researcher had preconceived ideas about this study's research questions. Regarding types of learning, the researcher believed the three subject groups would be focusing on different tasks within the context of a curricular innovation, and as a result, would learn different things. Students would be focused on the content, or basics of genetic technologies, while learning how to research these topics. TAs would be focused on managing the project activities and not as focused on the content of the project. Faculty would be focused on technologies related to developing lectures and class materials.

Although the researcher believed consideration of content was an important aspect of curriculum design, emphasis was placed on altering teaching (more than content) to impact student learning. This followed the belief that many teaching skills such as those involved in basic classroom management, were the foundation of teaching regardless of discipline. Additionally, the researcher believed that enthusiasm for teaching and a sense of professionalism were necessary factors in adequately preparing to teach and motivating students to learn.

The researcher also believed that the major factors influencing learning in the three groups would differ, as the groups had different roles and responsibilities in the course. Student learning would be largely impacted by personal beliefs and motivation, past course experiences, and other students. TAs would be impacted by teaching experience and interactions with students. Faculty would be impacted by computer technologies and time constraints. Additionally, the researcher believed interactions between these three groups would primarily direct student comments/concerns through TAs to faculty, which would potentially impact future curricular changes.

Based on the researcher's own TA teaching experiences and data on TA learning in the BI 10X courses, the researcher had several ideas on how the TAs would influence and be influenced by curricular innovation. First the researcher believed that prior course work and teaching experiences would not be sufficient to prepare the graduate student for teaching open-ended activities related to genetic technologies. The researcher did not feel that her own biology coursework prepared her to teach introductory biology due to the incredible breadth of topics within biology, and the issues associated with converting a personal understanding of a topic to a level understandable
by the student. Additionally, the researcher's previous research suggested that TAs did not have an understanding of many of the underlying principles of biology prior to instruction. Without extensive preparation, the researcher did not believe that many of the TAs would be prepared to be able to provide students with meaningful project assistance. Even with weekly preparation sessions, the researcher believed that some TAs would still have an inadequate understanding of the subject matter, resulting in improper responses to student questions.

As to whether graduate student knowledge is altered by the involvement with a curricular innovation, the researcher anticipated that this would vary with the individual TA’s motivation, time spent preparing for teaching, prior knowledge, courses taken in conjunction with teaching, and other variables not yet unidentified. Even in those TAs that exhibited a change in knowledge based on their teaching experiences, the researcher did not anticipate that the subjects would learn aspects of science process (such as historical context, processes, nature of science, relevance) to their knowledge. Additionally, the researcher perceived that some aspects of TA pedagogical knowledge, such as preparation of activity materials and addressing student questions may be developed due to TA participation in the course. However, other aspects of pedagogical knowledge such as developing materials with an appropriate level of difficulty for an introductory course, may not be changed due to participation as a TA.

The researcher had fewer perceptions of how students would respond to the curricular innovations. Students in the course had a myriad of learning styles and strategies, many students could be unfamiliar with researching information, critically reviewing the information, and formulating conclusion. The researcher predicted that student learning would center on information acquisition skills and concepts specific to individual projects and that student learning could potentially be limited by personal factors such as motivation.

The researcher believed that students would learn strategies with assistance from group members, and specific concepts on their own. Competition would possibly arise in some of the formerly cooperative groups, resulting in overall improved project quality and student learning. The researcher had observed this process repeatedly in smaller classes, and anticipated a similar process in this course.

Although the researcher had executed earlier qualitative studies, her background in experimental science led to initial unease with the analyses associated with exploratory and descriptive research. This may, in part, have influenced the adoption of
a grounded theory design relying on a structured coding system (Strauss & Corbin 1998) and the extensive scope of data collection.

In order, to control for her own biases, the researcher intentionally searched for examples that opposed her beliefs about faculty, TA, and student learning. For example, the researcher searched for evidence that faculty were not learning new content, that TAs were not learning how to manage the activities, and students were having little difficulty learning the skills necessary to construct the project.

A researcher journal was maintained to record thoughts and observations throughout the fall term data collection. Included in this journal were notes from informal interviews with the subjects (using coded names), reflections on any emerging concerns about the research design, and ideas for improving on the research methodology. When not in use, all materials were stored in a secure location to preserve anonymity.

Data Analysis

Analysis of the data occurred throughout the study. Following Wolcott's (1994) ways of transforming qualitative data, the researcher developed a narrative, a detailed description, and finally a hypothesis. The emerging profile of student, TA, and faculty learning was grounded in the views and experiences of the participants in the study, including the insider-participant researcher (Strauss & Corbin, 1990). Participants were asked to respond to the emerging profile of learning during the post-project interviews (Chapter 5). Interpretive analysis of the data shifted from strongly descriptive (ethnography) to abstract (grounded theory) as the study progressed. These changes were noted in the researcher journal.

In this section, a generalized description of data analysis is presented. More specific information on data analysis is provided throughout the results (Chapter 4), indicating the specific data and study events that shaped analysis.

Overview

A variety of data management techniques were employed to manage the large quantity of data generated in this study. The researcher used a portable laptop computer to take notes during structured observations and interviews, and a hard-backed notebook to collect more spontaneous field notes. Some of the written notes, sketches, and artifacts were scanned for digital access and storage. Audio-
videotapes were transcribed and available for review to support researcher notes. A numeric coding system was used to keep track of dates, names, and data collection instruments. The researcher coded personal comments and observations as "observer comments" (OC) or with double parentheses (()) in all writings including analysis notes and the researcher journal. This enabled the researcher to distinguish personal observations and interpretations from data in the analysis portion of the study.

Data analysis focused on bringing order, structure, and meaning to the mass of collected data (Marshall & Rossman, 1995). Data analysis began immediately at the beginning of data collection, with the intent of directing observations and interviews. Data were also reviewed upon collection to identify patterns and inform future data collection. Data and corresponding researcher speculations were organized in the researcher journal.

In data interpretation, the post-project interviews, revised curriculum, and follow-up interviews were supplemented by information gathered from multiple sources. The post-project interviews were used to partially resolve conflicting data concerns and confirm or refute emerging data categories. After the interviews, transcriptions were compared with researcher notes. These two data sources were synthesized and notes on this synthesis were recorded in the researcher's journal. Audiotapes and videotapes were erased following transcription.

After all of the data were collected, the final analysis began. All of the data were read and re-read to search for patterns. Data codes were developed to mark data that appeared to address aspects of the research questions. Two analytic procedures were used in the coding process: (1) the making of comparisons, and (2) the asking of questions. Embedded in these procedures was the labeling of phenomena, discovering categories, naming the categories, and developing the categories.

Emerging broad categories were noted and assigned titles that described them. Initially these categories were general, such as "group dynamics," and after re-reading of the data were broken into smaller themes such as "aspects that influenced inclusion of topic into planning." The researcher searched for non-examples and triangulation of themes from multiple data sources (McMillan, 2000). Disagreements between data sources, such as a difference between a self-report during a formative interview and a teaching artifact, were addressed in the post-project interviews. If data conflicts remained unresolved at that point, the researcher noted this in the final data analysis.
and attempted to provide an explanation. Single, meaningful incidents were also sought to re-direct or crystallize analysis.

As student, TA, and faculty profiles were developed, care was taken to not compare individuals, but instead to search for general themes influencing learning in each of the three groups. Discrepancies that emerged to challenge these broad themes were included in the data analysis to accurately represent the complexity of learning within a university classroom.

Once categories had been linked, the researcher searched for alternative explanations for the results. Several factors emerged that may have influenced data collection and interpretation. First, the researcher compared the solicited data (interviews, questionnaires) to the unsolicited data (informal interviews and conversations) to see if the unsolicited data supported or refuted the results. This led to an analysis of the data collection techniques. Next, the researcher attempted to determine her effect on the research subjects and their responses. This included classroom observations and the potentially frequent interactions that resulted from the data collection techniques and involvement in the same course.

As the primary instrument of data collection and analysis, the researcher sought to identify bias. This included debriefing research experiences with participant and non-participant colleagues, maintaining notes on inference in the researcher journal, and maintaining a lineage of decisions related to data collection and analysis. These processes were used to establish validity, or the dependability of the researcher’s conclusions.

Several aspects of data collection and analysis were included to enhance design validity. This included prolonged and persistent field work, use of verbatim participant language, recording of low-inference descriptors in the researcher journal, corroboration through participant review in the post-project interviews, and constant searching for negative cases of discrepant data (McMillan & Schumacher, 1997).

An additional consideration was establishing authenticity, or the best possible reconstruction of the participants’ multidimensional perspectives. An attempt was made to ascertain the effect of the research on participant views, and vice versa, by searching for examples in the data (such as a TA altering planning behavior after discussing planning with the researcher, or the researcher asking different questions after speaking with a student).
Emerging categories were used to generate a series of propositions and hypotheses that modified subsequent data collection and are discussed in depth in the results chapter. These categories underwent repeated modification, reflecting new data and new researcher interpretations.

Once data analysis was underway, it became clear that there were three significant temporal divisions in the data collected. All events leading to the project being studied, through the end of the project, relied on data collected in the context of the researcher's perceptions of the unfolding events. This was followed by the final interviews, which gave subjects the opportunity to confirm or contradict the multiple data sources previously collected. Responses from the interviews were compared with the categories developed prior to the interviews. This resulted in re-working of some of the existing categories and addition of new categories.

Student Learning

In order to address the research question regarding what students learned in the context of a curricular innovation, analysis focused on the note cards from the projects, formative interviews, presentations, exam scores, and the post-project interviews. Students acquired knowledge from many aspects of the course, including lecture, the activities, the textbook, or on their own researching their projects. Exam scores were used to analyze their understanding of basic concepts covered in the project, with follow-up questions in the post-project interview to verify that those concepts were new to the students. Information on types of knowledge acquired came from classroom observations and the post-project interviews, when students were asked to describe how they completed their projects.

Data from these multiple sources were coalesced, and the researcher developed coded learning profiles for each student and student group, searching for trends across students. Embedded in this process was the search for information to address the second research question regarding the factors augmenting or limiting student learning. For example, if student groups discussed communication skills as a major component of their projects, the researcher searched for factors that limited or augmented this process.
Teaching Assistant Learning

In order to address the research question regarding what TAs learned in the context of the curricular innovation, analysis focused on the preparatory sessions, lecture, personal preparation for teaching the activities, the textbook, and interactions with students. Classroom observations and collection of teaching artifacts were used to build a profile of the TAs knowledge of the topics being presented. These preliminary profiles were used to develop specific post-project interview questions.

TAs developed specific strategies for interpreting and implementing the curriculum. To determine how TAs applied their knowledge in the classroom, the researcher searched for skills such as classroom management and questioning during the classroom observations and with the classroom artifacts. Questions asked in the formative and post-project interviews were used to clarify what type of skills, if any, the TAs learned to teach the new curriculum.

Data from these multiple sources were combined, and the researcher developed learning profiles for TAs and searched for trends in the coded data. Included in this process was the search for information to address the second research question regarding the factors augmenting or limiting TA learning. The researcher searched for factors that influenced this learning process.

Faculty Learning

In order to address the research question regarding what faculty learned in the context of a curricular innovation, data sources included formative interviews, teaching artifacts, lecture observations, preparatory session observations, and post-project interviews. Detailed information on the preparation required to design the curriculum, including faculty meetings and independent research were maintained in the researcher journal. Faculty curriculum artifacts, including early curriculum drafts, supporting science education papers, and other sources of information, also documented the process of faculty learning. The post-project interviews were used to clarify trends seen in the other data.

Data from these multiple sources were united, and the researcher developed learning profiles for both faculty and searched for trends. Part of this process was the search for information to address the second research question regarding the factors augmenting or limiting faculty learning. For example, when faculty appeared to spend a
large percentage of their time learning how to use the computer technologies, the researcher searched for factors facilitating or limiting this process.

Potentially the most important component of this study was the examination of how learning within each of the three groups influenced the others, and the overall effect these interactions had on the success and continuation of the curricular innovation. This was the focus of the research question asking if the learning of each group is influencing or influenced by the learning processes of the other groups. Components of the data collection were intended to document the various interactions between the three groups of learners.

**Interactions Between Students and Teaching Assistants**

TAs directly interacted with students in the laboratory and recitation activities. Since the activities were designed to be student-centered, TAs spent the majority of their time assisting students in completing their activities or projects. The researcher monitored classroom interactions by making detailed activity observations, and followed these observations up with formative interviews. TAs and students also infrequently met outside of class, in scheduled office hours or informal help sessions. Since these interactions were difficult to monitor, the researcher asked both students and TAs about these interactions in the Post-Project interviews.

The researcher coded the data sources reflecting TA-student interactions and searched for emerging themes in the data. This process included the search for information to answer the research question of how each group's learning influenced subsequent learning and innovation.

**Interactions Between Faculty and Teaching Assistants**

Faculty and TAs interacted directly in weekly preparatory sessions. Faculty introduced the activity objectives and discussed their vision of how the activity could be run, and how the activity fit in with the rest of the course. TAs were given the opportunity to ask questions and discuss how they would approach teaching the activities. TAs provided information to the faculty regarding the previous week's activities, along with suggestions for changes. Many of these suggestions were based on student comments. The researcher kept detailed notes of these discussions, and later compare these notes to the revised curriculum, to determine whether TA experiences influenced faculty curricular design.
TAs also attended the faculty lectures. The researcher compared lecture notes with activity observations, to determine whether the TAs explicitly referred to lecture. The researcher also questioned the TAs about the influence of the preparatory sessions and lectures on their teaching in the formative and Post-Project interviews. Even if the TAs did not explicitly refer to these factors as influences on their teaching, the researcher looked for indicators of these impacts.

Since the TAs had more contact with students than the faculty, and were more likely to hear student concerns, they relayed information about students to the faculty. These TA and faculty interactions were detected in preparatory session observations, formative interviews with faculty, or Post-Project interviews with faculty. Other faculty-TA interactions included spontaneous conversations, or other forms of communication. The researcher noted as many of these as possible in the researcher journal.

The researcher coded the data sources reflecting faculty-TA interactions and searched for trends in the data. Part of this process included the search for information to answer the research question of how each group's learning influences subsequent learning and innovation.

**Interactions Between Students and Faculty**

Faculty have limited direct interactions with students in large-enrollment courses. The researcher videotaped her own lectures and noted any "atmospheric" factors not easily picked up by the camera, such as student attitudes toward questions, responses to humor, and attentiveness. Faculty and students also met during office hours, and the researcher asked both students and the other faculty subject whether these interactions influenced their ideas or decision-making. Faculty occasionally visited the laboratories to assist TAs with answering student questions and F1 also monitored TAs and students in the study. The researcher collected data on these interactions through classroom observations and formative interviews.

The researcher coded the data sources reflecting faculty-student interactions and searched for trends in the data. Embedded in this process was the search for information to answer the research question of how each group's learning influences subsequent learning and innovation.
Developing a Hypothesis of Learning in the Context of Curricular Innovation

This study was designed to develop a hypothesis of learning, contributing to construction of a theory of learning grounded in the data. The goal was to describe the way learning occurred within the studied course. This research involved constantly formulating and addressing a lineage of questions. For example, while addressing the question related to factors impacting learning, classroom observations of student group members assisting one another led to the variable of “group member impact.” This led to several questions: Did other data sources, including students themselves confirm the importance of this factor? What aspects of learning were students assisting one another with? What factors were promoting this interaction? Did these student interactions impact the TAs or faculty? Assumptions were amended and additional variables were added to develop a complex picture, or theory that explained how students impacted one another’s learning.

Variables were linked to form categories, and themes were sought between categories to construct a storyline of learning in the studied course. The categories and supporting data are discussed in the next chapter.
CHAPTER 4: RESULTS

Introduction

Data collected in this study were merged into categories addressing the specific research questions. In this chapter these categories are discussed in detail, including the relationships between categories, the rationale for why the categories were selected, and exceptions to the categories. Categories represent loose groupings of related data in some matter, and are not to be reviewed as irrefutable entities. Raw data are provided when necessary to represent how different data sources assigned to distinct categories, to clarify particular categories, and to illustrate themes.

Due to the extent of results generated by this study, discussion focuses on those results that represent general trends and exceptional occurrences in the data. Increased emphasis is placed on those results that pervaded data collection and analysis, such as learning about the project's topics of genetic engineering and gene therapy. More specific and thorough discussion of results addressing each research question will be explored in subsequent publications.

The results are presented relative to the two general research questions. First, data and categories related to what the subjects were learning are provided. This section begins with an overview of three general categories of learning, followed by an elaboration on these categories and supporting data. These categories are then discussed in terms of the characteristics of learning, including identification of student learning and continua that represent learning complexity.

Next, data and categories related to factors impacting subject learning are presented. This begins with an overview of the general categories of factors, followed by an elaboration on these categories and supporting data. These categories are then discussed in relationship to the factors augmenting and limiting learning, as well factors related to innovation.
Overview of Categories Representing Subject Learning

Research Question: *In the context of an instructional innovation, what do faculty, TAs, and students learn?*

Data have been organized into three general categories of learning: Cognitive Outcomes, Learning Strategies, and Affective Domain and a series of sub-categories (Table 4.1). Student, TA, and faculty learning are represented by each category and sub-category. The number of subcategories represents diversity of learning, but is not intended to represent degree of significance, as this study was designed to identify variables.

**Table 4.1:** Categories of Student, Teaching Assistant, and Faculty Learning.

<table>
<thead>
<tr>
<th>Learning Category</th>
<th>Sub-category of Learning</th>
<th>Sample Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Outcomes</td>
<td>Project Topics</td>
<td>S5B reviewed and presented material on genetically engineered tomatoes</td>
</tr>
<tr>
<td></td>
<td>Related Course Topics</td>
<td>S4D related the lecture topic of eugenics to gene therapy</td>
</tr>
<tr>
<td></td>
<td>Characteristics of Science</td>
<td>S4C learned that scientists do not know when particular gene therapies will be available</td>
</tr>
<tr>
<td></td>
<td>Relationships Between Science, Technology, &amp; Society</td>
<td>SSA developed ideas about the impact of economic considerations on the research and regulation of genetically engineered products</td>
</tr>
<tr>
<td></td>
<td>Course Participant’s Roles</td>
<td>T2 developed an understanding that student learning varies considerably</td>
</tr>
<tr>
<td></td>
<td>Course Policies and Procedures</td>
<td>F1 developed strategies to fit project grading into existing evaluation practices</td>
</tr>
<tr>
<td>Learning Strategies</td>
<td>Thinking Skills</td>
<td>S1C learned how to critique a science journal article</td>
</tr>
<tr>
<td></td>
<td>Self-Regulation</td>
<td>SSA reflected on the relationship of the genetic technologies in relationship to his own life</td>
</tr>
<tr>
<td></td>
<td>Obtaining Information</td>
<td>S3C developed skills to find science information using the library computer program</td>
</tr>
<tr>
<td></td>
<td>Communication Skills</td>
<td>Students in group S2 began to generate visual materials to illustrate their debate points</td>
</tr>
<tr>
<td></td>
<td>Teaching Skills</td>
<td>T1 altered overheads to address his concerns about classroom management</td>
</tr>
<tr>
<td>Affective Domain</td>
<td>Attitudes</td>
<td>S2B stated that biology was more interesting than he previously thought it would be</td>
</tr>
<tr>
<td></td>
<td>Beliefs in Abilities</td>
<td>T2 reported that after the debates she believed students were capable of far more independent learning than she previously had thought</td>
</tr>
<tr>
<td></td>
<td>Values</td>
<td>S1E believed that aspects of genetic technologies conflicted with his existing value system</td>
</tr>
</tbody>
</table>
In order to be classified as a Cognitive Outcome, a variable represented a subject acquiring knowledge, or a conceptual understanding (such as learning about genetic engineering techniques). Variables grouped within the Learning Strategies category represented a subject acquiring a skill or strategy that led to changes in knowledge (such as developing the ability to use the Internet to access project information). The Affective Domain category included changes in subjects' feelings and attitudes (such as changing views of plagiarism). Primary data sources for categories varied, as will be discussed in subsequent elaboration on these categories.

After initial formation of the three categories, these categories were compared to available literature in order to ascertain whether data were being overlooked or overemphasized. The three general categories generated from the data matched some of Gagne's (1985) five aspects of learning: verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills. In the studied genetic technologies project, motor skill development was not observed. Additionally, clear distinctions between intellectual skills and learning strategies were not apparent in the data collected, possibly because the point of the project was for students to develop interrelated skills and strategies.

An attempt was made to determine the manner in which learning could be observed and recognized. Fincher (1985) discussed that observable outcomes included knowledge, competence, and understanding. Snow (1989) developed a model of observable aptitudes and achievements related to Gagne's learning categories. The researcher compared the continuum of outcomes proposed by Snow with the work by Gagne and Fincher (Table 4.2) and combined these interpretations with study data to define the categories. This provided a framework for assigning observed variables, particularly those that were defined operationally, with specific categories of learning.

The sub-categories were comprised of nested categories Tables 4.3A and 4.3B summarize aspects of student, TA, and faculty learning, with colors representing specific subject group learning. White ("clear") boxes indicate aspects of learning observed in all three subject groups.

Data in the tables are organized from the general (categories) to the increasingly specific (sub-categories, nested categories). Differences between and within subject groups usually separated out at the nested category level. For example, S4E learning to formulate an argument based on research data was categorized Learning Strategies – Thinking Skills – Reasoning – Formulating Arguments, and S3A learning to critique a
A journal article was coded *Learning Strategies – Thinking Skills – Critical Thinking – Judging References.*

**Table 4.2: Learning Categories and Related Learning Theories.**

<table>
<thead>
<tr>
<th>Learning Category Observed in Study</th>
<th>Learning Task</th>
<th>Observed Outcome</th>
<th>Observed Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Outcomes</td>
<td>Conceptual Knowledge</td>
<td>Knowledge</td>
<td>Naïve theories and misconceptions to deep understandings</td>
</tr>
<tr>
<td></td>
<td>Principles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning Strategies</td>
<td>Intellectual Skills</td>
<td>Competence</td>
<td>Inadequate skills to efficient use and flexible strategies</td>
</tr>
<tr>
<td></td>
<td>Learning Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teaching Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affective Domain</td>
<td>Attitudes</td>
<td>Understanding</td>
<td>Action orientation to action control</td>
</tr>
<tr>
<td></td>
<td>Beliefs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Values</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Category construction began with grouping closely related data (nested categories). Linking themes were then sought to create sub-categories and general categories. A caveat is that the categories tables may be good visual representations, but also oversimplify the data by not showing subject distinctions, relationships between aspects of learning, the times in which changes occurred, or the various factors impacting each aspect of learning. Samples of this complexity will be explored further in the discussion of each category.

Categories were altered over time to incorporate new data and new interpretations. For example, under *Learning Strategies* the sub-category of *Teaching Skills* had been originally developed to represent faculty learning about aspects of planning and TAs learning about implementing the curriculum. During the post-project interviews, it became apparent that faculty were also learning about aspects of instruction, and TAs were learning about aspects of curriculum design. Additionally, students appeared to also be learning about aspects of teaching, including specific aspects of project design, classroom management, and assessment.

With the large number of sub-categories of learning occurring in the three subject groups, a theme or storyline was sought to organize the data. An emerging theme was the great deal of similarity in types of learning occurring within students, TAs, and faculty. Repeatedly, examples in the data suggested comparable learning in all three groups, such as changes in beliefs about the abilities of other course participants during...
the debates. The researcher sought differences between groups, and repeatedly encountered basic similarities. Discussion of each sub-category includes brief summaries of student, TA, and faculty learning, similarities of learning between subject groups, as well as differences.

Table 4.3A: Subject Learning: Cognitive Categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Nested Category 1</th>
<th>Nested Category 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Learning</td>
<td>Cognitive Outcomes</td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>Cognitive Outcomes</td>
<td>Project Topics</td>
<td>Definitions, Relative, GE Plants, Gene Therapy</td>
</tr>
<tr>
<td>Learning</td>
<td>Cognitive Outcomes</td>
<td>Project Topics</td>
<td>Techniques, Current, Future, Gene Therapy</td>
</tr>
<tr>
<td>Learning</td>
<td>Cognitive Outcomes</td>
<td>Project Topics</td>
<td>Applications, Current, Future, Gene Therapy</td>
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<td>Definitions, Processes, Importance of Genes, Genetic Diseases</td>
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<td>Evolution</td>
<td>Processes, Important of Genes, Genetic Diseases</td>
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<td>Genes and Behavior, Animal/Human Relationships</td>
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<td>Objective/Subjective, Use of Evidence</td>
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<td>Use of Evidence, Media, Scientists</td>
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<td>Change Over Time, Experimentation</td>
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<td>Accessing Science Information</td>
<td>Use of Evidence, Media, Scientists</td>
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<td>Societal Interests</td>
<td>Corporations, Ethics/Morality, Environment</td>
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<td>Fellow Learner</td>
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<td>Course Policies and Procedures</td>
<td>Assorted Procedures</td>
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Key

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<tr>
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Table 4.3B: Subject Learning: Learning Strategies and Affective Domain Categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Nested Category 1</th>
<th>Nested Category 2</th>
</tr>
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<tbody>
<tr>
<td>Thinking Skills</td>
<td>Reasoning</td>
<td>Formulating Arguments</td>
<td>Understanding/Discussing Arguments</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>judging References</td>
<td>Judging Course Participants</td>
</tr>
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<td></td>
<td>Novel/Creative Thinking</td>
<td>New Representations</td>
<td>Linking Information</td>
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<td>Problem Solving</td>
<td>Project</td>
<td>Class</td>
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<td>Self-Regulation</td>
<td>Organizing/Planning</td>
<td>Reflection</td>
<td>Metacognition</td>
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<td></td>
<td>Monitoring Through Others</td>
<td>Self-management</td>
<td>Self-evaluation</td>
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<td>Locating Information</td>
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<td>Reading Skills</td>
<td>Written Assignments</td>
<td>Classroom Materials</td>
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<td>Writing</td>
<td>E-mail</td>
<td>Curriculum</td>
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<td>Oral Discourse</td>
<td>Debating</td>
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<td>Planning</td>
<td>Other Course Participants</td>
<td>Learning Content</td>
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<td>Teaching Skills</td>
<td>Implementing</td>
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<td>Attitudes</td>
<td>Toward Course Participants</td>
<td>Orienting</td>
<td>Orientation</td>
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<td>Toward Project/Course</td>
<td>Motivating</td>
<td>Presenting</td>
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<td></td>
<td>Toward Biology/Science</td>
<td>Presenting</td>
<td>Clarifying</td>
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<td></td>
<td>Presenting</td>
<td>Confirming</td>
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<td>Affective</td>
<td>Own Abilities</td>
<td>Intellectual</td>
<td>Intellectual</td>
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<tr>
<td>Domain</td>
<td>Other’s Abilities</td>
<td>Behavioral</td>
<td>Behavioral</td>
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<tr>
<td></td>
<td>Personal Values</td>
<td>Interpersonal/Development/Behavioran</td>
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<td>Scholarly Ethics</td>
<td>Plagiarism</td>
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<table>
<thead>
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</table>
The categories and sub-categories represent examples of learning by subjects in each of the subject groups, and do not exclude any observed learning. Differences in learning between the three groups, particularly breadth/depth, and timing are described in subsequent sections. In addition to examples of learning, examples of what subjects were not learning were sought and related to the emerging categories of learning in the studied course.

**Elaboration on Categories of Subject Learning**

This section describes the sub-categories and nested categories constructed from the study's data. In order to limit the expanse of this section, raw data are not provided for every subject group in each category, but are presented to clarify identified variables used to generate this study's hypothesis of learning in the context of innovation (as presented in Chapter 5).

Specific numbers of the subjects acting or responding in a particular way are not provided; as this study was attempting to identify variables, not ascertain their relative significance. Additionally, as the non-random sample represented only about 5% of the students enrolled in the studied course, the extrapolation of a single response to a larger number of students is unclear. For the student and TA interviews, words like “some” and “few” refer to a small number of subjects, whereas “several,” “many,” and “majority” indicate that a larger percentage of the subjects responded in a particular way.

**Cognitive Outcomes**

In order to be classified as a type of Cognitive Outcome, a variable represented a subject acquiring knowledge, or a conceptual understanding. Knowledge can be defined as an individual's conscious experience and comprehension of self and the world (Chinn & Kramer, 1995). Knowledge can be shared with or communicated with others, although language may distort that communication (Finn, 1997). Communication of understandings and beliefs were a key component of data collection.

Subjects acquired knowledge about the Project Topics of genetic engineering and gene therapy, and Related Course Topics, to the Processes of Science, Relationships Between Science, Technology, and Society, Roles of Course Participants, and Course Policies/Procedures. To organize the discussion of each variable, selected
student results are generally presented first under each category heading, followed by TAs, faculty, and comparisons between the three groups.

The curricular innovation included topics that were more current, controversial, and complex than many of the other topics covered in the course. Additionally, the project had distinctly different procedures that altered the role of the participants. All of these aspects impacted changes in subject knowledge.

Project Topics

All subjects learned aspects of the Project Topics of human gene therapy and genetic engineering. This included basic Definitions of the technologies, understandings of the Techniques associated with the technologies, potential and actual Applications of the technologies, Issues associated with the technologies, as well as Recent Developments in the field. The project topics had not been previously taught to any extent in the course, and the limited degree of student, TA, and faculty background knowledge of genetic technologies impacted the sequence of learning of the various aspects of the topics.

Subjects had limited understandings of genetic technologies prior to participating in the project (students), teaching the project (TAs), and planning the project (faculty). Most of the students had only heard of either cloning (referring to news coverage of cloning of Dolly the sheep) or DNA fingerprinting (referring to news coverage of the O.J. Simpson trial).

I don't know about it. I mean, sure I had heard of cloning, but I have no idea what that means. (S1B, Week 2, Formative Interview)

You know, I had heard about O.J. Simpson and the DNA evidence used for that whole thing, but not much else. The other people in my group seemed to have heard more about the topics. (S1C, Week 2, Formative Interview)

In the first activity introducing the project, students utilized their textbooks to define the topic they had been assigned, either gene therapy or genetic engineering. Some of the students group responses demonstrated confusion over the distinction between human gene therapy and genetically engineered organisms.
They replace defective human genes with effective ones. Used to make new types of animals and plants to make them better but can prove harmful to the environment. (S5 – assigned genetically engineered organisms, Pre-Project Activity)

Gene therapy includes going into an embryo and changing the genetic codes so that it makes the embryo better in many ways and makes new organisms. (S3 – assigned genetically engineered organisms, Pre-Project Activity)

As students began to research their project topics, limitations in knowledge about genetics topics restricted abilities to locate, read, review, and write about project topics.

I didn’t know that DNA has been around as long as it has. (S3D, Week 3, Formative Interview)

As will be discussed, faculty had not anticipated the overlap between the two project topics (that gene therapy incorporates aspect of genetic engineering).

However, by the third week of research, students had begun to form understandings of genetic engineering, particularly Definitions and Issues associated with the technologies. Students extended upon the textbook definitions, relating topics to other genetics information they were learning in the course and their research.

Defining the topics was a necessary step to be able to generate key words for internet searches and complete project assignments, including the annotated references, group summary, and notecards.

Whereas somatic cell gene therapy concerns only the person being treated, germline gene therapy involves genetic alterations that can be passed on to future generations. (S4A, Annotated Reference)

While researching information for the individual annotated references, students located both current and future issues related to genetic technologies.

Researchers are trying to clone genes to correct human problems. It gets controversial when you put those genes in sperm or eggs. (S3C, Week 3, Formative Interview)

There’s huge controversy on how far scientists should go in genetically engineering foods. (S5B, Week 3, Formative Interview)

Analysis of the Internet and library references selected by the students suggested that the articles discussing ethical and social issues were easier to read and summarize than articles from genetics and medical journals that emphasized techniques.
By week 4, while formulating the group summaries, students were focused on *Applications* of genetic technologies.

The future of genetic engineering holds promises of bacteria that may help to destroy toxic waste, corn that produces anti-bodies useful to humans, and for java-lovers everywhere, naturally decaffeinated coffee. (S2, Group Summary)

First gene therapy offers the possibility of disease prevention. A second application would be curing the diseases that are already present. Probably sooner than the other two possibilities, is the third possibility that gene therapy can be used as treatment in cases where prevention and curing are not possible. In the future, gene therapy could be used to correct genetic disorders and even prevent them from being transmitted to offspring. (S4, Group Summary)

By the fifth week of the project, students were discussing *Recent Developments* in genetic technologies.

Millions of tomatoes are genetically made to resist the abuse of shipping and handling. Scientists have altered the gene on the tomato that caused softening, allowing farmers to keep the tomato on the vine longer, which in turn makes it taste better. The tomatoes have been genetically modified to ripen slower and still be extra flavorful. (S5, Group Summary)

Retroviruses are used to carry and "infect" target cells with new and improved genetic information and then using their replication mechanisms forcing the cells to replicate new cells containing the new DNA. (S4C, Week 4, Formative Interview)

Certain misconceptions about genetic technologies that had been observed in earlier weeks lingered, particularly related to the progress of the technology.

All of the vegetables in stores are already genetically engineered in one way or another. (S2E, Week 5, Formative Interview)

I have learned that gene therapy has not actually cured anyone of a genetic disease yet. (S4B, Week 5, Formative Interview)

The final aspect of the genetic technologies that students focused on were the details of the *Techniques* used in gene therapy or genetically engineering organisms other than humans. These techniques were described during the debates.
When our DNA is damaged, it doesn't make the right proteins and we get a disease. To fix it, we isolate normal DNA and put it into a vector that puts it into the cells it needs to go in, and those proteins make up for the missing, damaged proteins in the cell. (S4D, Week 4, Debate)

With gene therapy, you are modifying a person's genes by changing the gene at the root. Somatic cell gene therapy involves altering the genes in body cells, except the sperm and eggs, which would be germline gene therapy. With gene therapy you substitute a normal allele for a mutant allele (reading off the note card). A vector inserts alleles into cells. Results from the human genome project, locating the 150,000 human genes are leading to more types of gene therapy. Gene therapy can also be known as genetic engineering. There is an insertion of DNA into plasmids, which is genetic material that is not part of bacterial genetic material. (S3E, Debate)

Students had to compose notecards for the debates, and some of the TAs encouraged students to make detailed notes that would assist them in supporting their arguments. These notecards indicated that students were linking together aspects of project topic definitions, issues, techniques, applications, and/or recent developments (Figure 4.1).

When an animal eats a modified plant with this insecticidal protein – the protein is released & the animal dies. What proof do researchers have, if any, to exclude that this protein couldn't be harmful to small animals or even humans that consume these plants? Wouldn't this effect biodiversity?

In 1997, the commercializing of transgenic BT (Bacillus thuringiensis) plants came through major multinational chemical & genetic engineer companies. Transgenic B.t. – cotton, corn, & potatoes were planted on about 3 million acres in the U.S. Although the EPA failed to prepare an Environmental impact statement, which is required under the National Environmental Policy Act. How is the EPA regulating & controlling the amounts of biotechnological pesticides?

Questions

Is it possible for insects to become resistant to the genetic engineering techniques of the insertion of a certain insecticidal protein into a plant's gene?

When an insect eats a modified plant with this insecticidal protein – the protein is released & the insect dies. What proof do researchers have, if any, to exclude that this protein couldn't be harmful to small animals or even humans that consume these plants? Could it effect biodiversity?

In regards to the use of biotechnology used to break down waste products. What would be the result of an genetically altered bacteria that is released into the environment that goes out of control?

With the use of biotechnology in agriculture, won't this result in more expense to consumers? (S5B)

Figure 4.1: Excerpt from Subject S5B's Note cards for Debate.
During the debates, students discussed a wide range of information related to the project topics.

Consumers are not informed enough. As ___ (S1C) stated in the introduction, many foods have already been genetically engineered. For instance, approximately 15% of soybeans have been engineered, and 60-70% of processed foods contain soybean products. Transgenic organisms could fool consumers, just because it looks better, it may not BE (student emphasis) better. 37 people died, and 1500 were paralyzed from tryptophan made by a genetically engineered process. There is a need to label these foods. We don't know the long term effects of genetically engineered foods. We need life results, not just lab results. (S1B, Debate)

Similar to the students, TAs had limited knowledge of genetic technologies prior to the project.

I don't know too much about genetic technologies, just a bit about cloning and stuff. I mean, I've heard about genetic testing and things like that, but none of this was covered in my genetics classes. (T2, Pre-Project Interview)

I don't really know about gene therapy, except I can figure out it has to do with treating people genetically. (T5, Pre-Project Interview)

In preparing to introduce the activity introducing the project, TAs learned some of the issues associated with the project topics, particularly from the prep session.

Students may have heard different issues related to labeling genetically engineered foods. (F1, Week 1, Prep Session)

There is concern over whether certain engineered foods should be labeled. (T3, Week 1, Classroom Observation)

As students began asking for assistance in defining the project topics, TAs sought assistance from the textbook, faculty and the Internet.

While grading the group summaries and notecards, as well as attending the lectures and debates, TAs demonstrated increased knowledge of Recent Developments and Applications.

There were many aspects of the technologies that I was not aware of, especially the limited use of gene therapy. (T5, Week 4, Formative Interview)
Students are giving a ton of different examples of genetic engineering, like engineered foods, tomatoes, corn, potatoes, you name it. Not as much on animals though and I'm not sure how much of it is accurate. (T2, Week 4, Formative Interview)

TAs noted that they needed to learn about the topics to grade student papers.

There were things that were questionable, like being on the edge, I can't remember what else there was, there was something that came up that didn't seem, I wasn't sure if it was false or not, I just wasn't sure if it qualifies as genetic engineering. And leading up to it I heard a number of interesting things like the ear they grew on the back of a mouse, which turns out to not be an example of genetic engineering at all, but students pick up on things like that, thinking that it was genetic engineering for a while. (T1, Post-Project Interview)

TAs did not, through observations, artifacts, or interviews, demonstrate learning about the Techniques of gene therapy or genetically engineered plants, as did the students. Additionally TAs did not learn recent developments in government regulation (although they were aware of other developments such as Bt crops). Both aspects were presented in parts of the course when F1 briefly discussed gene therapy techniques in lecture and students wrote about gene therapy techniques in their annotated references (both scientifically-consistent conceptions and misconceptions). Likewise, TAs had been exposed to recent information about government policies in the annotated references and, in the case of two of the TAs, the debates themselves. The subject TAs did not indicate acquiring knowledge about these topics during formative or post-project interviews. This may have been due to the complexity of the techniques, limited exposure to these topics, and/or limited need to know about the techniques.

When asked to specifically state what they knew about the topics, the TAs often answered in general terms, even with repeated questioning. Some of the TAs noted that the students had gone into more depth about actual procedures and examples than they had.

They went into a depth that far surpassed where I had gone. I knew a bit about genetic engineering, but I hadn't explored all of the ethical issues, so I guess I had had classes that had addressed this, but not to the depth, and I did not understand the issues to predict everything they would bring up. And so, the content was not necessarily so different, but the relationships between. (T4, Post-Project Interview)
TAs expressed that they may not know the techniques of genetic engineering, but that they could look them up.

I'm still a bit confused about the vectors and how genes are altered, but I would look that up if need be. (T3, Post-Project Interview)

There are things I would have to look up before teaching. (T4, Post-Project Interview)

Some of the TA's interview responses to other questions suggested that they had limited knowledge of some of the project-related topics. Others suggested that TAs knew the boundary of their knowledge and were predicting future trends in genetics technologies.

I kind of ended up putting off dealing with the black ball of cloning because it just didn't seem to fall into either (debate topics) very well. It might become more and more appropriate to discuss cloning in gene therapy. (T5, Post-Project Interview)

Initially, faculty were aware of some of the Issues associated with the project topics, through teaching related topics such as issues associated with DNA fingerprinting and genetic screening. In designing the project, faculty curricular research focused on determining whether there were sufficient Internet sources covering issues associated with the technologies, so the students would have access to debate material.

However, faculty had limited background knowledge of other aspects of the project topics. Limited background knowledge on Definitions, particularly the distinctions between technologies led to selection of two overlapping topics. TAs asked faculty for assistance in defining project topics in response to student questions. Faculty researched the distinctions between the topics.

Definitely the two topics overlap, with the same basic techniques used to isolate, clone, and insert desired genes. It would have been a lot easier if I had distinguished between genetically altering humans (gene therapy) versus genetically altering other organisms, particularly plants. (F1, Researcher Journal)

We certainly know that gene therapy is an aspect of genetic engineering! (Both laugh) That was difficult for the students because they are trying to memorize terms instead of thinking about the concepts behind those terms. How important are the terms? Think back to psychology, do you remember the terms or the bigger concepts? (F2, Post-Project Interview)

In preparing for lecture F1 researched Techniques for and Applications of genetic technologies. F2 assisted F1 in locating information for lecture. For example, F2
located information on a company (Monsanto) developing herbicide-resistant crops. F1 added this to lecture, and the topic subsequently appeared in student debate comments, notecards, and post-project interview responses.

Through assisting students with research, preparing lecture, and formative interviews, and listening to the debates, faculty learned more about Recent Developments of the genetic technologies.

Although the basic concepts of genetics are the same, there are new areas, I think telomeres are where all of the excitement is headed. (F2, Post-Project Interview)

F2 learned about aspects of the project topics through continual reading of science journals and while assisting students and F1. However, F2 was also assisting in redesigning instructional strategies to further the new project, particularly when problems with the project arose. F1 was focused on learning new teaching techniques, but had to also focus on learning content, due to student and TA concerns, and subsequently due to role as researcher.

"What" subjects were learning was closely tied to "when" that learning was occurring. A subtle difference in learning appeared in the timing of learning, with some subjects learning a particular concept or skill earlier than others. For example, the project topics of genetically engineered organisms and human gene therapy could be explored in several ways as discussed: by simple definition of the technologies, applications or uses of the technologies, the techniques used, issues raises, and recent developments. Table 4.4 summarizes when different groups began exploring these different aspects.

**Table 4.4: Generalized Timeline of Subjects Learning About Project Topics.**

<table>
<thead>
<tr>
<th>Content</th>
<th>Pre-project</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
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<tbody>
<tr>
<td>Students</td>
<td>-</td>
<td>Issues</td>
<td>Definitions</td>
<td>Applications</td>
<td>Recent Development</td>
<td>Techniques</td>
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</tr>
<tr>
<td>TAs</td>
<td>-</td>
<td>Issues</td>
<td>Definitions</td>
<td></td>
<td></td>
<td>Recent Development</td>
<td>Applications</td>
</tr>
<tr>
<td>Faculty</td>
<td>Issues</td>
<td>Definitions</td>
<td></td>
<td>Techniques</td>
<td>Applications</td>
<td>Recent Development</td>
<td></td>
</tr>
</tbody>
</table>
Some of the student subjects considered aspects of the topics prior to the TAs or faculty. This led to an interesting shift in teacher-learner roles, as will be discussed in the later section on interactions between course participants.

An error that repeatedly occurred was an “error of omission.” For example there was little mention of pharmaceutical possibilities of genetic engineering, a topic commonly discussed at that time in the genetics research journals. Additionally, subjects had limited (if any) examples of trials for human gene therapy.

As few students initially had alternate conceptions regarding genetic technologies, examples had to be sought in the knowledge acquired over the six weeks of the project. There was evidence that misconceptions arose (such as progress of the techniques), with some persisting, and others replaced with scientifically correct conceptions by the time of the post-project interviews.

Some of the aspects of the project topics appeared to be more difficult to learn than others, as represented by misconceptions or limited conceptions (non-learning). For example, several students and the researcher had lingering misconceptions how a gene was extracted and utilized following the process of gene cloning. The techniques appeared to be the hardest concepts for subjects to master, possibly due to the number of concepts that needed to be understood (alleles, restriction enzymes, etc.) prior to understanding the most basic of techniques. By contrast, it was relatively easy for subjects to understand the basic social issues associated with adopting various technologies.

Some misconceptions persisted at the conclusion of the project. Groups were also not as familiar with the topic they did not research. As will be discussed, the nature of the information readily available for each topic impacted what the students learned during their research. Subjects were more likely to have misconceptions or limited conceptions regarding topics that they had not researched themselves. Students, TAs, and faculty repeated erroneous information present by other course participants, such as the story of deaths related to genetically engineered foods. Students could discuss more about their own topic than students assigned the other topics or their TAs. Faculty were well versed in the material they acquired for lecture, but had limited understandings of some of the topics students were researching.

Additionally, although there appeared to be more misconceptions in students, there appeared to be more limited conceptions in TAs and faculty, who, by the time of the debate, had not spent as much time immersed in the material. Students may have
been developing more misconceptions along with scientifically correct conceptions, whereas TAs and faculty were focused on other tasks, and as a result, not developing as extensive conceptual understandings of the project topics as the students.

Related Course Topics

Project participation impacted what subjects learned about Related Course Topics, including Basic Genetics, Evolution, and Animal Behavior. Subjects searched for similarities or unifying themes between the project topics and other course concepts. The project provided additional and varied sources of information about course concepts typically covered in the course lectures, activities, and/or textbook readings.

Students noted that during their research into the genetic technologies, they encountered definitions related to Basic Genetics concepts such as protein synthesis, eugenics, and genetics diseases, in text and pictorial formats. Protein synthesis had been covered in lecture, laboratory, recitation, and the text. There was no discernible difference in responses related to assigned project topics (either genetic engineering or gene therapy). Student descriptions of protein synthesis varied widely. Some descriptions were highly accurate, particularly those of students who researched topics related to using genetically engineered organisms to produce desired proteins.

In transcription DNA unzips and messenger RNA copies one strand; DNA rezips. Translation, mRNA leaves nucleus with DNA copy; moves to ribosomes in the cytoplasm. Ribosomes made up of rRNA. tRNA complements the mRNA. The tRNA has an amino acid and the codon, the three bases of the mRNA, makes a matching amino acid. Many thousands of these combine to make a protein. (S2A, Post-Project Interview)

Other descriptions missed multiple components of the process.

S1E: Step one is transcription. DNA unzips and is copied. Step two is translation, mRNA takes the copied DNA out of the nucleus to a ribosome where it meets up with rRNA. This is where cytoplasm is. Last step, tRNA take it to the correct spots were it codes for specific amino acids. F1: What is tRNA taking to the spot?
S1E: The DNA. (Post-Project Interview)

Some of the students attempted to sketch the process, but were unable to recreate the protein synthesis poster created in an earlier activity (S1C, Post-Project Interview).

Most students became familiar with the topic of the eugenics movement, which had been presented in lecture and in the textbook.
The eugenics movement was when making a "superior race" of humans became ideal. People thought you could use genetics and evolution to improve people. The movement ended sometime after World War II. (S4E, Post-Project Interview)

Students in sections that had discussed aspects of eugenics during the debate had linked descriptions of the eugenics movement to their own understanding of genetics.

The eugenics movement was when people were trying to rid us of "imperfect" genetic specimens. Something we may try with gene therapy. (S3E, Post-Project Interview)

The first midterm exam covered the basic genetics concepts covered in the first three week's of the course (Figure 4.2). The exam average was low (67%) and students in the course had difficulty with some of the questions related to basic concepts like "gene," "allele," and "phenotype."

<table>
<thead>
<tr>
<th>Genes can be best described as</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. always having two alleles, one dominant and one recessive.</td>
</tr>
<tr>
<td>B. regions of DNA that code for a protein.</td>
</tr>
<tr>
<td>C. areas at the end of chromosomes that contain repeated codons.</td>
</tr>
<tr>
<td>D. either &quot;good&quot; or &quot;bad,&quot; depending on the allele being considered.</td>
</tr>
<tr>
<td>E. completely isolated from any environmental effects.</td>
</tr>
</tbody>
</table>

Correct answer = B

If a Rr pea plant is crossed with another Rr pea plant, the possible offspring can consist of ____ different genotype(s) and ____ different phenotype(s). (R = dominant allele, r = recessive allele)

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<table>
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<tbody>
<tr>
<td>A. 1; 3</td>
<td>B. 3; 1</td>
</tr>
<tr>
<td>C. 2; 2</td>
<td>D. 1; 1</td>
</tr>
<tr>
<td>E. 3; 2</td>
<td></td>
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</tbody>
</table>

Correct answer = E
(Midterm Exam #1)

**Figure 4.2:** Sample Midterm Exam #1 Questions.

This exam was given on the Monday of the fourth week, after students had submitted annotated references for the project. Similarly, many students expressed confusion about genes, alleles, and phenotypes in their annotated reference papers.
The second midterm exam, was given the week following the debates (week 7). The class average was slightly higher (69.5%). Students scored higher on questions incorporating the concepts of genes and phenotypes than on the first midterm exam (Figure 4.3).

Which of the following is an example of a polygenic trait?
A. Blood type
B. Chin dimples
C. Eye color
D. Mid-digital hair
E. Male-pattern baldness

Correct answer = C

If a parent with IA and IB alleles for blood type has a child with a parent with IB and I alleles, what are the possible phenotypes of the offspring?
A. AB, O
B. A, B
C. A, B, AB
D. I^A_i and I^B_i
E. I^A_i and I^B_i

Correct answer = C
(Midterm Exam #2)

Figure 4.3: Sample Midterm Exam #2 Questions.

These terms were used in the non-project portions of the course (lecture, lab, recitation, text readings) since the first midterm, but had not been formally re-defined. Some of the students stated that they had run across the concepts of genes and phenotypes in their debate preparations and had to define the terms to understand their topics.

Genes are the biological structures that compose DNA and structure the specific characteristics of living organisms, in essence the genes are a blueprint of life. (S5, Group Summary)

Students had persisting problems associated with understanding the project-related and general course concepts of alleles and mutations.

In the genetic engineering of plants, new genes are introduced in order to mutate and supposedly strengthen the crop. They may not only effect a seasonal crop, but may harm the surrounding environment. Logically, the same can be held for mutating viruses and bacteria. (S2, Group Summary)
Manipulations of these genes can cause mutations that damage the functioning of the natural genes. Some altered foods and plants have been found to create toxins and allergens that can be harmful. (S5, Group Summary)

Several misconceptions remained at the end of the study. Students had struggled with the concept of genes as the project progressed, understanding that genes related to proteins, but not grasping the relationship of alleles as different versions of a gene. There was also a great deal of confusion lingering about how mutations occurred and how they related to alleles and genetic engineering. Additionally, although most of the students understood that locating genes though research associated with the human genome project could lead to treatments for certain diseases, far fewer could explain how genes were located or altered.

Some of the students researching genetic engineering were using biology terms and concepts (like zygotes and plasmids) before they were formally introduced in other parts of the course. Many of these terms matched what the students submitted as part of their annotated references.

I have learned that an engineered gene is inserted into the zygote of an organism in order to produce change. The cells with the engineered gene will then be passed on to that organism's future generations. (S4D, Week 5, Formative Interview)

I also learned that plant cells can have their genes mixed by dissolving the cell walls between them. ... Foods can be genetically engineered using vectors such as plasmids. Plasmids can carry the desired gene into the nucleus of a host cell. (S2C, Week 5, Formative Interview)

Similar to the group researching genetically engineered organisms, students researching gene therapy frequently mentioned aspects of genetics not yet discussed formally in the course.

The human genome project should be completed by 2003 and there are over 50,000 genes to map. (S3A, Week 4, Formative Interview)

I have learned that one out of every 4500 babies born in the U.S. have a genetic disorder. They can be tested for, but many parents don't know about the testing so they don't do it. (S4A, Week 5, Formative Interview)
Some of the student's comments suggested a broader understanding of genetics.

I learnt that genetic engineers make use of both natural and induced variation. (S2D, Week 5, Formative Interview)

It may be possible to erase a problem in our family history such as a disease or other common defect seen through generations... it may be possible to cure certain inheritable diseases by human gene therapy. (S4D, Week 5, Formative Interview)

New misconceptions, such as confusing the topic of selective breeding with genetic engineering appeared.

Genetically engineered foods may be sometimes good and sometimes bad, it depends on what's changed in them. Something like seedless watermelons may be good because they are easy to eat, but bad because of loss of some nutrients in the seeds and an inability to reproduce. (S3E, Week 5, Formative Interview)

Selective breeding was discussed as a component of biotechnology in the textbook and examples of triploid organisms were covered in lecture.

TAs discussed learning about eugenics from lecture, reading student project papers, and listening to students during the debates.

...especially eugenics. They linked that to gene therapy and I hadn't seen that connection made before. (T4, Post-Project Interview)

Some of the TAs had more limited descriptions of the processes of protein synthesis and gene cloning than students, even though they introduced and taught a laboratory on protein synthesis and attended lecture on gene cloning.

You have the RNAs, the mRNA and the other ones, that copy the DNA and are used in producing the proteins. (T3, Post-Project Interview)

Faculty discussed eugenics prior to and immediately following F1's lecture covering the topic, and again after the debates. Although F2 had prior familiarity with the American eugenics movement, F1 was only generally aware that it related to misapplying science to make "improvements" in the human race prior to the course. Both F1 and F2 noted that students had difficulty with basic genetics concepts, such as defining alleles or calculating probabilities.
In the debates students repeatedly confused genes for alleles, saying that people had the wrong gene instead of a different allele. (F1, Post-Project Interview)

Students don’t understand the term allele because an allele is a concept, not a concrete part of the DNA molecule. An allele is defined by its function. (F2, Post-Project Interview)

Subjects also linked aspects of Evolution to the project topics. In the post-project interviews, subjects from all three groups discussed genetic diseases, and several subjects linked that topic to potential advantages of genes associated with genetic diseases (cystic fibrosis, sickle cell anemia) in an evolutionary sense. Additionally, a student (S2A) and a TA (T4) linked aspects they had learned in the project with concepts they were learning in the evolution unit. This included inheritance and genetic variation, key supporting ideas of the theory of natural.

In the post-project interviews subjects also discussed aspects of Animal Behavior in relationship to the project topics. Although the animal behavior unit followed most of the post-project interviews, the faculty were preparing for the unit, and a few of the students and TAs discussed the relationship of the unit to the project. Representatives from each group discussed the relationship of genes to behavior, and consequently fitness. A student (S2C) also mentioned similarities between human and other animals genetically, suggesting that these similarities could also result in similar behaviors.

Subjects in all three groups exhibited conceptual changes that could be represented as a sequence of learning and forgetting, which was evident in limited understandings of how changes in allele frequencies resulted in different attributes. Some of the students and TAs had difficulty describing how different alleles could result in different proteins even though they had previously taught or correctly answered questions over those concepts. Some of the subjects may have only formed weak forms of conceptual change regarding topics they had explored during the genetic technologies project.

Characteristics of Science

Subjects discussed learning more about a variety of Characteristics of Science, including the Structure of the Discipline, Historical Context, Knowledge Development, and Accessing Science Information. Although individuals from all three subject groups learned aspects represented by these subcategories, more differences in learning
existed within these sub-categories than any others. In previous terms and the studied term, attempts were made to incorporate readings and lectures that presented aspects of scientific inquiry. The project added another potential source of information about characteristics of science. However, subject understandings of science were extremely varied and limited to a few aspects of science, possibly because fulfilling the debate requirements did not necessitate fuller understandings of the workings of science. Additionally, it may have been difficult for subjects to learn about models and theories associated with genetic technologies research without more complex understandings of genetics.

Data representing learning of the Structure of the Discipline included aspects of Objective/Subjective knowledge and the Use of Evidence in science. Students and TAs discussed that, based on their project involvement, they believed that the search for information in biology was based on objective inquiry, but that decisions related to applying that knowledge were subjective. This indicated that the subjects did not view subjective processes such as creativity as having a role in scientific inquiry. Some of the students and TAs appeared to have limited understandings of the process of scientific inquiry, which remained unaltered by project participation.

T4: The students learned about the human element of science, that its not necessarily this separate, completely objective process. I think the project really facilitated this discussion and I facilitated this discussion often.
F1: During the debate? Or, more during the earlier activities?
T4: It was more during the activities that led to the debate to give them something to think about and also at the end of the day of the debate and we talked about that a bit more. (Post-Project Interview)

A few students discussed learning that biology, and science in general, depended on evidence, and that while scientists waited for evidence to draw conclusions, other disciplines such as philosophy might draw on other sources for decision-making.

This is science, and in science we need to have results that support how to do something. Its not just what we want to do. (S5A, Debate)

As a result, some of the students confirmed prior beliefs that science was distinct from other disciplines, not citing similarities other than overlapping problems related to genetic technologies.
Students and faculty learned aspects of the Historical Context of science in relationship to the project, including Biology vignettes and references to Other Disciplines. Historical stories were used by students and faculty to support claims and predictions related to the future of genetic technologies. During the debates, students referenced inheritance ideas pre-dating Mendel that had been presented in lecture (S5B).

Students and faculty both cited the eugenics movement, with F1 researching the material for lecture, and several students doing additional research on the topic to support arguments against gene therapy. Additionally, students went to other fields, such as nuclear physics and medicine to draw comparisons between the bomb (S5C) or antibiotics (S3B) with genetic technologies. F1 and F2 heard these and other examples during the debates and discussed together ways to integrate the histories of other disciplines into the courses. Additional information on the historical context of scientific information will be discussed related to the factor of Background Knowledge.

Students discussed learning about aspects of Knowledge Development in biology, including how knowledge can Change over Time and the role of Experimentation in providing information. Some students gave examples of how scientific ideas changed as new evidence appeared, citing that current understandings of genetic technologies would change as new research and years of practice unfolded. Students discussed learning that changing evidence made scientific knowledge tentative.

It seems like there is a lot more to learn about it, like going back to the gene therapy thing, I mean, I think I would be totally sold on going ahead with that, except for possible long term effects. It's difficult because it is so new now, we don't know what can happen (S1A, Post-Project Interview).

Additionally, students discussed experimentation as the means by which scientific knowledge grew over time. Students discussed aspects of the scientific method (although not by name), particularly testing hypotheses. Although students stated that they had equated experimentation with science prior to the project, they believed that they had a more complete understanding of the complexity of the experimental process. Students repeatedly stated that they learned how experimentation could support or refute particular ideas. Students did not appear to
learn that there are ways in science to gather information in science besides experimentation.

I learned that we have been eating genetically engineered foods for years. It doesn’t have to be so scientific as lab altered food. More testing and time are needed to be put into engineered food to see the broad range of affects and possibilities. (S1A, Week 4, Formative Interview)

Several students discussed realizing that a great deal was not known about the potential effects of genetic technologies, and that only further research would reveal these effects.

Possibility for an unforeseen disaster to occur because not everything is yet known in this field, more research is needed. Changing genetic make-up may combat genetic diseases. (S1C, Post-Project Interview)

Although all of the TAs and faculty had prior science research experiences, interview comments suggested that participation in the project broadened understandings of the complexity of science. Students also mentioned that they had developed a clearer understanding of the complexity of the research process than they had obtained in previous courses.

There is a lot more going on in genetics than I ever realized. (S5B, Post-Project Interview)

All three subject groups learned about ways of Accessing Science Information, including the role of Media Sources and Scientists. As subjects from all three groups engaged in research related to the project topics, understandings developed about how science was represented. This included distinct differences in how various types of media represented science knowledge. Although students did not express surprise that TV and magazines presented sensational information (Dolly the Sheep, O.J. Simpson Case), several did learn that information presented could be out-of-date, over-simplified, or simply incorrect.

I found articles that said the opposite of each other. That was pretty frustrating. (S4D, Post-Project Interview).

All three subject groups noted that Internet information was the most accessible, although inconsistencies between different Internet sources made research more difficult. University, government, and research journal websites were identified as generally being reliable.
Students and TAs noted that primary sources of information on genetic technologies, particularly journals for research practitioners, focused too specifically for an individual seeking a broad understanding. A few TAs noted that although they previously believed students should always go to a research journal for information, they thought that speaking with a researcher directly, as they did in their graduate classes, would be more useful (T4, T5). Students and faculty cited secondary sources, such as the journals *Scientific American* and *Discover*, as the most understandable and reliable sources for an individual seeking an introduction to a topic.

Some of the students discussed realizing that scientists do not have all of the answers, and that they have limited access to information on how technologies will be used.

> Also I have learned that there are a lot of questions that scientists do not have an answer to. Such as long-term effects and how the technologies will be used by people. (S4C, Written Debate Response)

Other students believed scientists had motives that differed from their own.

> These things that are going on are really scary. I mean, scientists are out there moving genes around from one animal to another and nobody even knows its happening. (S2D, Week 3, Formative Interview)

Understandings of the characteristics of science came from different sources, with knowledge of the structure of the discipline and understandings of science knowledge development primarily coming from personal research, and ideas related to the historical context and aspects of access to science knowledge primarily coming from group discussion, lecture, and the debates. As will be discussed, varied learning contexts associated with the project impacted diversity of learning.

In this study, none of the subjects discussed science at great depth, although the specific characteristics of predictability and objectivity were mentioned.

> Yeah, I think it changed the way I view that purchase of food. And it changed the way I look at things. At first I was very anti-one way or another, but the issues are so broad and there are so many pros and cons and it really opens up your way of thinking... you need to look at all of the possibilities like a scientist. (S2C, Post-Project Interview)
Relationships Between Science, Technology, and Society

All three groups of subjects discussed learning about Relationships Between Science, Technology, and Society. The interactions discussed represented a variety of connections, including the Significance of Technology, Impact of Science on Society, Societal Interests, Responsibilities and Roles, and overall Complexity. The new project was the only part of the course that contained an emphasis on the relationship between science, technology, and society (STS).

Students discussed the Significance of Technology as an avenue to Solving Problems and Changing Science, although most viewed science and technology as interchangeable endeavors. Students demonstrated an initial belief that science and technology would solve global problems. Many students were surprised that there was not more extensive testing of genetically engineered foods, but remained relatively confident that technology will find answers to global problems. Some student’s confidence in technology was replaced with skepticism by the post-project interviews. This was not generally skepticism that technology was ineffective, rather that humans were incapable of correctly applying technologies.

I'd like us to consider the scientific side of this. Scientists are trying to improve crops and other foods, but it will take time to learn the long-term results. There are a large number of genetically engineered foods, including potatoes and tomatoes. Genetically engineered plants can have toxins and severe viral infections are found in many genetically engineered crops. Genetically engineered plants may be protected against pests, but they may also grow beyond our control. These plants may escape into the wild and become super plants. We used to find out how nature works, now we are trying to figure out how to make nature better. (S1C, Debate)

When discussing the significance of technology, students often discussed science and technology as interchangeable, with science finding answers to questions, and technology solving problems (Figure 4.4). Rather than just discussing science and technology as being interdependent, involving similar context and processes of invention and creativity (Barnes, 1982) but different goals (Callery & Koritz, 1992), subjects repeatedly referred to them as the same thing. This may have been in part an artifact of the term “genetic technologies,” and the overlap of geneticists with multiple roles within both theoretical and applied research.

Students were focused on technology as a driving force in scientific developments. Students did not mention that science process resulted from asking new
questions, only from new technologies and new experiments, such as the development of the microscope (S1A) or testing of genetically manipulated crops (S5A). More mention was made of the importance of technology, than the importance of scientists.

![Diagram showing Goals of Science and Technology](image)

**Figure 4.4:** Goals of Science and Technology (A) Subject Ideas, (B) Actual.

Students frequently discussed the possible misuse of technologies, and resulting impact on society.

All innovation does not necessarily result in progress. Because of the potential power of genetic engineering, many people are concerned, ourselves included. This is a new and powerful technology, similar to nuclear technologies. Some scientists believe that these new changes can be irreversible, and may cause devastating damage to our environment. (S5C, Debate)

Subjects from all three study groups discussed the *Impact of Science on Society*, primarily in the general sense of forcing decisions on citizens and consumers. Interestingly, subject language always referred to science or scientists impacting society, rather than implementation of new technologies impacting societies, or societies impacting science. Subjects cited examples from other disciplines such as development of the nuclear energy (physics) or antibiotics (pre-pharmacy), as ways in which science research could change basic societal behaviors and survival.
The principle question to be answered is whether genetically engineered organisms will ultimately benefit or doom our society in the future. The pros and cons on both sides are numerous and both side's claim they are right. (S5, Group Summary)

Subjects discussed developing more complete understandings of the variety of different Societal Interests impacting and impacted by genetic technologies, including Corporations (representing economic interests), Ethical and Moral considerations, and Environmental concerns. Most subjects repeatedly referred to one of these interests (such as economic interests) throughout the project, developing additional understandings of that interest through their own inquiry, and understandings of other interests primarily through communication with other course participants.

Monetary gains must not go before the safety of our society as a whole. The public's right to know and assess potential dangers and ethical problems must have priority over both corporate secrecy and the naive views of academic freedom that accord scientists the right to experiment with whatever strikes their fancy without regard for the consequences. (S5, Group Summary)

Earlier you said we could feed the world. There is no profit in sharing and it is naïve to think that companies are doing all of this just to share their technologies for free. Without government regulation, how do we put people before profits? (S2E, Debate)

Students also discussed society's impact on the use of technologies.

Historically new technologies like artificial insemination have been restricted, people are scared and it all seems creepy until it becomes mainstream. Then everybody wants it and progress is made. (S3B, Debate)

This may be similar to breast implants. There were experts that thought they would be harmless, but we know that this turned out to not be the case. We may be able to alter people's cosmetic appearance, but is that a good thing? What if society decides something is good or bad, and then changes its mind. (S4C, Debate)

TAs commented that students learned about the complexities of science issues, and that these issues transcend the science course.

They seemed to learn that there were issues that could be seen in both pros and cons. I think it was really valuable in getting them to understand that there is these issues in society that everyone is going to deal with, and it gave them a better understanding of the ethical issues within genetic technologies. (T1, Post-Project Interview)
Many subjects discussed Responsibilities and Roles related to science, technology, and society, with students discussing the roles of Scientists and all three subject groups discussing the roles of Self/Citizenry/Consumers. Members of all three subject groups discussed learning more about the roles of scientists, particularly in relationship to genetics research. Many of the student subjects referred to scientists as “them” or “us” depending on how they viewed themselves, scientists and the aspect of science being discussed. A few students stated learning more about scientists’ roles, primarily related to experimentation and development of new technologies. Some students persisted in thinking that many decisions were up to the scientists, shunting responsibility from citizens to science. This distinction was echoed in students’ beliefs of science and scientists as amoral or even immoral, which in most cases, persisted throughout the project:

Gene therapy is not safe enough, but scientists want to move ahead (S4C, Post-Project Interview).

Most of student mention of scientists or the manner in which science was performed were negative.

Something I learned is that when scientists are conducting experiments some don’t report the results if they’re bad. (S3C, Week 5, Formative Interview)

Researchers are limited to how much they can actually do in human gene therapy. There are moral and legal limits on what scientists can do because it can affect the human population. Otherwise they would get out of control. (S4C, Week 5, Formative Interview)

Students did not focus on scientist’s day-to-day roles, and none discussed researchers collaborating on research within a community, despite students’ continual mention of the importance of information technologies as a means to genetic mapping and other advances. Although, as will be discussed, some students stated that scientists collaborated on teaching within university settings.

Subjects increasingly mentioned their own roles as citizens and consumers as the project progressed.

As individuals, we must put ourselves in the shoes of those who take each side of the issue, look carefully at the arguments, do research to understand what the debate is all about and choose the side which corresponds to your individual values and beliefs. (S3, Group Summary)
All ordinary citizens must insist on mandates and take responsibility for the enormously important decisions that are to be made about this highly controversial topic for years to come. (S5, Group Summary)

Some of the subjects indicated learning more about their personal abilities and responsibilities to purchase particular products or support particular businesses. Representatives in all three subject groups mentioned their increased awareness that the government would have to allocate more funding toward dealing with genetics issues. TAs noted reflecting that their future employment could be related to genetic technologies in some manner.

During the audience question/answer portion of the debate there was a great deal of consensus in the classes that consumers needed to be educated about emerging genetic technologies. This often was often summarized as the need to label genetically engineered products.

We as a society must educate ourselves on the subject and use our knowledge to decide whether this practice is good for society or best left alone. (S5C, Debate)

You do need information to make decisions. That's what we get out of debates like this, we are deciding how to control our futures. (S3B, Debate)

Early in the project, many students confused their simplified or limited views of topics as reality. For example, some of the students viewed the technologies as being extremely complex, but the ethical issues as relatively simple. Later, many students discussed ethical issues as more complex and challenging than the technologies themselves.

We're going to have all of these cures, but no idea whether we should use them. (S4E, Debate)

Although student groups presented the complexity of technologies, some of the individual students still saw this as a "either-or" issue, where one side of the issue was clearly right and the other clearly wrong. These students had learned a variety of aspects of the technologies, but believed that one overriding principle, generally ethical, would override any other arguments.

Commonly subjects discussed general aspects of STS (Science, Technology, and Society) rather than specific aspects of the nature of science. At the completion of
the project, some learning appeared to occur related to STS, but little change was evident in understandings of the basic workings of science. Although many of the students noted that science changed over time, those changes were generally attributed solely to new technologies and experiments.

Course Participant’s Roles

In the post-project interviews, subjects repeatedly mentioned learning about the roles of other Course Participants, including their roles as Fellow Learners, Teachers, Researchers, and individuals with a multitude of Extracurricular Roles. Several subjects stated that learning what other course participants think and do was an important aspect of their debate participation. Subjects discussed learning about how other course participants performed in their roles. This included time spent on tasks and abilities as well as deficiencies.

Subjects discussed learning about the knowledge and abilities of Fellow Learners in the course, including limitations of knowledge and capabilities. Students sometimes registering surprise when other students misspoke about something related to a course or debate topic by gasping or making a facial expression.

Students judged one another’s intellectual abilities, verbally valuing those who had prior related biology experience, gave quick, focused answers, and had high exam scores.

Some of them (group members) were really good in biology. They got higher exam grades. (S1D, Post-Project Interview)

Student’s expressed views of one another closely matched those expressed by the TAs and faculty. Students engaged in the genetic technology project were linked to one another through grades and had more stake in one another’s contributions, possibly leading to more consideration of one another’s intellectual skills.

The TAs discussed that they understood more about their students as learners due to teaching the project activities.

I developed an understanding of how they perceive science. Initially when they got these topics they had this very relative view of what they might be, and they were wrong. And then understanding how they worked that out, and also understanding where their misconceptions come up. It was impressive, they brought a lot of information that day to the debates. (T4, Post-Project Interview)
TAs noted that their students had learned a lot because of the project. Similar to the student post-project interview responses, TAs believed that students learned a variety of concepts and skills.

Right now they are sitting back and if someone asks them about it, they'll remember (the debate arguments) more than anything else, and they'll remember the arguments that ensued and the personal aspect of the debates. So I think all of them learned some debating skills. I think I had three or four people who raised their hands that they had ever been in a debate out of the eighty or so students. So I think they just got some experience about discussing issues. Some of them will remember what they researched and what they were in charge of talking about, I think. Especially the facts, not just the general stuff. (T5, Post-Project Interview)

TAs discussed learning that certain aspects of the course were challenging for students. All TAs noted that the written assignments (annotated references, group summaries, notecards) were difficult for some of their students, particularly understanding concepts.

Similarly, TAs discussed that other TAs did not always understand the project topics.

It was really obvious that they were not understanding the way the technologies worked. (T1, Post-Project Interview)

Students were also learning about the roles of TAs and faculty as Teachers. Some of the students in this study stated that they had learned more about faculty lives, primarily through the formative interviews. Other comments indicated that students and TAs were learning that faculty collaborated on teaching, as they watched this collaboration occur during the project.

Student comments about their teaching assistants ranged, with some students stating that they were learning that graduate students had similar constraints and concerns to undergraduate students, and other different and challenging commitments. The TA subjects stated that they had altered their conceptions about their own roles as teachers, primarily due to reflection and watching other TAs engage in teaching.

A few subjects learning more about other course participants as Researchers. Students in T5’s section were familiar with his research, as he discussed it in class. TAs also discussed their research and degree requirements with one another. At the conclusion of the post-project interviews, students and TAs discussed their participation in this research study with the researcher.
Subjects in all three groups mentioned changing views of their own roles as well as their views of the roles of other course participants. This was frequently repeated in the formative interviews, to the point that it appeared in the researcher journal under the label “course cultural phenomena.” Students discussed their roles as teachers (primarily of group members), TAs discussed their roles as learners, and faculty discussed their roles as continuing learners.

Some of the students focused on learning about how other students functioned outside of the classroom, including the variety of Extracurricular Roles. Some students mentioned social activities of other students.

I think you do need to get to know people in your group... They did different things on the weekend, you know, fishing and things. (S1B, Post-Project Interview)

Other students expressed surprise over the complexity of their group member’s lives, including balancing family obligations and employment.

You know, one of the girls in my group actually has two kids! I don’t know how she does it, I couldn’t get anything done if it was me. (S2B, Post-Project Interview)

Faculty mentioned the importance of learning what was occurring in the lives of students and TAs, and the impact of those events on classroom performance. An increasing number of students were working, supporting families, and adjusting to learning disabilities.

Course Policies and Procedures

Course participants were developing understandings of Course Policies and Procedures. Policies included Grading and Due Dates. This knowledge impacted behaviors related to project completion. Course policies and procedures were changed to accommodate the new project. Ambiguity associated with these changes resulted in increased participant emphasis on clarifying requirements and expectations.

Students developed knowledge of Grading policies, which impacted the emphasis put into the project (particularly the initial annotated reference assignment), turning in assignments on time (to receive credit), and working with group members. TAs learned grading policies, such as assigning project points. Different grading schemes was being incorporated for the annotated references, group summaries, note
cards, debate presentations, and written debate comments. Students repeatedly asked their TAs and faculty about grading, and faculty came to decisions about grading policies as problems and concerns arose. Typically grading policies were established prior to each course and were fairly stable in nature. The project necessitated flexibility as it was not possible to predict how students would do on the various assignments (where as traditional grading schemes were made for “tried and true” activities – F2, Formative Interview).

Due Dates were also critical, in that students needed to meet those dates to receive maximum credit, and be able to assist other students in preparing to debate. TAs also needed to be clear on due dates to remind students to complete requirements in a timely manner. Non-project related activities did not have due dates; tasks were completed and turned in at the end of each activity. The addition of the long-term project, with three distinct due dates (annotated references, group summaries, debates/notecards) led to concerns associated with late work.

Knowledge of Procedures included understanding a range of tasks from reading activities ahead of time, to arriving on time to class or prep sessions to hear important announcements. The complexity of the procedures associated with the project necessitated repeated detailed announcements and directions. As will be discussed in the Attention/Awareness section on factors impacting learning, those subjects who had lower attendance or who devoted less attention to course activities (prep sessions, lectures) knew less about course policies.

F1 learned how the course worked through frequent conversations with F2. Additionally, both faculty had to revisit old procedures and design new procedures to match genetic technologies project. Prior to the term, F1 and F2 needed to select a grading scheme for the project, and selected a small point value relative to the overall possible course points. This was primarily due to concerns about TA grading, particularly since TAs usually graded short answer responses to specific questions, and a certain amount of consistency between different TA’s classes was considered desirable by the faculty. Through the project, faculty developed procedures, such as standard detailed grading schemes and checks of randomly selected papers, to assist TAs in grading and enhance consistency between sections.
Learning Strategies

Variables classified as Learning Strategies were observable behaviors or skills used in acquiring knowledge. A skill was defined as the ability to do something, not simply having the potential to act (Fitzgibbons, 1981), which was beyond this study's ability to determine. Sub-categories included Thinking Skills, Self-Regulation, Obtaining Information, Communication Skills, and Teaching Skills.

The curricular innovation required subjects to engage in behaviors that were not a component in other aspects of the course, such as students critiquing science journals, TAs generating grading schemes, and faculty altering lecture content to clarify activity topics.

Thinking Skills

Thinking skills were necessary for completion of all aspects of the project. Subjects demonstrated changes in thinking skills, including Reasoning, Critical Thinking, Novel/Creative Thinking, and Problem-solving. Thinking skills were difficult to classify as skills commonly overlapped (Figure 4.5).

![Figure 4.5: Relationships Between Aspects of Thinking.](image-url)
For example, a student learning to review a source of information involved learning aspects of problem solving (how?), which often involved reasoning (if, then) and critical thinking (why?).

Evidence of thinking could be seen in a subject's opinions, deliberations, skills, and imaginings (Howard, 1996) in communication and behaviors. Vocabulary representing thinking included words like appreciate, assume, believe, conclude, consider, convince, criticize, decide, define, discover, doubt, estimate, examine, explain, grasp, guess, interpret, investigate, judge, justify, know, observe, propose, question, realize, recognize, remember, research, review, study, suggest, think, and understand (Tishman, Perkins, & Jay, 1995).

Reasoning skills developed during the project included Formulating Arguments, and Understanding/Discussing Arguments. Although subjects may have been using a variety of reasoning skills in the general course, data only showed shifts in argumentation related to the project. Other portions of the course did not require as extensive work formulating or understanding arguments, so changes in reasoning were tied very closely to artifacts related to teaching or completion of project activities. Reasoning was a component of weighing the relationship between genetic technologies issues. Students demonstrated learning how to formulate arguments as the project developed. TAs assisted students in phrasing a statement in argument form prior to the debates, and students discussed observing ways to make different arguments during the debates.

The con group was very impressive. They gave outstanding yet sometimes gruesome examples against genetically engineered foods. They raised a number of health and even ethical concerns that I haven't even thought of or even considered. There arguments make you really think about the foods you are putting in your body, what is in them, or even what the potential long term effects are. As the debate got going, this group got real excited. (S3A, Student Debate Critiques)

Students also elaborated on their abilities to formulate arguments.

You know, we could have made our argument better. The other group seemed really well organized and had specific examples, like that one guy who had examples of different genetically engineered crops. That was pretty effective, wasn't it? (S1B, Written Debate Response)

Students discussed the inherent difficulty in resolving arguments that can a moral or ethical basis.
Genetic engineering can be both harmful and beneficial, and cannot be judged from a general basis. As we look into the future of genetic engineering it appears that the resolution of the surrounding debate is a long way off, and more moral and ethical questions will be raised as our technologies improve and our exploration of genetics continues. (S2, Group Summary)

Students combined information from their research with course information to formulate arguments that other groups judged to be persuasive.

There are many benefits to gene therapy. In fact we are only going to talk about a few because there are so many of them. Ask yourself. If you are a parent, wouldn’t it be great if you could pass on genes to your children that were free of diseases? Okay, think about it, a vaccine cure for muscular dystrophy, a child born free of tay sachs even though his parents have the disease, or inserting a gene to increase blood flow to the heart. These are possible benefits of research already in progress. (S3A, Debate)

Subjects critiqued the arguments made by other course participants.

They were effective when they said that they were for curing diseases and not for using it in a “Hitler style” to produce an ideal race. Making it emotional, by explaining the human characteristic of wanting to help each other was also effective. The pro group did a great job and I feel that they won. (S2E, Student Debate Critiques)

Individuals in all three subject groups discussed learning ways to understand and discuss arguments. Since these were always linked in the data, they were not separated into distinct subcategories. Students discussed having to read and understand arguments in science articles in order to be able to write about them and share them with group members. Students also discussed arguments from other debating supergroups.

The introduction was very well prepared and delivered. I think that many of their arguments are irrelevant to the issue, for example the issue about money. The pro side said that the companies will pay for gene therapy, so I don’t understand why they kept bringing it up. (S2B, Student Debate Critiques)

TAs stated that considerable time was spent trying to understand student arguments in the paper assignments and then discuss the problems with those arguments with students. Faculty, similar to the students, were reading science articles
and news stories in order to communicate the material in lectures and through course materials.

Building on understanding and using reasoning skills, subjects in all three groups engaged in new or more in-depth practices of critical thinking, including Judging References, Judging Course Participants, and Judging Self. Each of these subcategories involved establishing criteria by which a person or performance could be assessed. Students, TAs, and faculty mentioned developing and expanding upon criteria by which a source of information could be judged. Although some subjects early on believed they already could determine which sources of information were reliable, emerging inconsistencies in Internet information led to development of more detailed criteria and a realization of the inevitability of social context.

Representatives of each subject group discussed the steps necessary to critique scientific articles. This included interpreting pragmatic meaning when reading science articles, searching for bias, degree of certainty, and the scientific status of statements (Norris & Phillips, 1994). Faculty were finding new ways to locate information quickly. All groups were judging the sources of information, only for different reasons, with students and faculty demonstrating the most similarity of judging sources of information for presentation.

Many students stated that they had limited experience critiquing resources prior to the project.

F1: How do you judge how reliable sources are when you research a paper?
S2E: This is my first paper, here at (school name), I haven’t really had to do anything like that yet. (Formative Interview, Week 2)

The student groups compiled several characteristics that could be used to judge whether a source of information was reliable, consistently emphasizing the importance of reputation.

We judge it reliable if the author is backed by a reputable organization, contents contained on an official website, credentials displayed, or work published in a scientific journal. Also be aware of special interest groups. (S1, Pre-Project Information)

Check credibility and background of source
Make sure its official
Supported by reputable organization
If the source comes from government, learning institution or professor, then the source and information is reliable and also date of the sources. (S4, Pre-Project Information)

Most of the annotated references, completed early in the project, included only a brief summary of the information, with few critical comments.

A bacteria known as Deinococcus radiodurans shrugs off doses of radiation many thousand times stronger than those that would kill a person. Scientists are trying to genetically engineer the bacteria to destroy radioactive material. If this works it would be of much use. It would be wonderful to be able to breakdown dangerous radioactive material. (S4E, Post-Project Interview)

Many of the students indicated that they had difficulty in judging the reliability of sources of information.

I didn’t know (how to judge) the information, so I went with of course government agencies, I would think those would be pretty reliable. As best I could. (S1C, Post-Project Interview)

Students developed opinions of particular types of bias in the articles they reviewed.

What we, tried to figure out to do was how to find books that weren’t biased, so many of them were written for like a cause and they were like genetic engineering is good because it helps my cause, business, and so on, and so like we had to look hard to find books. (S2E, Post-Project Interview)

Some of the students indicated that they saw a clear difference in the amount of bias between Internet and journal resources

I think some of the Internet articles are terrible and its just one sided and it can easily sway you the other way and a lot of times the journals are more objective, and I went to the journals. (S5A, Post-Project Interview)

Early in the study, subjects did not extensively discuss aspects of Judging Course Participants. However, as the project and overall course progressed, subjects had more opportunities to assess and evaluate the performance of others. Students evaluated group member’s performances, TA assistance, and the quality of lectures. TAs discussed learning about how to assign grades to student performance, the utility of other TA’s approaches, and recognizing limitations of lectures. Faculty focused on determining how much students were learning about the project topics and what TAs
were learning about teaching. Problems that arose during the project were immediately linked to establishing whether other course participants were adequately meeting these performance criteria.

Later in the study, subjects exhibited aspects of Judging Self, discussing “why” the exhibited a specific behavior or believed they learned a particular concept. This was related to increased reflection on personal behaviors, as well as increased self-management. By thinking about what they were teaching and learning, in part due to research participation, and the need to manage time to complete course-related responsibilities, subjects were considering why they received a particular grade, why they had trouble maintaining the attention of others, etc.

Subjects also demonstrated adapting forms of Novel/Creative thinking, including developing New Representations of concepts and Linking Information from different sources. Students primarily drove this process by coming up with different ways to represent topic information and providing examples from different disciplines. A few students linked the topic of eugenics to the field of animal cloning.

Cloning is another version of creating a superior race, like the eugenics movement. Human cloning goes against the beliefs and values of every major religion. It would create a permanent lower class of “genetically undesired” people. (S5D, Post-Project Interview)

We don’t know what could happen if humans can be cloned. Problems could occur which may alter looks or behaviors of the clone. It would partly be an advancement in using “healthy” proteins to keep humans from disease, but it may go to far by trying to create a “superior” race like eugenics. It may completely get rid of some naturally occurring traits. (S3B, Post-Project Interview)

Some of the students described researching other topics as they had the project topics covered in the genetic technologies project.

It would be important to have a realization of long-term possible problems, you would not know all the outcomes. I would try to list out the pros and cons about human cloning. I would consider religion and ethics for my decision. (S1D, Post-Project Interview)

TAs and faculty read and listened to these student examples and stated that they valued this type of thinking. TAs supported student’s creative approaches to the debate project through verbal feedback and note card grades (“Interesting” - T4 comment on annotated reference).
**Problem Solving** related to integrating the various aforementioned thinking skills in order to resolve situations occurred relative to either the *Project* or the *Class* in general. Subjects varied in their overall problem solving approaches, with some stressing critical thinking, and others emphasizing creative thinking. Representatives of all three subject groups discussed and/or demonstrated learning how to bring together different thinking-related tasks in order to successfully complete project involvement. Students were asked to elaborate on how group members decided to work on the project.

Does anyone want to do the introduction, you know the introduction is really important, probably one of the more important way to grab the audience, so they said we'll do the introduction. They said they wanted to do it and I said Ok and it would be really good if you could get something like a case study, maybe if you could find a picture of somebody, cause you want those kind of things that just grasp an audience and convince them why we need regulation. (S5A, Post-Project Interview)

TA and faculty problem solving largely centered around addressing student concerns. This included finding ways to clarify topics, assist students with research, and identify various debating skills.

As this study was not designed to discern between thinking skills that originated within the context of the course and those that were transferred from other settings, it was difficult to assess the degree of transfer of thinking skills. There is also limited data on the durability of these skills over time.

**Self-Regulation**

*Self-Regulation* indicated a learner using personal strategies to monitor and control his/her own behavior and included *Organizing/Planning*, *Monitoring Through Others*, and *Self-Management*. Evidence for self-regulation could be seen in planning, organizing, monitoring, and self-evaluation behaviors (Ley & Young, 1998). Cues that self-regulation was occurring included evidence of goal-directedness, time management, directed practice, meaningful action, and use of appropriate cognitive and meta-cognitive strategies (Schunk & Zimmerman, 1998). Although these skills can be related directly to teaching skills, self-regulation was more generally contextualized in subject learning within this study's results. The project required much more out-of-class work than the usual laboratory and recitation activities. Additionally, the project was designed with students receiving little initial assistance in beginning their project research,
necessitating self-regulatory skills that were not a component of other parts of the course in which expectations and examples were clearly provided.

Early in the project, data primarily revealed subjects engaged in learning new Organizational/Planning skills. This began with faculty developing the curriculum and continued as TAs prepared to teach and students started their project research. Students utilized declarative, procedural, and conditional knowledge to adapt strategies for different tasks, content areas, and classroom contexts.

Um, Well, research probably about an hour, and on the summary that we did as a group and I pieced together everybody's paragraphs, that took me probably about an hour, hour and a half. Um, we got together and decided who would do each paragraph, who would do the pros, who would do the cons, and um did our research separately and compiled a paragraph for the summary and we just e-mailed the pieces to me and I did it. ...Maybe we could have done it faster, but we hadn't done this before and it took a while to figure out. (S1B, Post-Project Interview)

Organizational and planning skills included sequencing tasks, prioritizing tasks, and checking off tasks as there were completed. As many of these skills related to transmitting knowledge to others, they will be discussed further under Teaching Skills. Subjects developed strategies for Monitoring through Others, or assessing their own performance based on the actions and reactions of other course participants. Students talked extensively with group members prior to debate to confirm that they were focusing on appropriate tasks.

S2B: We're pretty much ready to go, we know what everyone has to do during the debate. Now we just have to work on what we're going to say in our own parts and...
S2E: We have to do the notecards.
S2B: Yeah, we have to do notecards, but we can pretty much do those on our own. (Week, Formative Interviews)

TAs sat in on other TA's sections to see ways a particular activity could be managed differently.

...definitely helpful to sit in on ____ (non-subject TA's) section and get ideas for teaching. (T3, Week 2, Formative Interview)

F1 frequently sought feedback from F2, TAs, and students regarding the lectures. Subjects repeatedly discussed their behaviors in relationship to those on their "peer" group (fellow students, fellow TAs, or fellow faculty).
Self-Management included the related but distinct sub-categories of Reflection, Meta-Cognition, and Self-Evaluation. Even though reflection was a pre-cursor to the ability to assess one's own knowledge and evaluating personal performance, some subjects appeared to rely on previously developed reflection skills, or reflected and reviewed past events without coming to apparent conclusions.

Subjects mentioned learning more about the process of reflection due to participation in the course and research study. Reflection was often specific, such as a TA focusing on an interaction with an irate student or a student focusing on a particular concept, such as the economic impact of genetically engineered crops on small farms. Student and TA reflection appeared to be an important factor related to learning about course policies and procedures. Subjects commonly returned minutes after a prep session or class to confirm their understandings of a policy or procedure, indicating that they had been thinking about those ideas.

S1D: Um, my view, like you mean good or bad, how I feel about it, I think its good to be informed about it. I'm just neutral, I see the good sides and I see the bad sides. Um, probably seeing the negative on GE, it would effect my vote, yes. I wasn't really aware how much it does affect us.

F1: How would you vote?
S1D: You know, I would think twice, it probably would be good to label, but there is a lot of potential benefits too. (Week 6, Formative Interview)

Some of the students mentioned thinking that by being required to do certain behaviors, they did things and learned things that they would not have experienced on their own.

Well, actually, we weren't really forced to do it, because we kind of had to do it, and I think it was good for us because it makes us aware and if it wasn't for this project, I mean most people don't go on the internet and type the words genetic engineering for fun, I mean I wouldn't. (S1B, Post-Project Interview)

In follow-up questioning, students mentioned that the project made them think about their own lives differently.

When we were talking about genetic diseases, especially Down's Syndrome, I'm close to 30, another girl in my class is close to 30, and this kind of makes you think about things, its really amazing they come out normal. (S5A, Post-Project Interview)
TAs appeared to primarily focus on pedagogy, rather than content knowledge. Two TAs commented on reflecting on the concepts presented in science education courses in the context of BI 102 teaching. Reflection did not necessarily transfer to practice, as will be discussed. TAs particularly reflected on aspects of teaching strategies that had not been effective.

Well my afternoon class had a few problems, a few people were trying to have conversations during the debate and even though I had given them the debate rules and format the week before, and each individual had their own copy of it, hardly anyone if the afternoon class was prepared to give ten minutes of examples. It's like they gave their intro and were completely stunned when I asked for ten minutes of examples. But by then, they enough that they managed to do it anyway. I think it may not have gone ten minutes, but at least seven or so. (T1, Post-Project Interview)

Another group of skills acquired related to Metacognition, or an individual's awareness of his/her own learning. Subjects of all three groups discussed becoming increasingly aware of what they did (and did not) know as the project progressed. This in part reflected research participation that involved more reflection, and in part, the degree the project challenged participants to express knowledge.

Now that I'm thinking about it, I think we decided to work separately because it's sometimes just easier to work on some things by yourself, and other times as a group. (S1A, Post-Project Interview)

Self-Evaluation techniques changed as the project progressed. Through the formative interviews, subjects increased discussion of trying to assess their own performance in comparison to peers. Students were assessing their own contribution to the project, developing and expanding upon existing personal criteria, and weighing personal performance against the performance of others.

I have learned a lot about gene therapy, who it affects and why we should concentrate on the rights of people, and the responsibility of our society on the whole. From our research, I have learned a lot about the genetically engineered foods and their benefits. (S4A, Written Debate Response)

In the post-project interviews, subjects discussed new, broader, techniques of self-evaluation that reflected the diversity of project-related tasks. Student subjects stated that they thought they were not able to do well in biology, but that they realized that they were better at some tasks (such as judging resources or oral communication) than
others (such as exam performance and writing) and that those were aspects of learning as well. Similarly, TAs and faculty were evaluating their own performances on their broad range of abilities.

**Obtaining Information**

Students obtained information to develop their project-related assignments, TAs obtained information to teach the activities and answer questions, and faculty obtained information to lecture over unfamiliar material and answer TA and student questions. Representatives of all three groups developed new behaviors related to *Obtaining Information* and *Technical Reading Skills* that enabled them to collect information and convert the information into a usable form.

As a result of the project requirements, students were locating information from the *Library*, the *Internet*, and *Other Course Participants*. Many students had not previously used the library to locate resources. Although many of the students were generally becoming more proficient at using computers, the project required students to learn how to select key words, use the computer catalog, locate materials on shelves, and utilize other library resources such as study rooms and librarian assistance.

Yeah, with the library we started with their computers and went through like a medical directory of files and we had no idea what we were doing and we had to get help. And then the medical journals along with that, I had never looked at medical journals or anything like that, and it was really tough. (S2C, Post-Project Interview)

Students stated that in other courses they had not examined science information beyond material provided with a formal class structure.

That's the new thing you know, having to go find information on my own somewhere else besides the textbook. (S3C, Post-Project Interview)

All participants were learning to obtain information from the Internet. Even long-term library users were investigating the use of search engines. Along with selecting key words and using net browser programs, subjects were faced with attempting to judge the reliability of sources that commonly are not referred or include authorship, an aspect of critical thinking.
Students primarily used sources of information from the Internet, and spoke extensively about their use of the Internet over the course of the project.

I just typed in gene therapy and got a lot of hits. Most of the material wasn't very helpful, but I found a few good sites. Like (shows me printouts from folder) I have sources on cloning and the human genome project. (S4A, Week 2, Formative Interview)

I found some good information on gene technology. It has to do with changing genes, so we'll be able to make new things like new beans and other better foods. (S5B, Week 2, Formative Interview)

S4A: I used the internet mainly. There are a few really good websites and I mainly used them.
F1: How did you decide that they were good websites?
S4A: Well, one of them was managed by the institute of health, the National Institute of Health, and the other one was from a university. (Week 5, Formative Interview)

S1D: Most of my information was from the internet.
F1: Why did you decide to use these sources of information
S1D: It was quick and easy, I found a link right away that had all the negative aspect of genetic engineering.
F1: How did you decide that this was a good website to use?
S1D: It had so many arguments and I had to write up the negative aspects for our paper. (Week 5, Formative Interviews)

Some of the students expressed more interest in the researching than in the content itself. This included students who were learning the extent of Internet resources as well as students who had never utilized libraries for research materials. E-mail also played a role, as many course participants shared web addresses and other resources. Students e-mailed TAs, TAs e-mailed faculty.

TAs and faculty did not indicate learning more about utilizing the library to obtain information, possibly as they did not use the library for the project. When asked how they would research a topic, the three TAs primarily mentioned science journals.

Well, I would start with the primary literature, the original research article. And, um, I would look for these subjects in journals like Science. (T4, Pre-Project Interview)

TAs altered teaching based on their research in the context of the genetic technologies project. Most of the TAs had a more elaborate scheme for preparing to teach and assessing student work. One of the TAs noted utilizing a wider range of secondary sources in other course work.
Both faculty mentioned researching the topic for human cloning further before formulating a decision.

I would probably draw on some of the knowledge I have run across this term in preparing the lecture covering adult mammal cloning. Particularly the aspects of limited benefits and the likelihood of a lot of failures along the way. Human cloning sounds a lot like the assumptions behind the eugenics movement, that some humans have better genes than others and those individuals should be the ones that reproduce. (F1, Post-Project Interview)

Similar to other decisions regarding scientific advancements, weighing the costs and benefits, examining who would control access, as well as the motivation of those putting the issue up for a vote. (F2, Post-Project Interview)

Both faculty also indicated that they were using information technologies more frequently that they had in the past. These uses were for researching topics, editing activities and exams (that had formally been word processed by office staff), and communicating with students.

I am probably spending more time researching with the Internet and using popular journals like Discover to find current news stories and hot topics. (F1, Post-Project Interview)

F2: Nope, same as usual, except turning over more things to you so you have the experience to manage the courses.
F1: How about using the computer?
F2: Yes, I have been using the computer more over the past year, although I have been having difficulty retrieving my files.

The researcher thought that there was minimal data on transfer of learning regarding learning to obtain information. Transfer did occur, in a variety of different ways. Students and TAs used e-mail more frequently near the end of the course. Representatives of all three subject groups reported using the Internet as a source of course information more frequently, students and TAs for other courses, and faculty for the BI 10X series and writings. Interestingly, subjects from all three groups also said that they spent more time reflecting on their teaching and/or learning outside of the studied course. This reflective practice was developed in part due to research participation.

Numerous examples and embedded controversy made transfer more likely related to project topics than other course material. Transfer of learning is perceiving,
thinking, and processing in a way that prior knowledge is adapted to a novel situation (Haskell, 2001). In other words, transfer refers to dealing with a situation that differs from that in which learning originally occurred. Subjects in the study acquired general and domain-specific knowledge (Perkins and Salomon, 1989) to different degrees. As students summarized research articles for the annotated references assignment, they developed basic reading skills to locate key points, but due to limited content knowledge, misinterpreted those points.

One of the major factors encouraging course participants to find a broader range of information was reading the annotated references. Students judged other students' debate research in their group, and searched for types of information that had not been covered in the references. As a result, much of the topic research occurred after the annotated references were turned in, or in some cases, returned by the TA.

Part of obtaining information involved developing Reading Skills that included summarizing articles. Students repeatedly commented on developing these skills to be able to read science articles due to their distinct differences from readings representing other disciplines. Although students reported changes in reading skills, it was difficult to access changes on reading skills from any of the data other than the formative interviews in this study. As a result, this was one of the few variables that could not be "triangulated" with multiple forms of data.

Communication Skills

In order to participate in the project, subjects wrote and spoke in a variety of contexts, including teaching, working with others, and in the debates themselves. Subjects discussed and demonstrated obtaining Writing and Oral Communication Skills, but the subcategories of communication skills varied by subject group. The project stressed different aspects of communication skills than other parts of the course. In the typical laboratories and recitations, students answered short answer questions through small-group discussions and TAs primarily assisted students in this process. During the project, students completed a variety of written assignments and contributed to the class debate. TAs spent increased time presenting information, such as suggestions for finding information, and learned to grade a variety of student assignments. Similarly, faculty increased emphasis on writing course materials and generating weekly materials to address project-related concerns.
Some of the students demonstrated acquiring basic Writing skills while completing the Written Assignments, which included the annotated reference, group summary, and notecards assignments. These included summarizing thoughts in their own words, developing paragraphs, writing text to match assignment requirements, using computer word processing programs, checking spelling and grammar, and citing resources. Some of the students mentioned having previously used the skills but not remembering them, and others stated that they had never learned aspects of technical writing or using computers. Two of the subject TAs worked with students to assist them with sentence and paragraph formation. Some students also helped one another while developing the group summaries.

Subjects representing all three subject groups discussed developing abilities related to writing Classroom Materials. Some students made overheads and posters for their debates, and discussed emulating lecture materials to capture class attention and interest.

As you can see (brings out poster with pictures and words), there are different processes covered by genetic engineering. This is a collage of uses. How can we deny these advantages to our kids? (S2, Debate)

In previous terms, TAs typically did not prepare overheads in advance to teaching. Instead they wrote on overheads during class. In the context of the project, TAs generated overheads and handouts prior to class, altering techniques to generate desired student outcomes. T1 began preparing an overhead for the third week’s class, due to concerns related to difficulty in maintaining student attention. Other T2 and T3 chose to use this overhead. By week, all five of the subject TAs were making their own overheads. These overheads were typed and prepared in advance, in contrast to overheads used the third and fourth weeks. The overheads reflected the TAs teaching objectives, as described in the formative interviews. For example, T1 was concerned that students would not follow directions, that they needed clear directions and structure to develop the group summary, and that plagiarism would occur in the summaries (Figure 4.6). Additionally, T1 wanted the directions to be written as he perceived “the students are coming late and not listening to me” (T1, Week 3, Formative Interview). T2 was particularly concerned that the students would have difficulties distinguishing between the two debate topics (Figure 4.7).
### Genetic Technologies Summary

#### Group Summary

The summary should be typed and double spaced. Although you may write more if you wish, you should have at least five paragraphs. These paragraphs should include: introduction and overview, pros and cons, and your conclusions. The citations for the paper should be cited in a reference form at the end of the summary. Do not use World Wide Web Sites only, and give credit to any resources that you use. In addition, do not cut and paste information web sites or any other resources into your document. The completed summary will be due at the beginning of your week five laboratory. If you have any questions about the assignment, then ask me!

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#### Figure 4.6: T1’s Group Summary Overhead.

<table>
<thead>
<tr>
<th>HGT – Human Gene Therapy</th>
<th>GEO – Genetically Engineered Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans - Δ genes - therapy</td>
<td>i.e. diseases – genetic</td>
</tr>
<tr>
<td></td>
<td>Everything but humans</td>
</tr>
</tbody>
</table>

Summary – Group

- Double spaced – typed
- 4 – 6 paragraphs
- intro
- pros
- cons
- concl.
- citations

next Tuesday

biblio

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#### Figure 4.7: T2’s Group Summary Overhead.

Faculty produced overheads and handouts to reflect student and TA concerns and suggestions. These materials were not prepared for the other parts of the course that had been established in previous terms, and altered as the project progressed. F1 and F2 prepared overheads of possible grading schemes for the various student project assignments (Figure 4.8). Additionally, faculty prepared an overhead on plagiarism for the TAs (Appendix J), as well as handouts summarizing weekly goals for TAs to try to reduce confusion and levels of TA concern related to the project (Appendices K and L).
Repeatedly subjects in all three groups discussed learning how to use E-mail in order to convey project information. This appeared to be a different challenge than other forms of writing, first due to learning how to use the technology and next to transmit ideas without misinterpretation. Subjects representing all three groups sent Internet links in e-mails for the first time, relaying websites with information about project topics. Additionally, many students sent attachments of text and noted that it was the first time they had completed a group project (the group summary) using e-mail.

Students and TAs indicated the need for more explicit directions and definitions that could be used as key words to initiate independent research. TAs did not mention student difficulties with writing without prompts, but when specifically asked, confirmed that many students turned in poorly written papers. Faculty discussed learning ways to write curricular materials, such as activities and project requirements to eliminate points of potential vagueness and confusion.

Subjects used a variety of representations of knowledge, including Abbreviations. Students drew on abbreviations to communicate with one another through e-mail and notes. Initially one or two students within a group used abbreviations, which were later adopted by group members. These abbreviations were used as a form of group membership, with students stressing abbreviations with other course participants as a manner of representing acquired knowledge. T2 formulated abbreviations (HGT for human gene therapy and GEO for genetically engineered organisms – Figure 4.7) to clarify topic distinctions for her students. Students in group S2 adopted use of these definitions on their notecards. In interviews students and TAs stated that science
communication differed from other forms of expressing information, and that abbreviations allowed different information to be conveyed.

Subjects also developed Oral communication skills, including Debating, Talking With Peers, and talking with Other Course Participants. Students and TAs discussed learning oral debating skills, including speaking clearly, repeating important points, and linking ways of representing information (such as visual and oral). Some of the students spent hours scripting what to say during the debate.

We are in an age where unbelievable advances in genetic engineering are taking place. Its hard to comprehend what is being researched but if we look at how genetic engineering is affecting our lives as humans, at the expense of microorganisms, plants, and animals, we will see how this new knowledge is able to promote our overall wellbeing. We decided as a group to focus on findings of new research being done on plants and animals to alter diseases, to increase a crop in nutritional value, to improve the taste of foods and how fruits and vegetables are being altered in shape, thus changing the way we package certain crops. (S1, Group Summary)

Subjects from all three groups developed skills related to Talking with Peers, the term peers applied to members of the same subject group. This category included general skills like TAs speaking loudly to gain multiple students’ attention, to skills specifically adapted to a particular person, such as a student speaking clearly at a slower pace for a group member with English as a second language. In these cases, cues for learning how to communicate often came directly from the peer though directing comments such as to wait a moment or speak slowly.

Students frequently reported the challenges they faced learning to work with others in the course, particularly their group members. Part of learning to work with others was related to developing communication skills such as knowing when to “...agree to disagree.” (S1A, Post-Project Interview).

Subjects also discussed learning how to communicate with course participants other than peers. Students noted that listening to their TA’s stories enabled them to ask their TAs more questions in the activities. F1 learned to speak clearly and emphatically in the preparatory session related to project requirements, as the TAs would often repeat the material in the same manner.

TAs originally focused on students’ communication skills (grammar, spelling, tone). F2 was not focused on learning new skills, but instead altering existing skills to work with new course participants and changes in the content, course, and institution.
F1 was developing new writing skills related to generating documents expressing curricular goals (Appendices K and L) and new oral communication skills related to lecturing and speaking with students and TAs.

**Teaching Skills**

*Teaching Skills* included aspects of Planning and Implementing teaching behaviors. Although different subject groups began with different tasks in the course (faculty directing, TAs interpreting, students learning), all three groups had teaching opportunities and exhibited learning a similar range of teaching skills. Various aspects of the new project, including the relatively undefined nature of the tasks, variety of assignments, and increased interactions between course participants led to increased need for developing teaching skills.

Related to Planning, subjects exhibited Learning Content in a way that it could be taught, Selecting Topics to teach, developing Scope and Sequence of ideas, and a variety of Instructional Strategies. Although all of these sub-categories tied closely to one another, subjects were learning within specific sub-categories, drawing on previous experiences and understandings of different sub-categories.

Learning about pedagogy included learning what to teach as well as how to teach. Subjects demonstrated Learning Content in a manner in which it could be taught, indicating formation of pedagogical content knowledge (Van Driel, Verloop, & de Vos, 1998).

I have learned a lot about gene therapy, who it affects and why we should concentrate on the rights of people, and the responsibility of our society on the whole. From our research, I have learned a lot about the genetically engineered foods and their benefits. Lecture helped me understand how the therapy is actually done. (S4A, Written Debate Response)

TAs were reluctant to discuss limited knowledge related to teaching as much as they were reluctant to discuss conceptual understandings. TAs did not know if project or related concepts discussed by students were accurate, but were reluctant to discuss their content knowledge. TAs demonstrated difficulty in learning that it is normal to not know everything and that it can be appropriate to learn from students. Most unresolved data conflicts revolved around TA conceptions.

Although all subjects were learning about aspects of teaching specific content, there were subtle differences related to what was being taught. Faculty were learning
how to teach specific content, TAs were focused on classroom management but beginning to teach related to content (checking references, grading). Students were initially focused on skill development, and later on presenting content. In the context of the project, the faculty were trying “new” teaching strategies with a “new” group of students. Many of the teaching skills developing in the subjects included those that could be utilized in subsequent learning, including learning to focus on particular aspect of a topic and transferring knowledge into a form that can be communicated to others. In other words, subjects were becoming life-long learners.

As previously discussed, subjects could have inadequate development of either general strategic knowledge or specialized domain knowledge. Another case of this incomplete transfer, related to F1 developing the genetic technologies activity, acquiring general knowledge of design but limited understandings of topics.

Subjects exhibited aspects of learning about Selecting Topics to teach and determining the Scope and Sequence of those topics, although not always at the same point. As students began preparing for the debates, they initially focused on selecting topics, and later shifted focus to ordering those topics in a manner that would support their arguments. Similarly, TAs initially discussed the importance of selecting specific topics to cover independent of one another early in the project. Later, TAs began generating suggested scenarios for sequencing project requirements and the depth at which those topics should be covered. TAs' planning focus was on reviewing the lab manual and making an outline rather than considering what content was important to teach. This may account for TAs not mentioning that they developed an understanding of differences in teaching particular content.

During and after the project faculty repeatedly discussed with one another which aspects of the project topics were important for students to learn and as well as challenging for all course participants. F2 also discussed sequencing topics in future terms, based on his previous knowledge and participant difficulties with the project’s structure. These considerations on sequencing related to what students brought to the classroom.

An aspect of genetics that students always struggle with is basic probabilities. Watch how they do the fruit fly problems, they have to complete the entire Punnett square and count up the offspring, but do not see the larger pattern. ...Some of these concepts have to be addressed up front, how are they going to understand the basics of genetic
technologies in they don’t know what a gene is? (F2, Post-Project Interview)

Part of learning about teaching was beginning to recognize the qualities inherent in effective studenting and teaching, using critical thinking skills to determine criteria. Subjects from all three groups discussed these Instructional Strategies extensively. A variety of teaching skills were acquired by subjects in all three groups, including: Orientating (setting the scene and explaining requirements), Motivating (sustaining interest and discussing relevance), Presenting (introducing new information within a clear structure), Clarifying (providing and explaining examples), and Confirming (verifying understandings). These categories often overlapped, as subjects orienting others to a task may have potentially added specific motivations for completion, or subjects presenting information needed to clarify understandings when others indicated confusion.

Subjects often exhibited developing multiple teaching strategies simultaneously. For example, in the fifth week of the course, the researcher noted multiple changes in TA teaching, including preparation, instruction, and assessment in the researcher journal.

There are definitely more typed overheads by the projector and more handouts by the copier. TAs are talking with another about how they are going to teach a week or more before class. The TAs are coming to me more with concerns about their teaching and students, and I wonder if that has something to do with the open-ended nature of these activities. During T1’s class this week he seemed to have difficulty with classroom management. The students were talking in their supergroups and did not appear to listen when he tried to talk to the whole class... Also, the TAs are going to be grading all of the group summaries and supergroup plans, that’s going to take more time than grading than some of the fill-in-the-blank activities... Some of the TAs seem to be checking the student’s references... This project does appear to require more TA prep and grading. Maybe the increased prep is due to difficulty in managing the students. (F1, Researcher Journal)

Subjects from all three groups discussed learning techniques related to Orienting other’s to a learning task. This included students preparing group members for a specific task. TAs designed overheads and introductory statements to prepare students for project tasks. In order to increase student interest and reinforce due dates, F1 developed lecture introductions. Both F1 and F2 mentioned that students learned skills that were not just related to biology content.
The students and TAs seemed more organized than last term (Salmon Project), everybody was listing what they intended to do and say. Also, many students had said that they had not previously researched a science topic at [university name]. (F1, Post-Project Interview)

Subjects repeatedly discussed realizing the importance of Motivation in their own learning, as well as the role of motivation in increasing the probability of other’s learning.

I think it was the group pressure that made people do it because they would have let the rest of us down. (S5A, Post-Project Interview)

You have to give people choices and sometimes you had to step in their face to get them to get things done. We got things done. (S5C, Post-Project Interview)

Some of the TAs discussed learning the extent of the relationship between student motivation and learning during the project.

I liked it. It was fun, they seemed to get something out of it, they enjoyed it. Although they didn’t enjoy actually preparing for it, but once it happened, they had fun. (T1, Post-Project Interview)

Well, I think this was by far the best thing we’ve done this year. They did a great job and I think they learned a lot. Of course, the Salmon Project was interesting too, but this seemed to have a different flavor, I think they were really excited by the whole thing. (T3, Post-Project Interview)

Faculty discussed concern that some of the TAs and students were becoming overwhelmed by project requirements. To stimulate interest, F1 and F2 discussed ways to add interest to the lectures. This included locating more visuals such as political cartoons addressing genetic technologies.

Subjects also demonstrated learning aspects of Presenting information to other course participants. The importance of clearly presenting course information was repeatedly mentioned by students, TAs, and faculty in the context of the confusion over the project topics, group dynamics, and assessment. Students discussed the importance of having written directions.

Even someone in my group had the debate question wrong, she said “we’re against gene therapy,” I think it wasn’t really written out, maybe because it was still being decided. (S5A, Post-Project Interview)

Students also mentioned specific aspects of the debate format that they thought were effective.
And I think it (structure of project) was good, I think it made people look at other sides of the debate, to look at more than what they already know. (S5E, Post-Project Interview)

It is good to have people like look up the definitions I really like that cause then you know exactly what it was and then. Maybe you could like have in one of the recitations, we could bring in definitions, yeah just so we could see if we had the right things and could talk about it...and like after everybody brings in their definitions, we could have the real definitions, and do a discussion, that would be kind of fun. (S2C, Post-Project Interview)

Well, at first when I heard that we were being assigned pro or con I thought that was pretty harsh, because what if you felt strongly one way an had to debate the opposite, but on the same side, it was good because you were forced to read something, I mean I really didn't feel one way or another. Later I thought it was good because you have to learn about it and its not just a one-sided thing. (S1A, Post-Project Interview)

Many of the students initiated discussion about the structure of the project and had specific ideas for how it could be altered. Related to the topic confusion, a few students discussed somehow altering the topics so both sides were debating over the same basic material.

Maybe something to synchronize the topics, like being more specific about what is being engineered. They (other supergroup) didn't necessarily respond, they just made their own points, so the debate wasn't as strong. (S5D, Post-Project Interview)

... or maybe just talking about, say just focus on the plants, are they really that beneficial, is genetic engineering really that beneficial? What would we do without it? I don't know if that would be a good topic, but... At least you would have a serious debate, no one really wanted congress to be involved, it just sounds bad. (S5B, Post-Project Interview)

Students also generated ideas for altering aspects of the debate itself.

There was a structure for the debate, but there was no real structure for the question/answer so we ran over. TA said a few times “nothing personal here.” Maybe we could have used a bit more structure at the end. (S2D, Post-Project Interview)

Many of the recommendations focused on improving group dynamics, which had been a major point of discussion earlier in the interviews.
If you are going to use groups, split them into two, yeah cause larger groups allow people to migrate away, but if you have two, it's a lot easier to get on your partner to get things done. (S4D, Post-Project Interview)

Maybe there should even like be something in the manual that tells people how to work in groups, maybe specific roles. A lot of times groups don’t know what to do, and it could say, like you do the last half or we’ll do it as partners. A lot of people don’t think of categorizing the tasks. (S4D, Post-Project Interview)

TAs also discussed encountering problems associated with student group dynamics, including students dividing up the work for the group summary and the debate.

I think some of the groups had a bit of trouble organizing and delegating work, especially once the larger groups were formed. (T3, Post-Project Interview)

T4 indicated that most students had contributed to the project, and that different students played different roles in the groups.

They didn’t really have an opportunity to fall back and not work within the group. In some groups there was a computer jock or somebody who would go to the library, there was plenty for everyone to do. There was one case where they were not really working together, but in the end they got the job done and everyone came up with resources. (T4, Post-Project Interview)

F1 and F2 differed in their views of whether the project impacted their own knowledge of teaching. F1 discussed how designing new activities and lectures related to the genetic technologies topic took a great deal of time for research.

Most of my teaching related to the project was leading the prep sessions and the genetic technologies lectures. Regarding the prep sessions, I don’t think I spent much more time preparing handouts or overheads. As always, I was really short on time, especially with balancing research along with meeting with students and preparing for lecture. I probably would have liked to have spent more time on prep, but the lectures were time-consuming. For the new genetic technologies lectures, I was learning about new topics (new to me) like animal cloning and new directions (artificial chromosomes, DNA banking, mutator genes). It was taking a lot of time to pick the “important topics,” those students may encounter in the future, synthesize and consolidate the concepts into four lectures, and find adequate visuals. (F1, Post-Project Interview)

F2 stated that his teaching had not been impacted by the new project.
F1: Any difference in interacting with the TAs?
F2: Not really. This was a good group.
F1: How important is the time you spend with students and TAs?
F2: Probably as important as anything, except possibly designing the curriculum. Most of our TAs go on to teach in some capacity, possibly in science education or in the life sciences. If you think about it, each of the TAs may teach thousands of students in their careers. Possibly the most important part of my teaching has been the time spent with TAs. (Post-Project Interview)

Subjects also demonstrated acquiring skills related to *Clarifying* material. Clarifying included repeating directions, providing additional examples, and mimicking desired task.

I think the, my personal preference would be to have a little more guidance on specifically what to address like there was in our group anyway, such a wealth of information and it seemed almost overwhelming. I would say, if it was an assignment to say, what exactly is the process of gene therapy and how does it work, making that something that they have to get, something around those lines. (S3A, Post-Project Interview)

It seemed like a lot of it was fairly general information, not very specific. So you get a good general feel for what it is about, but not necessarily real specifics. It probably had something to do with how we all found our information. (S3A, Post-Project Interview)

One of the TAs discussed the outcomes of encouraging student questioning as a technique to clarify student understandings.

I had a lot of student questions over the term, I really pushed questions, always like asking them. It was really nice that it was their responsibility to find the information. In some of the laboratories they were bored because it was all laid out there for them. (T5, Post-Project Interview)

Other TAs focused on generating overheads to clarify project requirements. In formative interviews, T4 was concerned about the potential quality of the individual preparation notes (Figure 4.9), and T5 expressed concern about students knowing what to do within their supergroups (Figure 4.10).

Similarly, student supergroups generated written lists of the strategies they would follow, to confirm roles and responsibilities (Figure 4.11).
Several students mentioned clarifying the distinction between the debate topics of gene therapy and genetic engineering.

We got confused with gene therapy, what it was and what it was not. (S3D, Post-Project Interview)

TAs discussed learning that letting students work on their own could have positive learning outcomes.
Strategy:
- Cures for genetic diseases
- Bolstering immune system
- Fixing defective genes
- Cosmetic reasons
- Identification
- Eliminating acquired diseases
- Cancer and AIDS

Questions we need to answer:
- Is it moral? Ethical?
- What is the success rate?
- Cosmetic use a good thing?
- How about cloning?
- Is this eugenics?
- Privacy?
- Possible psychological effects?

(Supergroup containing S4)

Main Arguments
- Bad for health and farm's finances
- Testing is still new and therefore we don't know long-term effect.
- Nature will find a way around our technologies.
- There will be a lack of control without regulations.
- We need to focus more on our distribution methods, than coming up with new foods.
- Possible allergic responses.
- Environmental problems, super plants.

Questions for other groups
- Who will have the economic control of these new technologies?
- Isn't science going too far?
- Why not work on reducing human population instead?
- What if gen. Engineered plants kill off natural plants?

(Supergroup containing S2)

Figure 4.11: Supergroup Debate Preparation Notes.

I guess it was really the first time I let students go and do a lot on their own. I think before that I felt much more like I had to coddle them and help them through every step or they couldn't do it, which is sort of a TA ego booster, because you think all of these students rely on me, but it was good because I realized that that wasn't the situation at all that you could give them an assignment and some of them will do great jobs and some of them will do O.K. and some of them will forget all together, but they can become experts without having too much direction at all. And I think that was a good teaching thing to let students go like parents have to do. (T5, Post-Project Interview)
T4 discussed his efforts to assist students in their learning through questioning and methods of organization.

They had to define everything and tell me how they were going to do that (first day). Later on when I had them come back again, then I had them exchange ideas. I didn’t want everybody kind of talking about different things, with the other group not knowing what was going on. I tried to bring them together, to engage them and say, this group made a list of the points they would like to talk about, what are your points? I kind of liked it that way because they were more prepared to debate. (T4, Post-Project Interview)

Typically lectures were planned well in advance of presentation, with minor changes reflecting breaking news stories or lecture concerns. Problems associated with the overlap of the project definitions, as well as conversations between F1 and other participants led to changes in the lectures. These changes were primarily intended to clarify concepts, and as discussed, increase student interest in the subject. Changes necessitated reprioritizing concepts.

Subjects also developed skills related to Confirming other’s learning, including informal comments, formal assessment, and evaluation.

One thing I found was that like for every learning style, there seems to be like a way to adapt to that persons learning style. (S2B, Post-Project Interview)

One student mentioned the need for some type of closure to the debate project.

There was basically the rule, like don’t be defensive. I think people took things too personally, afterwards there need to time for people to shake hands, but there wasn’t, we just ran out, I just said that was a really great debate and ran out. You know I don’t want to see someone on campus, and think, well there’s that bitch, you know... (S5A, Post-Project Interview)

A few of the students also mentioned assessment as an important consideration in the project's structure.

It was OK, I don’t really have any improvements. ... Maybe do something about the grading, I don’t think so many of the points should be given for just talking. Some people didn’t get to say anything anyway because others did all of the talking. (S1C, Post-Project Interview)

Just because I like to have all of the corners covered, I think I am more of an extreme case. I spent a lot of time, I’d hate to tell you so many hours, or something like that. I spent a lot of time for the five points we got. We
were like, only five points! Just for all of the work we did it should be worth more than showing up to a lab, you know, because basically, if you just sat there and said anything, you got five points, and some people really had a lot and others hadn’t done anything short of that day. You know that’s OK, but it seemed anticlimactic to this big project that you were supposed to work on for so long. (SSD, Post-Project Interview)

All of the TAs also discussed how they had to interpret assessment differently within the context of the project.

With five points for one thing and five points for another, its kind of hard to figure out where the points should go. Like what to do about people who miss the actual debate students missed, giving partial credit to students who miss. (T1, Post-Project Interview)

Apparently conflicting views of confirming knowledge arose repeatedly in subject comments about teaching. For example, TAs cited value of learning from a scientist in the same interview they stated that many scientists were not good teachers. They did not acknowledge that this was a potential conflict of beliefs that they were preparing to tackle.

Students and TAs focused on specific recommendations for improving aspects of presenting information in the projects. Students and TAs who were interested in teaching talked extensively with F1, and occasionally F2, about aspects of teaching within the course. S2C, who expressed interest in teaching at the middle school level, repeatedly came up with ideas for improving aspects of teaching within the course.

Another thing, maybe if the groups worked more closely together, like in my group I know we had like, you do the introduction, you do the conclusion, and like you do three do the body of the paper. (S2C, Week 6, Formative Interview)

Maybe if we had a recitation before the lab presentation, for like a practice run-through or something, cause like when you get your notecards done, and figure out what you’re going to do, you can leave, I think everybody should stay to the end of lab and discuss it, and like maybe in the recitation when you’re going to practice, have a group piece of paper with your main topic and main points for each section, like for the introduction, have five words that focuses that, you know the main questions, and I think like the groups should be able to evaluate the other group members like on a scale of one to ten, like this group member contributed a lot, or not so much. I don’t think it’s a bad thing, as long as other people don’t see it. (S2C, Post-Project Interview)
Some of these student and TA recommendations were thought out to such a degree of detail that they were easily incorporated into subsequent projects.

**Affective Domain**

Categories of learning that were classified as *Affective Domain* indicated that subjects were developing a context in which learning occurred, including *Attitudes*, *Beliefs in Abilities*, and *Values*. Classifying variables within the affective category was challenging as it was difficult to capture with means of data collection other than interviews. However, changes in behaviors, such as F1 giving TAs more autonomy and T2 adopting other TA’s teaching strategies, reflected changes in personal views of the course and other participants.

Various aspects of the curricular innovation impacted subject attitudes, beliefs, and values. The debate format revolved around the idea of controversy, and assigning students to particular arguments irrespective of personal beliefs, encouraged exploration of personal beliefs and values. The writing assignments associated with the project opened avenues for aspects of critiquing information, as well as problems of plagiarism. As will be discussed, the project also increased interdependence of course participants in comparison to other course activities. As a result, subjects had more opportunities to form opinions of other individuals.

**Attitudes**

Subjects demonstrated developing attitudes toward variety of aspects of the course, including other *Course Participants*, the *Project/Course*, and *Biology/Science*. Multiple headings such as *Project/Course* indicate that attitudes developed toward the course appeared to be tightly linked to attitudes toward the project. Subject attitudes toward other participants and the project/course were represented by strong language.

*I completely disagree with you!* (S4D, Debate)

*I really, really, learned a lot from the debate.* (S5B, Written Debate Response)

This language appeared to reflect the extent of subject feelings at a given time.

Subjects in all three groups indicated that they had altered some of their attitudes toward other *Course Participants*. These attitudes were both positive and negative. Students provided detailed analyses of their group members and debate
partners/opponents. Generally attitudes toward group members and others who worked on the projects were positive by the post-project interviews, with several students expressing surprise over the high quality of work produced by other students. Conversely, students reported developing negative attitudes toward other students who, in their mind, did not put adequate effort into the project. TAs and faculty indicated developing a positive attitude toward individual students based on working with them during the project. TAs also mentioned their feelings toward particular students. T3 developed close relationships with some of the students and repeatedly discussed concerns about how her students felt about the project, and made attempts to support her students.

My heart went out to them, they were so nervous about having to present. I still feel that way when I have to present so I know what they were going through. One of my girls in particular was very nervous to begin with. (T3, Post-Project Interview)

Subjects discussed developing attitudes Toward the Project and Course. The closeness of their responses did not make it possible to tease this sub-category apart into two separate categories. In general subjects stated changing attitudes from ambivalence or a negative impression, to liking the project and the course in general. These positive responses did not appear to be linked to project or course grade, as some of the students did not do well on the overall assessment. Instead positive attitudes toward the project and course appeared to be linked to the subject’s own beliefs that they did a good job on the debates and were learning something in the process. Some of the student and both of the faculty subjects noted that they were developing negative attitudes toward other activities in the course that were more “paper-pencil” and less “engaging.” TAs noted developing negative attitudes toward activities that were not well-organized or generated a lot of repeated student questions (as it was difficult for TAs to answer a large number of questions from 40 students in each class). A few of the students cited aspects of the debate format that they did not like, primarily citing the tone and organization of the debate.

The debates didn’t accomplish much. The boundaries didn’t seem well enough established. It was not possible for everyone to have a job. When the people running the debate asked if anyone had something to say, nobody had any comments. The reason being everything had been covered. And what are we supposed to say? Some random comment? Another reason the debate didn’t make sense is you are assigned
something to debate. If you're going to have a debate you should decide which side you want. How can you debate a side that you don't believe in? you can't. (S3C, Written Debate Response)

Students also discussed changing Attitudes Toward Biology, and as a result, Science in general. Repeatedly, students commented to the researcher or their group members that they were surprised to find themselves interested in biology, particularly genetics. Some of the students equated their change of attitude to liking science in general, stating that even though they had “never been good at science” (S2B).

There was generally at least one area of the course that they liked. S1A discussed liking the material and help from group members as factors impacting class performance, but not background experience.

I like it so it makes it easier to do well. This one guy I work with in the class doesn't like biology, so he's doing horrible. Its not that bad, you get to work with your group, you're never by yourself and everybody wants to come over and help you right away. (S1A, Post-Project Interview)

Representatives of all three subject groups mentioned developing a greater awareness of the significance of biology, and the ideas of significance held by other course participants. In several subjects this was coupled with developing positive or negative attitudes toward the discipline and classmates.

There are many pros and cons to an issue and it is very hard and very important for humans to determine which outweighs the other. Before I researched genetically engineered foods, I thought they were great. Now, I still think they can be helpful but there are many potential problems that need to be addressed. New technology needs to be used with moderation. (S2E, Written Debate Response)

A few of the students discussed developing either positive views of scientists (because of what they accomplished) or negative views (also because of what science accomplishes). Two of the students spoke in a manner that appeared to represent changing attitudes toward educated people in general. This was difficult to tease out as they themselves would be classified to an extent in this group, but their comments suggested that the project challenged their attitude that educated individuals were in some way evil or greedy by nature.

As students learned more about their own abilities and course concepts, they frequently found ways to demonstrate what they learned, almost “showing off.” Similarly,
TAs and faculty commonly shared new ideas and thoughts with one another. There was an apparent change in attitude due to enthusiasm and interest related to learning.

Subjects from the different study groups had different focuses relative to their views of teaching, similar to the ideas of egocentrism (teacher-centeredness), allocentrism (learner-centeredness), and systemocentrism (teacher/learner-centeredness) (Robertson (1999). Students spent a great deal of time discussing other students, TAs primarily focused on discussing their own actions, and faculty discussed students and TAs. This indicated that there may have been a wide lens of subject views of teacher's work, with students primarily allocentric (although arguably also a dash egocentric as they are students themselves and often spoke allegorically), TAs primarily egocentric, and faculty primarily systemocentric. This wide range of views may have explained in part how subjects could view similar teaching events and come up with such disparate interpretations. The range of teaching views may have also supported the process of developing subsequent curricular changes due to the range of proffered suggestions from subjects.

I think the progress is inevitable because that's what we do, I mean we just keep going, but we don't know what were doing and that's what's scary because, this is kind of a negative view, sometimes I think we'll just keep going and going and going and something is just going to stop everything. There are too many things we don't know about, I mean progress is good too, but something will happen. (S1A, Post-Project Interview)

Belief in Abilities

Subjects discussed changes in beliefs about their Own Abilities and the Abilities of Others. Research participation, numerous conversations among course participants, and the degree of work associated with the project impacted the degree of reflection on these beliefs.

Representatives of all three groups identified limitations in their own abilities. In the short term, identification of those characteristics appeared to negatively impact subject learning, with students discouraged from using the Internet, or TAs reluctant to read student papers due to perceived grading inadequacies. However, by the post-project interviews, subjects still recounted identified limitations, but appeared to have developed more positive beliefs in their overall abilities. These changes in self-efficacy could have been a critical component of observed changes in self-management skills.
Subjects' beliefs in their Own Abilities were classified as either Intellectual or Behavioral. Intellectual beliefs included what subjects felt they could understand, behavioral beliefs included what they felt they could do. Students repeatedly discussed developing beliefs about their own intellectual abilities. During the project, individual students repeatedly stated that they believed they could not accomplish particular tasks (find adequate information, present information in public, work with other students, etc.). However, these problems were sometimes resolved, and by the post-project interviews most students had adopted the idea that they could master aspects of genetics and biology in general. Students recounted their various “victories” mastering material and tasks that they thought would be impossible or extremely difficult.

The genetics was so hard but its interesting and I did so good on the tests, I only got three wrong, and I didn’t know anything about it coming in, I think that its good for me. (S1A, Post-Project Interview)

Subjects in all three groups suggested that they believed that could do more things because of project participation. Students primarily discussed learning to locate information, read research reports, write about scientific information, judge valid arguments, present information orally, work with other students, organize a debate, and manage large quantities of course work. TAs discussed learning how to prepare to teach, assist students with group dynamic problems, grade assignments, organize a debate, and judging validity of student arguments. Faculty discussed learning how to design a long-term project, organize a debate, judge issues that are good debate topics, prepare TAs for teaching, and dealing with curricular problems.

TAs and faculty discussed that the realized more about limitations in their own knowledge. When asked in follow-up question whether there were aspects of the project topics or teaching that they had not fully learned, all TAs responded affirmatively. “Oh, there’s always something more to learn about.” (T3, Post-Project Interview). Similarly Fl developed understandings of her own content limitations by watching what the students were learning.

They went well beyond my own research in many areas and I learned a lot just by sitting in on the debates. Related to content, many of the topics I lectured on were topics I did not know about before the term began. For instance, I did not know about the progress of gene therapy for genetic disorders or the progress made related to locating genes related to behaviors. Also, I learned from watching the debates which foods were being engineered and the different misconceptions or alternative
conceptions students have about genetics. There were a lot of teaching issues to deal with, including differences in preparing the TAs to teach with new overheads and handouts, and addressing TA questions throughout the term. (F1, Post-Project Interview)

Beliefs in Other's Abilities included Intellectual, Behavioral, and Interpersonal/Developmental beliefs. Intellectual and behavioral categories were similar to the categories developed for subject's beliefs in their own abilities. Interpersonal/developmental beliefs included beliefs in the other's attitudes and interactions.

Students, TAs, and faculty discussed changes in their beliefs in own intellectual abilities and the abilities of classmates. Initially, subjects commonly underestimated the abilities of other course participants. By the post-project interviews, many students expressed that they believed their fellow students had different intellectual abilities than they had anticipated. Several of the students expressed surprise about the conclusions other students had drawn related to the debate topics

I think the thing that shocked me the most, was you know the human genome therapy, one girl brought up that you shouldn't work on the human genome to cure diseases because we are already overpopulated. Do you know how the other side refuted it though? (S5D, Post-Project Interview)

TAs who had taught in the previous term's BI 101 course were initially concerned that students might not be able to complete the project successfully.

That sounds great! I'm looking forward to learning about these things myself. I'm not sure how the students will like it, it was hard to get them motivated for the salmon poster. They just didn't get into it. (T2, Pre-Project Interview)

There may be issues with group dynamics. A few students didn't contribute to the poster, and these group projects seem to let some of the students slip by without contributing. (T4, Pre-Project Interview)

As will be discussed, TAs introduced the project in the context of their beliefs of student's abilities to comprehend genetic technologies. Beliefs impacted how subjects interacted with one another, and changing beliefs led to changes in these interactions (such as seeking more assistance, sharing more information, and participating in decision-making).
After reading the annotated references, TAs and F1 expressed concern that the students would not be able to handle the preparation for the debate because they were still struggling with basic genetics concepts.

How are they (the students) going to debate the details of genetic engineering in two weeks if they still don’t know what a gene or an allele is? Maybe we need to cover some of these topics in better detail before the students run across the terms in the literature. I think I’m going to cover more about the technologies in my lectures week after next so there will be some basic concepts related to the project that we can test for on midterm #2. (Researcher Journal)

After beginning to grade the group summaries later in the week, TAs expressed surprise over the high quality of some of the group summaries.

The papers are generally well-written. Sometimes there is bit of repetition because they (the students) didn’t work together putting the paper together, but there are some really good points. (T4, Week 5, Formative Interview)

They included a lot of things I had never heard of before, and were pretty interesting to read. One group has really spent a lot of time researching the details of genetically engineered plants. I’m looking forward to seeing what they do in the debate. (T5, Week 5, Formative Interview)

At the end of the project, subjects in all three groups discussed believing that students were capable of intricate and exemplary intellectual work that exceeded their own expectations.

I think my biggest change in knowledge has been my awareness of what students are able to research and learn about on their own. (F1, Researcher Journal)

Students also discussed developing a positive attitude toward the lecturing abilities of faculty, but altering beliefs to consider that TAs were not necessarily essential to their own learning. This did not mean that students were stating that they believed TAs had inadequate skills, but reflected the students’ changing beliefs that they could handle biology content on their own. Although TAs believed students were capable of high-quality work, they expressed developing negative beliefs in students’ abilities to self-regulate and interact with other students. Faculty were developing beliefs that they and TAs had inadequate content knowledge to direct students to appropriate keywords without further Internet or library research.
Students and faculty also discussed altering beliefs in the behaviors of others. Similarly to intellectual skills, both groups had more limited beliefs in the skills of students prior to the project than at the conclusion. Students also indicated that they were surprised by the reactions and behaviors of other students.

This one guy just went off about this team of researchers, and I thought YES (subject’s emphasis), he’s on my side, it was really interesting, he just talked about studies and it was funny that the other team asked him a lot of questions because he made so many points. I remember, our TA asked, if this was on the ballot for next year’s whatever, how many would vote... it was interesting to see that people had learned that it was more complex than that. (S1A, Post-Project Interview)

(S5C) had really good dissemination skills for a freshman, really we all had something to contribute. (S5A, Post-Project Interview)

Although earlier comments in the formative interviews suggested that students were focused on group conflicts, student subjects frequently praised fellow group members in the post-project interviews.

One of the guys was really quiet and passive, but he was really good at the research. So we saw if anyone had a preference in doing this. They needed reminders, but most of them really were good, they just needed some guidance. (S5A, Post-Project Interview)

Students also discussed that they had learned what their classmates thought about genetic technologies.

I have learned that no matter what happens in society, or even the classroom, views from different people are going to differ. Both sides seem to agree on some common points, but there will always be some kind of disagreement in the world as long as people have the free will of thought and organization. (S1E, Written Debate Response)

I think the debate was pretty fun. It was really interesting to see how other people feel about this issue. (S2B, Written Debate Response)

That was amazing! Everybody, well almost everybody was really prepared. They had things I never heard of before, I was pretty impressed with how well they did. (T2, Week 6, Formative Interview)

They did a great job. They were quiet, interested, and everybody contributed. I haven’t looked at their notes yet, but they appeared to be writing quite a bit down. I didn’t expect it to go this well, but it went off without a hitch. (T1, Week 6, Formative Interview)
I was really impressed with how well the debates went when we actually got students out there and I wasn't expecting that also. I guess part of what I learned was that these things can work, even with glitches. (T1, Post-Project Interview)

Students commented about other groups that appeared to not be prepared for the debates.

I thought the discussion would have been better um, if the other group had done research, and we thought it was frustrating to try and talk to them, and they turned out very argumentative towards us, probably didn't have anything to say. (S2C, Post-Project Interview)

TAs did not discuss beliefs about student behaviors without researcher prompts, instead focusing primarily on intellectual abilities. Faculty also expressed changes in beliefs about TA behaviors, noting that there was a larger variation of impact of individual TAs on student learning than was previously considered.

Representatives of all three subject groups discussed changes in their beliefs of the interpersonal skills of other course participants. This included changing beliefs in other's attitudes, beliefs, and values.

I think that all of us, the entire table, enjoyed it [the project] and learned a lot. (S2D, Post-Project Interview)

Subjects demonstrated a range of beliefs in their own abilities to learn. For example, some students considered whether intellectual skills were genetically predetermined in others, but were convinced in their own ability to change over time. Similarly some of the TAs discussed the need for students to learn discrete information, but also discussed how science related to other disciplines.

All of the twenty-four interviewed students replied that they had learned a lot from the project and many without further solicitation, went on to provide multiple examples of what they had learned, with emphasis on cognitive aspects.

I have learned a lot – that third world countries have a lot to do with this. I also did not know that all of the foods were being injected w/ vaccinations. I learned a lot more about what kind of genetic technologies are out there. I also became more aware of different perspectives out there and different sides of the issue. I learned that are two different kinds of gene therapy somatic and germ line. Both are very different from one another. I agree with the con group that there should be regulation and there shouldn't be cosmetic gene therapy. Overall, I feel I learned a lot from this project and feel that I am more aware of what is out there. (S4B)
Subjects believed that they had mastered at least some of the content or learning strategies inherent in the project.

Values

Changes in values included Personal Values, distinguishing between Science vs. Other ways of placing value on phenomena and delineating aspects of Scholarly Ethics. These changes were subject group specific. The project challenged subjects to consider their values related to the debate topics and project activities.

Representatives of all three subject groups discussed changing or strengthening Personal Values related to aspects of implementing gene therapy and/or genetic engineering of other organisms. There was not a great deal of discussion about ethical or theological issues associated with genetic technologies in the beginning of the debates, but the topic did emerge in the later questioning.

Audience Member: What would you tell a third world country who needed food?
S5D: There is no concrete evidence that this will solve world hunger, or what the long term effects will be.
Audience Member: So how long would you like this banned?
S5D: Long enough for society to decide it wants the new foods, when asked, 97% say they don’t want them.
Audience Member: Yeah, but people are not informed and don’t know the possibilities, so that’s what they’ll say.
S5D: disagree with that. People know if something bothers them, and manipulating genes bothers a lot of people, me included. (Debate)

Students discussed their individual values related to genetic technologies.

Are we playing God? Are we creating our own destruction because we’re messing with things we don’t understand? (S1E, Debate)

We should not treat humans as experimental animals. We were not put here to be guinea pigs in someone else’s experiment. (S4E, Debate)

Students also discussed their perspectives on why genetic technologies were controversial in an ethical or social sense.

I have found that the to biggest reasons to debate are the theory of “slippery-slope” and the act of messing with nature. (S3B, Week 5, Formative Interview)

I have learned that people could die from experiments on human gene therapy. This makes it a hot topic even if the questions about its use are still unanswered. One question is whether even the study of gene
therapy is moral if people are going to die in the process of learning. (S4C, Week 5, Formative Interview)

A few students stated that even though they had learned new material about genetic technologies, their basic views about the use of the technologies were unchanged.

I don't think any of my thinking has changed, really, everybody has different opinions and I'm not sure you can decide whether these things are right or wrong unless you face the situation yourself...but some of these things, like altering the human genome and the project just seem wrong. I learned about some of the things that are going on, like altering our food, and germ warfare. (S1C, Post-Project Interview)

Subjects were asked to consider how they would approach making a personal decision about a topic not addressed in the debates.

If you were asked to vote on whether human cloning should be permitted, how would you make your decision? (F1, Post-Project Interview)

Many students responded to this question with a combination of concerns about the science behind human cloning and ethical considerations that they had developed related to the project topics.

The ability to bypass certain genetic diseases by altering genes and then cloning. Maybe this way some diseases or viruses can be eliminated. Where will it end? What will be considered immoral? Total chaos can be produced by continual cloning; somehow diseases can be produced or inbred through this. What will happen if new diseases occur? (S2A, Post-Project Interview)

Cloning is unethical because we are acting like God. Dow we really have the right to tamper with creation, it's a moral question. Humans would have no control, and would start to clone without limits, this could lead to problems. There would be no diversity, everyone would be the same. I guess a pro is that it is a way of getting rid of disease, but this could lead to a society much like Hitler wanted, unless you were a clone or a super human, you were killed. There would be far-reaching problems that we would not discover until generations have gone by. (S4E, Post-Project Interview)

Students and TAs discussed comparing value systems associated with Science vs. Other ways of knowing about the world. Subjects, including the graduate students, noted that they had not extensively considered how value systems could vary and impact science issues.
Most TAs stated that they would try to learn more about the topic and that they would also be influenced to a degree by non-science based beliefs.

T3: I think I would go about it in much the same way as the students did in this project, I would try to weigh the costs and benefits, to society, and I would gather more information about the technology. It sounded like from lecture that human cloning is a possibility right around the corner, and I would want to learn more about the technique.

F1: What would be the biggest factor impacting your decision?
T3: I would have to consider impacts on society, there are definitely moral issues associated with cloning, or any of the genetic issues.

(Post-Project Interviews)

One TA stated that a decision would likely depend on personal reactions.

Well, I know I should probably research the topic, but I think it's a lot more likely I would go with my gut instinct. (T2, Post-Project Interview)

Individuals from all three subject groups discussed reflecting upon and changing or strengthening values to the Scholarly Ethics of related to Plagiarism and Group Work. This included developing and strengthening personal values associated with student behaviors and generated a great deal of heated discussion.

A course discussion on plagiarism was initiated when T1 noticed that a student paper contained sentences that appeared to be copied directly from an uncited source. By entering the complete sentence into an Internet search engine, T1 was able to locate the original source of information. T1 stopped by F1's office and they discussed ways to deal with plagiarism and university policy. F1 had not previously dealt extensively with plagiarism, but realized that the project, one in which students were required to research a great deal on their own, can lead to direct copying of information. As will be discussed near the end of the chapter, all subject participants discussed their views of plagiarism by the post-project interviews.

Students and TAs were developing values relative to Group Work. Although some of the students and all of the TAs gave detailed descriptions of the pitfalls of group work, subjects generally indicated learning the value of students listening and learning from one another, in both a course specific and more general social sense.

A major component of the project was a discussion of the ethical issues raised by new genetic technologies. Most subjects noted that this was the most interesting and engaging aspect of the debate topics. As many course participants had not actively
engaged in group or classroom discussions of controversial topics, value conflicts occurred. These conflicts disturbed students and challenged them to reevaluate their own beliefs.

Although prior to the project some of the students (and one of the TAs) expressed that they would not likely utilize genetics in their jobs, discussion of the value of the project in the post-project interviews focused on whether subjects thought they had learned something. This "something" did not have to be perceived as job-related in order for students and TAs to value the project.

There are many sources of values, including society, the organizational context of a group (such as the university), a teacher, group members, the process of interaction (Cooper, 1979). Values can emerge from group interaction as the consequences of other's actions can be observed, and feedback can be provided to one's own actions.

In addition to discussing the values of genetic technologies, some of the student subjects developed ideas of the value of a course community, particularly the value of support from group members.

It was great to have someone to bounce ideas off of. ...yea, we were all in this together. (S1E, Post-Project Interview)

As the term progressed, course participants spent more time with one another in the classroom and learning center spaces.

**Characteristics of Subject Learning**

The reviewed research and pilot study suggested that student, TA, and faculty learning would occur. However, each classroom group was treated as a distinct entity, learning different aspects of content and teaching, as well as experiencing changes in beliefs. The pilot study, although primarily designed to test methodologies, suggested that students were learning course concepts, TAs were learning teaching strategies, and faculty were learning to develop curricular materials. Unexpected was the intricacy of learning outcomes that emerged in this study and the extensive similarities between subject groups. Following is a discussion of the characteristics of learning observed, including aspects of identifying subject learning and representing learning along multiple continua.
Identifying Subject Learning

Key to this study was an ability to identify learning through subject actions and outcomes. Early subject learning behaviors that appeared to represent learning, or a change in the subjects' knowledge, ideas, or behaviors was often an example of copying or parroting sources of information. For example, although some of the annotated references appeared to demonstrate complex understandings of genetic technologies by week three, students often did not understand words or concepts when asked during formative interviews. Similarly, although some of the TAs altered their teaching on the recommendations of faculty in the prep sessions, but were unable to state why the changes were recommended. This changed as the project progressed, such as students being able to orally report on what they had learned and TAs describing the reasons for why they were teaching in specific ways. Formative interviews were key in determining whether written reports “ glamorized” with grammar-check and spell-check were actual representations of changes in subject knowledge.

The categories of learning reflected subject strategy use, with each category of learning interdependent on another. Cognitive Outcomes consisted of declarative knowledge (knowledge of the content the strategy is for), Learning Strategies consisted of procedural knowledge (knowing how to do something), and Affective Outcomes reflected subject metacognition (knowing if the strategy is effective). Some forms of subject knowledge necessary for strategy use were developed prior to project participation, others developed as the course progressed.

Subjects altered knowledge when confronted with new situations, contexts, and alternative ways of knowing. Subjects also demonstrated changes in knowledge as the project progressed, moving through different stages and developing differing degrees of understanding, or literacy.

Variation in categories of learning appeared as great within subject groups as between subject groups. For examples students in the same group could have completely different examples of research related to their topics, but students frequently researched the same information as faculty or TAs. For example, F1, S2E, and S4E all read and discussed the same point from a website on genetically engineered foods.

Differences appeared at the nested category level. For instance, although F2 and S4A were learning to locate reliable sources of information on the Internet, F2 was specifically learning to find sources with descriptions of current advances in genetic
technologies that could be used in lecture and S4A was looking for sources with a broader description of how the genetic technologies worked.

Students tended to strongly associate course concepts, such as allele frequency and dominance/recessiveness, specifically with other course concepts such as natural selection and pedigrees. However, students associated project topics with other course topics as well as other courses, work experiences, and cultural backgrounds. Subjects also often appeared to be learning, but did not appear to be aware of that learning, a type of latent learning.

In addition to speaking with subjects, the researcher sought evidence of learning in subject writings. For example, as students became more familiar with the project topics, many spelled more of the technical words correctly, used genetic technology terms in context, and abbreviated commonly used terms like genetic engineering (GE) and gene therapy (GT).

However, written assignments did not necessarily indicate that subjects understood the concepts words represented. For example, S4E wrote provided a detailed description of the techniques used to produce transgenic animals.

A transgenic animal has grown from a zygote injected with foreign genes. Typically, foreign DNA is microinjected into the nucleus of the embryo before the first cell division. The specific gene is incorporated into the zygotes genome and is replicated during cell division. The most important feature related to transgenic animals is that the foreign trait must be able to be passed on to the offspring. (S4E, Student Debate Notecard)

When later asked to define “zygote” or “embryo,” this student could not distinguish between the two, and did not understand that a transgenic organism contained genetic material from a different species.

Often the questions subjects asked were a source of data on thought processes and changes in knowledge. For example, some questions suggested how students were thinking about particular aspects of the project topics.

Does genetically engineered food taste any different? (S4B, Written Debate Question)

A few of the student's written questions suggested that students did not have as elaborate an understanding of the project topics, which was confirmed in later formative interviews.
How far will scientists change genes? (S1D, Written Debate Question)

During the post-project interviews the researcher went through some of the preliminary research conclusions with the subjects to get their feedback. These questions and the TAs answers were specific to each subject, and diverse in nature, so a small subset of this data is provided here. In general, the TAs confirmed the researcher's categories of learning.

F1: (showing TA an early version of the list of categories of learning) Which of these categories, if any, includes things you learned about during the project?

T3: (studies list) O.K., so do I pick the top three?

F1: Sure.

T3: OK, definitely I learned quite a bit about genetic engineering and gene therapy, so definitely that one. (pause) And maybe how to help students to prepare for the debate, that one (points to debate skills), and uh (pause), well actually quite a few of these, but if I have to pick a third, I would say (points to beliefs/motivation/enthusiasm) something to do with how to help students enjoy class. (Post-Project Interview)

Subject learning focus changed over the course of the project, with the widest diversity of learning variables observed around the week 6 debate. Different subjects were concentrated on different aspects of knowledge, learning strategies, and affective change during the week of the debate (Table 4.5).

Learning phases were observed and varied subject by subject. These phases included preparing to learn, acquiring knowledge, relating to previous knowledge, transforming knowledge through conceptual framework for interpretation, and developing a personal understanding.
To add to the complexity of the accumulating data, subjects appeared to be learning different things in different ways as the project progressed. For example, students S5C and S5D were in the same group, but appeared to be learning quite differently. Basic categories of learning and their timing for S5C are in Table 4.6, and those for S5D are in Table 4.7. An important caveat is that these categories are not assumed to be inclusive or representational, but are instead those categories directly observed by the researcher from the data collected.

Although both subjects S5C and S5D did interact and develop common ideas related to locating references and the use of animals in genetic research, most of their learning differed. This is despite taking the same course, with the same lectures and labs, the same TA, and the same project topic. As will be discussed more in the section related to the factors impacting learning, most similarities in learning occurred when subject’s were “forced” to work together toward a single, specific outcome such as students writing a group summary, TAs setting up the debate room, or faculty choosing an exam question. The differences in categories of learning and timing of that learning,
Table 4.6: Timeline for S5C's Categories of Learning.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts</td>
<td>Genetic engineering relates to medicine, Issues with genetic technologies</td>
<td>Basics of xenotransplantation</td>
<td></td>
<td>Genetics changing constantly, Engineered tomatoes, Importance of labeling</td>
<td>Numerous examples of science knowledge changing, Extensive development of genetic technology, Role of US and other countries</td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td></td>
<td></td>
<td></td>
<td>Locating references</td>
<td></td>
<td>Effective way to learn material</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td>Beliefs about animal use</td>
<td></td>
<td>Other students capable of good work</td>
</tr>
</tbody>
</table>

Table 4.7: Timeline for S5D's Categories of Learning.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts</td>
<td>Issues with genetic technologies</td>
<td>Engineered tomatoes, Role of EPA</td>
<td>Engineered potatoes and corn</td>
<td>Role of restriction enzymes, Issues more political than science, Overpopulation may relate to topic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>Word processing</td>
<td>Locating references</td>
<td></td>
<td></td>
<td>Balancing instincts with data to judge reliability</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Personal religious beliefs relate to topic</td>
<td>Beliefs about animal use</td>
<td></td>
<td>Additional ethical considerations of animal use</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

even within the same subject group, forced the researcher to consider a simple visual model (as often appears in educational research) to represent the categories of learning. An additional point is that S5C learned about the genetically engineered *Flavr savr* tomato from S5D, demonstrating that subjects were learning from one another, as will be discussed further in the interactions section.

**Continua of Learning Represent Complexity**

Although this study did not seek to quantify aspects of learning, it was apparent that individual's subject's learning could be classified as different points along a number of different continua of analyses. These continua of learning included: deep/surface, depth/breadth, persistence/novelty, learning/non-learning, and remembering/forgetting.
(Figure 4.12). These characteristics of learning added further complexity to describing student, TA, and faculty learning.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Breadth</th>
</tr>
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<tbody>
<tr>
<td>Persistence</td>
<td>Novelty</td>
</tr>
<tr>
<td>Remembering</td>
<td>Forgetting</td>
</tr>
<tr>
<td>Deep Learning</td>
<td>Surface Learning</td>
</tr>
<tr>
<td>Learning</td>
<td>Non-Learning</td>
</tr>
</tbody>
</table>

**Figure 4.12: Continua of Learning.**

Subjects varied in the degree of overall learning within categories. In other words, some subjects only exhibited limited sub-categories of changes in knowledge. This resembled the idea of deep vs. surface learning (Biggs, 1994). The deep approach was characterized by subjects focusing on learning the meaning of material, attempting to relate parts of the task, relating new knowledge to prior knowledge, and relating to everyday experiences. The surface approach was characterized as viewing the task as a requirement, memorizing, performing the task through rote memorization, and viewing a task as isolated.

Students had deeper understandings and more well developed skills than TAs or faculty. For example, S3B researched eugenics and knew more about the extent of the eugenics movement in the United States than F1, who had lectured for 15 minutes on the topic (an extensive amount of lecture time for a single topic in a ten-week introductory biology course).

A related issue was whether subjects focused on learning in a broad (breadth) or specific (depth) manner. Subjects also exhibited variation of breadth of knowledge development across categories. Although individual subjects did not necessarily appear to be acquiring concepts and skills from each category, as a whole, the subject group covered a broad range of learning. Different subjects were adopting these dimensions at different times and to different depth, but on a collective scale, all of these aspects of thinking emerged at key points during the project.
Students S1E and S1D both learned computer skills, with S1E exhibiting a breadth of learning, including using the Word program, how to conduct an Internet search, and how to send e-mail attachments. By contrast, S1D exhibited a greater depth of learning using the Internet, including advanced searchers, comparison of web browsers, and down-loading of images. This indicated that even though both subjects' learning was categorized similarly (*Learning Strategies – Computer Skills*), these categories inherently oversimplified breadth and depth. To attempt to compensate for this in data coding, nested categories were assigned whenever possible (S1E: *Learning Strategies – Computer Skills – General*; S1D: *Learning Strategies – Computer Skills – Detailed*). Breadth and depth were also developed to indicate whether subjects primarily learned within one category such as *Cognitive Outcomes* (depth), or across categories (breadth).

Another variation was the degree of persistence of utilizing recently acquired knowledge. Some subjects repeatedly revisited ideas, concepts, and opinions that they had researched, written about, or discussed during the project. Word use, once adopted, was used within individual subjects. Students either consistently missed basic concepts or consistently mastered concepts. Other subjects changed continually with novel ideas, understandings and skills, rarely repeating particular behaviors or statements. These subjects bounded from one aspect of the project to another, not blending together ideas, skills or belief systems acquired at different points in the project.

Some aspects of persisted in subjects to the post-project interviews. For example, T1 recalled information about tryptophan he researched week four, and S2B recalled the reasons for why she now considered it important to consider other culture's viewpoints in science decisions. Other concepts did not appear to persist. For example, S1C was no longer clear about the role of the FDA in regulating genetically engineered foods, which he had researched for the group summary.

Another characteristic was the magnitude of learning. It was clear that some subjects exhibited a great deal of change over the course of the study (F1, T1, S5A), whereas other subjects exhibited fewer examples of learning (F2, T3, S5E). However, quantification of variables was not part of the study design, so this characterization was left general as "learner" and "non-learner", with individual subjects exhibiting aspects of both learning and non-learning related to different topics. With the diversity of learning occurring within the subject groups, examples of non-learning were not always apparent.
Subjects also demonstrated degrees of remembering balanced by episodes of forgetting. Examples and behaviors were often abandoned, either to be revisited later in the project, or not again evidenced in the data. Subjects tended to forget certain concepts and strategies more than others. For example, procedures and definitions appeared to be more readily forgotten by members of all three subject groups than Internet skills and beliefs in particular topics.

There were also variations within the factors impacting learning that linked directly to the variations in learning itself. These factors were addressed with the second research question. This study did not quantify aspects of learning. As a result future studies would be necessary to identify where subjects lie upon distinct learning continua.

Categories Representing Factors Impacting Subject Learning

Research Question #2: What factors limit or augment learning in each of these groups (students, teaching assistants, faculty)?

The second research question addressed in this study involved identifying the variables that impacted learning. Multiple factors inhibited and enhanced subject learning, and the factors impacting learning changed over time. This study did not seek to assess the relative significance of variables, and all factors were incorporated into the nested categories.

There were notable similarities and differences of conditions of learning between students, TAs, and faculty. These conditions were classified as Internal or External referring to the origin of the factor (Table 4.8). Internal referred to conditions originating from the learner, and External referred to conditions originating from individuals or settings other than the learner.

The internal and external conditions resemble the personal and situated factors that interact as presage (presage, process, product) (Biggs, 1994). In the research literature, personal factors include: ability, personality, locus of control, cognitive style, motivation, values, attitudes, prior knowledge, conceptions of learning, and general experiences. Situational factors include: nature of task, time pressures, context, method of teaching, assessment, and perceptions of requirements (Chinn & Brown, 2000). Since not all of these sub-categories were represented in the data from this study, the internal and external category headings were maintained.
Table 4.8: Internal and External Conditions for learning.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sub-Categories</th>
<th>Sample Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Conditions for Learning</td>
<td>Attendance/Awareness</td>
<td>T3 missed a prep session and did not inform students of project changes, many students did not complete the assignment</td>
</tr>
<tr>
<td></td>
<td>Interest/Goals</td>
<td>S2C’s interest in teaching promoted her to critique instructional strategies in the course</td>
</tr>
<tr>
<td></td>
<td>Beliefs/Values</td>
<td>T2’s belief that students would have difficulty with the project led to more directed teaching and student responses that mimicked her statements</td>
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<tr>
<td></td>
<td>Identity/Personality</td>
<td>S3D’s perspective in disease in Thailand impacted student ideas of U.S. research responsibilities</td>
</tr>
<tr>
<td></td>
<td>Background Knowledge</td>
<td>F1’s limited knowledge of genetics technologies led to overlapping debate topics</td>
</tr>
<tr>
<td></td>
<td>Teaching and Studenting Experiences</td>
<td>F2’s teaching experiences led to implementation of a debate-formatted project to address applied genetics</td>
</tr>
<tr>
<td></td>
<td>Communication Skills</td>
<td>T1 located examples of plagiarism while grading assignments, which led to class discussion of the topic</td>
</tr>
<tr>
<td></td>
<td>Learning Skills</td>
<td>S1B assisted group members in using the library to locate references</td>
</tr>
<tr>
<td>External Conditions for Learning</td>
<td>Structure of Content</td>
<td>Students assigned the topic of genetically engineered organisms were less likely to understand techniques associated with the technologies than those students assigned to gene therapy</td>
</tr>
<tr>
<td></td>
<td>Project Design</td>
<td>In the process of debating, S4A learned that you can learn to understand an argument you don’t agree with</td>
</tr>
<tr>
<td></td>
<td>Course Structure</td>
<td>S1B understood the concept of genes in relationship to engineering genes from lecture</td>
</tr>
<tr>
<td></td>
<td>Course Participants</td>
<td>S5D learned about genetically engineered plants from students belonging to a different supergroup</td>
</tr>
<tr>
<td></td>
<td>Institutional Factors</td>
<td>Several subjects used the learning center as a convenient way to meet with group members to prepare for the debates</td>
</tr>
<tr>
<td></td>
<td>Other Commitments</td>
<td>T5 was only able to spend a limited time grading due to completion of his research</td>
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<tr>
<td></td>
<td>Research Participation</td>
<td>T4 reflected more upon his teaching due in part to formative interviews</td>
</tr>
</tbody>
</table>

The internal and external categories are comprised of a series of sub-categories and nested categories (Table 4.9A and 4.9B). Similar to the categories for learning, sub-categories represented learning in all three subject groups, with varying degrees of emphasis, and differences primarily appearing in the nested categories. For example, students and faculty were impacted by variables within the category of External factors and sub-category Project Design, and nested category of Format, with differences appearing at the nested category of Assessment.
Table 4.9A: Factors Impacting Learning: Internal Factors.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Nested Category 1</th>
<th>Nested Category 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Conditions</td>
<td>Attendance/Awareness</td>
<td>Attendance</td>
<td>Class</td>
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<td></td>
<td>Awareness</td>
<td>Awareness</td>
<td>Peer Meetings</td>
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<td></td>
<td>Interests</td>
<td>Interests</td>
<td>Project Requirements</td>
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<td></td>
<td>Performance Goals</td>
<td>Performance Goals</td>
<td>Course Activities</td>
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<td></td>
<td>Achievement Goals</td>
<td>Achievement Goals</td>
<td>Metacognition</td>
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<td>Attitudes</td>
<td>Attitudes</td>
<td>Personal Preferences</td>
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<td></td>
<td>Beliefs</td>
<td>Beliefs</td>
<td>Other's Interests</td>
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<td></td>
<td>Identity</td>
<td>Identity</td>
<td>Grades/Evaluation</td>
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<td></td>
<td>Values</td>
<td>Values</td>
<td>AppearingCompetent</td>
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<tr>
<td></td>
<td>Biology Courses</td>
<td>Biology Courses</td>
<td>Learning</td>
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<td>Other Courses</td>
<td>Other Courses</td>
<td>Long Term Job/Degree</td>
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<td>Cultural Experiences</td>
<td>Cultural Experiences</td>
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<td>Work Experiences</td>
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<td>Media</td>
<td>Media</td>
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<td></td>
<td>Teaching and Studenting Experiences</td>
<td>Previous Similar Courses</td>
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<td>Course Participant Relationships</td>
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<td>Instruction</td>
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<td>Assessment</td>
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<td>Content Examples</td>
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<td>Concurrent Courses</td>
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<td>Multiple Pedagogies</td>
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<td>Communication Skills</td>
<td>Writing</td>
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<td>Assignment/Curriculum</td>
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<td>Computer Use</td>
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<td>Course Participants</td>
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<td>Debating</td>
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<td>Pronunciation</td>
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<td>Creative Thinking</td>
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<td>Problem Solving</td>
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<td>Preparation</td>
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<td>Reflection/Maintenance</td>
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<td>Library</td>
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<td>Internet</td>
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<td>Learning Skills</td>
<td>Thinking Skills</td>
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<td>Self-Regulation</td>
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<td></td>
<td>Obtaining Information</td>
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</tbody>
</table>
Table 4.9B: Factors Impacting Learning: External Factors.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Nested Category 1</th>
<th>Nested Category 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Conditions</td>
<td></td>
<td></td>
<td>Varied Nature of Concepts</td>
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<td>Media Coverage</td>
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<td>Recent vs. Older</td>
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<td>Multiple Representations</td>
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<td>Linked Concepts</td>
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<td>Application</td>
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<td>Participant Roles</td>
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<td>Research Requirement</td>
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<td>Debate</td>
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<td>Assessment</td>
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<td>Time Considerations</td>
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<td></td>
<td></td>
<td>Project Directions</td>
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<tr>
<td>Structure of Content</td>
<td>Project Topics</td>
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<td></td>
<td>Other Course Content</td>
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<td>Format</td>
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<td>Supplementary Information</td>
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<td>Accessibility</td>
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<td>Classroom Environment</td>
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<td>Course Structure</td>
<td>Peer Interactions</td>
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<td></td>
<td>Other Interactions</td>
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<tr>
<td>Course Participants</td>
<td>Facilities</td>
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<td></td>
<td>Atmosphere</td>
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<td>Institutional Factors</td>
<td>Employment</td>
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<td>Health</td>
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<td>Family</td>
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<td>Activities</td>
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<td>Reflection</td>
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<tr>
<td>Other Commitments</td>
<td>Time Considerations</td>
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<td>Relationship With</td>
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<td></td>
<td>Participants</td>
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</tr>
</tbody>
</table>

Key:
- White: Students, TAs, & Faculty
- Yellow: Students Only
- Orange: Students & TAs Only
- Green: Students & Faculty Only
- Pink: Faculty & TAs Only
- Purple: TAs only
- Blue: Faculty Only
Fincher (1998) suggested that learning conditions can be grouped by (1) the individual differences in the learners themselves, (2) the nature of the learning materials and tasks, (3) the nature and quality of the instruction, and (4) situational or environmental variables. Data in this study encompassed all of these conditions.

Analysis of the data also suggested that nonintellectual factors played a role in learning. Other studies have suggested the importance of nonintellectual factors (noncognitive), or personal habits and attitudes, such as peer relationships, employment, time management skills, (Larose, Robertson, Roy, & Legault, 1998). These were added to the more intellectually-focused conditions representing knowledge development, with all factors appearing to involve some type of cognitive component.

Some categories were not identified until all of the data were collected and large, more pervasive themes emerged. Similar to the myriad of types of learning emerging in the study, the factors impacting that learning were also extremely variable. Not only were there often, if not always, multiple variables impacting each learning event, the process of learning often occurred over time, meaning that factors impacting a single factor of learning could change over time as well.

The factors impacting learning changed rapidly, even within the same subjects. As an example, the following two tables (Table 4.10 and 4.11) list the identified factors impacting the learning categories previously presented for subjects S5C and S5D in Tables 4.6 and 4.7.
As seen with students S5C and S5D, the factors varied depending on the type of learning and time in the course. Factors ranged from Background Knowledge, to Interest in materials, to Interactions with Course Participants. The Project Design also impacted learning, in that many students appeared to learn about researching from other students and TAs, aspects of the nature of science from the debates, and aspects of the
historical and social context of science from both the lectures and the debates. The complexity of factors impacting subject learning is apparent in the elaboration on these categories.

**Elaboration on Factors Impacting Learning**

This section draws describes the sub-categories and nested categories constructed from the study's data on factors impacting learning. Data are not provided for every topic discussed due to the extensive breadth of results. Data included in this section were selected based on the information they provide to address the research questions.

**Internal Conditions**

To be classified as an *internal* factor, the factor needed to originate from the individual subject. These factors may have existed prior to the course and project, or originated in the context of the project. Internal conditions included *Attendance/Awareness, Interests/Goals, Attitudes/Beliefs, Identity/Values, Background Knowledge, Teaching and Studenting Experience, Communication Skills, and Learning Skills*. Categories represented by two names such as *Attendance/Awareness* indicates that variables within these sub-categories were interrelated, and could not be completely separated from one another.

**Attendance and Awareness**

*Attendance and Awareness* were grouped as categories since both factors were necessary conditions for observed learning. Attendance referred to physical presence and participation in settings related to the project. Awareness indicated mental attention and processing of events. As can be expected, limited awareness and attendance impacted learning. The project required students to participate in repeated activities over time, which may have related to subjects missing particular aspects of the project.

*Attendance* included *Class* and *Peer Meetings*, such as informal meeting between faculty and student groups meeting at the library. Subjects varied in attendance. For example, students may have attended all of lectures but missed the activities, or TAs may have attended all of prep sessions, but missed lectures. Students with poor attendance relied heavily on text and lecture notes form classmates. Subjects
attending activities related to the course demonstrated learning relative to that attendance.

Students who attended class regularly noted course details, such as the links between material. A few students who later stated that they had missed lecture were unaware of the topic.

Eugenics was the principle of how people were made up and their chemical genes. It was changed by the invention of DNA and RNA. (S4B, Post-Project Interview)

Student attendance was high during the week of the debates. Additionally, students appeared to be attentive.

Students were quiet and appeared attentive for the entire debate, even when they were in the audience, watching the other supergroups debate. Sometimes when a point was made, students would nudge each other or say something related to the debate. Students, TAs, (F2), and I have all commented on how surprised we are that everybody was so into this project. (Researcher Journal)

TAs discussed observing firsthand how students who put more effort into their research were able to learn more about their project topic.

...there was a big dichotomy in the class about the people who just sort of knew the topic and had a few little comments versus the people who had a couple of facts and were able to expand on those and formulate an opinion about the genetic technologies. I think those were the ones who got more out of it. Those were the things I think of as well. Is that really what they were thinking, or is that the way I saw it? (T5, Post-Project Interview)

Faculty and TAs correlated attendance in the course with student achievement in the project-related activities.

It [the debate] went well, you probably would have a better feel for this. The students were engaged and attendance in lecture was high. (F2, Post-Project Interview)

TAs who attended lecture developed ways to review lecture topics they considered difficult to understand. Faculty who observed the debates were able to make changes to project requirements that clarified desired student outcomes.

Although most subjects participated in all components related to the project, including informal meetings in settings such as the library and learning
center, attendance did not necessarily indicate awareness. Awareness of Project Requirements, Course Activities, and Metacognition impacted learning.

Awareness of project requirements impacted the three subject groups. Many of the students who were aware of Project Requirements early in the term spent time researching project topics over the five-week period.

TAs were not always aware of project requirements and course procedure, even if they had attended the prep sessions where this information was presented. For example, when asked in class about the break-down of the points for the project, T4 was unable to answer, commenting “That was a little awkward, it's a good thing you were there. Did we talk about the points already?” Another TA was unclear of what the “pro” or “con” sides of the debates were one week before the debate.

T3: You're pro, so you will be arguing for gene therapy
S3B: So does that mean we're for the technology and against regulation?
T3: (Pause) Um, no I think it means you are, wait...
S3E: It (holding activity) says we're arguing for government regulation.
(Week 5, Debate Prep Activity)

TAs unaware of project requirements spent less time learning about course topics, although the relationship between these factors was not clearly elucidated in the data. As faculty became aware of problems with the project topics, they tried new strategies for altering the curriculum.

Awareness of Course Activities also played a role. This included awareness to the formal class activities including lecture, activities, the debate, and textbook activities, as well as awareness of informal project-related events such as meeting with other course participants. Some of the student students were not aware of due dates, particularly for the annotated references.

Uh, no, I'm not really too worried about the whole thing. There's plenty of time and we'll all be working on this. (S2E, Week 2, Formative Interview)

There was confusion over whether anything was due the following week, as mentioned in the prep session. Only three of the five subject TAs had reminded their students that the annotated references were due the following week. This appeared to impact the number of annotated references that were turned in.

I'm really surprised at how many students didn't turn in the references. Students say that they forgot about them and didn't know that they were due. Maybe they needed more reminders from their TAs and in the
Subjects stated that even though they participated in project-related activities, there were times they could not always remember what happened, even within minutes of completion. As could be expected, not all aspects of what was presented in the class lingered in the minds of participants.

Awareness also extended to awareness of behaviors, or *Metacognition*. Some subjects were not aware of their own focus on concern about self, such as students not realizing how important it was to appear competent to group members.

Subjects also were not always aware of the extent of their own learning. When asked if they were teaching the project activities differently than other course activities, TAs did not think so. "No, I'm not really doing anything different this term in my teaching." (T2). I noted that this disparity between my observations and TA perceptions would have to be addressed in the post-project interviews.

A wide variety of factors impacted attendance and awareness, and those factors often fluctuated within subjects. Subjects noted that other course participants impacted their attendance and awareness of project requirements. Additionally, students and TAs viewed their peers as both assistants and distracters from ability to focus on course activities. Both groups cited the importance of answering questions or solving problems independently, even when working in groups. The amount of time the subjects spent working independently may have impacted metacognition, but it was not possible to determine this from the data.

Attention and awareness may have been confounded by varying subject exposure to a particular concept or skill. For example, although T3 considered the environmental impact of genetically engineered plants in week one, she missed the debates, which may have resulted in not learning many of the other issues that her students discussed week 6. Also, the TAs did not, in general, appear to be learning about basic techniques, which were only briefly covered in lecture and often covered rapidly by students in the debates.

**Interest and Goals**

Aspects of *Interests, Performance Goals, and Achievement Goals* were frequently mentioned by subjects as primary reasons for learning. There was a close
overlap between these interests and goals, resulting in their grouping as a sub-category. The project had components that differed from other aspects of the course, such as controversy and public speaking which appeared to impact subject learning.

Interests included Personal Preferences and Other's interests. Subjects repeatedly mentioned that they chose to focus their time on topics and practices that they found more interesting. This included reflecting on arguments and conflicts that challenged personal belief systems. Although not discussed by subjects as a factor impacting learning, observations suggested that the interests of others (including both course participants and other individuals) also impacted subject learning. Students found information their group members were interested in, TAs followed the lead of other TAs, and faculty researched lecture topics based on student comments from previous course evaluations.

The content and forms of media impacted individuals subject's interest in the project topics. Students stated that they were more interested in certain topics related to their majors and backgrounds, and noted that the debates held interest more than other pedagogical techniques. The arguments against genetic technologies were primarily health related, then a bit environmental or ethical.

One series of follow-up questions asked students what they thought caused them to acquire new knowledge. The primary response was that they either were or became interested in the material.

I thought it was fascinating how they use genetic technology in horticulture, and the improvements they've made, and the protection of plants. I think the production, making it more productive, will only benefit us. I ran across this and since I'm interested in plants, had to read about it. (S1B, Post-Project Interview)

The degree of interest in the topics was apparent as several of the students asked questions even though the project was over.

Doesn't gene therapy kind of fall under genetic engineering? How about cloning, is that considered to be gene therapy or genetic engineering? (S2B, Post-Project Interview)

So, did you ever find a picture of that half-sheep, half-goat, the chimera? I looked but did not find any. (S1D, Post-Project Interview)

Other students mentioned that this was the first time they had researched a science topic of interest.
F1: So you selected horticulture because you garden?
S1B: Yes, it was great, I don’t think I had ever researched anything to do with science that I was actually interested in.
F1: Did that make a difference to you?
S1B: Oh, sure, I am much more likely to spend more time on something if I’m interested in it, I didn’t realize how important that is. (Week 4, Formative Interview)

Students also acknowledged specific ideas in the debate that they found interesting.

They did pretty well. I liked the point about us trying to help others before we try helping those we already can. It seemed like a few people addressed stuff a lot more than others in the group. (S2A, Student Debate Critiques)

They brought up some good points about gene therapy being stronger than other medicine. Would it be fair if rich people could afford increase intelligence in offspring some day? (S2E, Student Debate Critiques)

Students have a vested interest, their abilities are on display. When you do this type of project, it enables even the less than stellar student to do a good job. A little bit below average student in the course, one who comes regularly to class, they can really excel. This type of project can develop a different attitude in students towards biology. (F2, Week 6, Formative Interview)

S4A: The articles that I reviewed were all from good websites.
F1: Do you remember which websites they were?
S4A: No, not really, I did a search and some of the hits had a lot more information than others and I went with those.
F1: How did you decide which sites to use?
S4A: Well, uh, the easiest to understand and if they were interesting since I had to read them. (Week 3, Formative Interview)

Some of the students noted that they were interested in teaching, although they were not sure what form the teaching would take. A few of these students also talked extensively about teaching during the formative and post-project interviews (S2C, S5A).

In this study it was not clear that individual interests (interests in broad domains or preferences for subjects) were distinct from situational interests (specific situational stimuli that determine motivation and emotion) (Harackiewicz, Barron, & Elliot (1998). Instead, situational interests (such as the interests of others as expressed during the debates) appeared to override individual/personal interests and vice versa. Factors such as the structure of the project appeared to impact individual interests.

Interest impacted whether TAs sought out more information about specific concepts. Students in each TAs section discussed human deaths related to genetically
engineered crops in Europe. None of the TAs were sure about this information, but only three sought information on the topic. The motivation behind this varied from personal interest to the desire to appear competent.

Many of the subjects demonstrated that they were impacted by the Interests of Others, either by being motivated to do what other's found of interest, or to somehow support another participant's interests. Students repeatedly researched topics that their group members thought were interesting, because they had not themselves keyed in to a particular topic. TAs also learned material during the debates that had been of interest to the students. One of the five TAs repeatedly discussed his student's interests.

That sounds pretty interesting. I think it will be a good opportunity for the students to learn more about something they may run across in their own lives. (T5, Pre-Project Interview)

Other TAs often discussed their own interests and those of their students interchangeably. T4 indicated that the biggest impact on his teaching had been his interest in interacting with students throughout the term.

I had a lot of student questions over the term, I really pushed question, always like asking them. It was really nice that it was their responsibility to find the information. In some of the laboratories they were bored because it was all laid out there for them. (T4, Post-Project Interview)

F2 discussed his continued interest in thinking about what students needed to get out of a genetics unit.

Look to what you want students to be able to do in five years. You want them to continue to read about and understand genetic technologies as they develop, not necessarily the history of genetics. Not the math, the chemistry. You want them to be able to read and understand the significance, the scientific and social dimensions. It is easy to go astray in curriculum development, it all seems interesting to you, but is it what the students need in the long run? For instance, you may want students to understand the timeline of genetics, like the chapters in the textbook, but leave off the emphasis on names and specific dates. There are times you leave this stuff in, especially related to the social aspects of science. For instance, the story of jumping genes has specific details and can teach students about the social aspects of science... The challenge is to open the door and allow them to succeed. Not a set curriculum, you have to consider, what is active teaching? (F2, Post-Project Interview)

Goals, or what subjects set out to accomplish, represented the intersection between motivation and cognition. Motivation, the desire to act, was impacted to a
degree by all of the factors listed, but most noticeably in the data by subject goals. The subjects that indicated learning the least during the course also mentioned having low levels of motivation.

Observed goals in this study indicated focus on achievement, or the pursuit of some sort of competency. Goals were either related to performance (demonstrating abilities to others) or mastery (developing skills and task competence). Performance goals included *Grades/Evaluation* and *Appearing Competent*. Mastery Goals that impacted learning included *Learning* and *Long term Job/Degree* goals.

The process of assigning *Grades/Evaluation* for the project appeared to impact learning in all three groups. Students completed assignments in part because those assignments were worth points. The relatively small amount of points related to time spent on the project (only 3.7% of the final grade allocated to the annotated references, group summary and notecards) did not appear to be a factor impacting the amount of time students spent on the project, as many students spent far more time on the project than studying for midterm #2 which was worth 20% of the final grade.

Material related to the genetic technologies project was included on the second midterm exam (Figure 4.13).
Which of the following is an example of a genetic technology that is already available and widely used?

A. Enhancement human gene therapy
B. Manipulation of human genes to elicit particular social behaviors.
C. Production and sale of transgenic food crops.
D. Cloning of adult monkeys.
E. Germ-line human gene therapy, the altering of cells that produce sperm and eggs.

Correct answer = C

Genetically altering cells of the body, other than those cells that produce sperm and eggs, is an example of
A. crossing-over.
B. genetic screening.
C. germline gene therapy.
D. gene marker analysis.
E. somatic cell gene therapy.

Correct answer = E

Figure 4.13: Sample Midterm Exam #2 Questions Related to Project Topics.

Students did not appear to alter behavior based on the knowledge that some of the genetic technologies material would be on the midterm #2 exam.

TAs spent much more time grading project assignments than the other activities. This grading included reading the variety of written assignments, evaluating contributions during the debate, finding time in schedules to grade, and managing large quantities of student work.

Related to grading and evaluating students, faculty usually primarily focused on constructing exams. Faculty typically were only peripherally involved in grading individual student work, with occasional suggestions to TAs during prep sessions regarding distributing each activity’s points. However, the project put more emphasis on grading techniques and altered faculty focus to respond to misconceptions or missing conceptions in individual work. Additionally, the researcher was viewing more samples of individual student work as a component of data collection.

Concerns about grades and grading did not have an overwhelming impact on student interest in the project. Instead, interest was impacted by other factors, including cultural identity, structure of the content, and interactions with other course participants. Even students with low midterm exam grades, and TAs with consistently negative oral student feedback expressed interest in the project.
Students, TAs, and faculty appeared to be impacted by similar categories of goals, particularly *Appearing Competent* in the eyes of other course participants. Focus on public speaking appeared repeatedly as a factor impacting learning (both positively and negatively), with some student subjects not even aware of what the project was worth relative to the course grade.

The emotions during the debate appeared quite high. Students were talking and planning last-minute strategies as they entered the room, but quieted down quickly when the TA began to speak. When they began to speak, some of the students were shaking and/or stammering... Within the two hour time, there were moments with almost the entire class laughing, moments of “pure” quiet when a sad, personal story was shared, and moments of tension when students began to argue. When the class was over, several students continued to talk out in the halls, even though they often clear out of the building after class. (Researcher Journal)

Anxiety is not all bad, it’s a great motivator. Aren’t they supposed to learn skills like public speaking in college? (F2, Post-Project Interview)

Concerns related to public speaking were factors impacting learning in all three groups. F1, all of the TAs, and most of the students at some point mentioned the desire to speak effectively in front of a group (whether lecture, lab introduction, or debate) as a major motivator for learning content. Although judging significance of variables was not addressed in this study, subject speculations on the potential consequences of not being prepared to speak involved terminology such as “horrific” (S2C) and “catastrophe” (T2).

In the context of the project, TAs were repeatedly placed in situations where they needed to address content and pedagogies that they were not familiar with. When later asked whether they thought that pedagogical concerns such as classroom control were a factor in deciding to instruction, all five of the TAs stated that they were concerned about how students perceived their teaching, especially during the first week of class.

It is really important to me that we get off on the right foot. As you know, I wasn’t really happy with how things went with one of my sections last term. This term I’m making sure that everything goes without a hitch, that students are quiet, listen to directions, are on time, come to class prepared. (T2, Post-Project Interview)

One of the TAs expressed that her concern over student responses to her assessment practices affected her grading.
I tried to consider that there were so many points put toward the project. Usually they get most of their points just for doing the activity, and I was worried about how they would respond if all of a sudden I gave them threes and fours. (T3, Post-Project Interview)

Another of the TAs was concerned about her handling of the confusion between the two topics.

The first thing that comes to mind is how we separated genetic engineering from gene therapy. It was kind of hard to draw a line between the two. It was just in terms of defining it for them, I actually wish that I had had a better idea, it seems like I and all the TAs kind of came up with clarifications over the term of how we wanted to separate the two, so. But, I mean, I think that overall, that they got so much out of it, they learned so much more than any questions out of the book or lecture. (T2, Post-Project Interview)

T1 repeatedly expressed concern over his ability to control student behaviors and how that reflected on his ability to teach. When asked why they used the handouts for the debate, TAs stated

You know, I'm really not too comfortable with going into class unprepared. Its hard enough to keep the students quiet and paying attention. At least this gives them something to do during the debate so they are paying attention and doing something for the five points. (T1, Week 6, Formative Interviews)

Similar to the TAs, faculty (particularly F1) were engaging in new teaching practices (curriculum design, changing lectures to address student and TA concerns, developing grading schemes) within the context of the project.

Achievement Goals impacting learning included subject emphasis on Learning and Long Term Job/Degree plans. Repeatedly subjects, including TAs and faculty, stressed that they were interested in Learning about the project topics since they, as consumers and citizens, would have to make decisions regarding those topics.

The focus on learning was evident in those students who spent time reviewing articles that they knew were not part of their own assigned topic. Several of the students, assigned genetic engineering or gene therapy, included references on human cloning.

This article provides a history of cloning along with an explanation of the cloning process in laboratories and how it occurs in nature. It presents several examples of the benefits of cloning and the usefulness of cloning in research. (S3C, Post-Project Interview)
Faculty and TAs who focused on learning about the project topics, did so to be able to teach and recognize scientifically acceptable conceptions in student work.

The learning goals between the three subject groups were much more synchronized than the researcher had anticipated.

Now that ____ (F2) and I are looking up information along with the TAs, everybody seems the have their eye on the same prize -- learning about genetic technologies. (F1, Week 5, Researcher Journal)

A few of the students mentioned specific goals in learning about aspects of teaching. Other students mentioned interest in developing values related to the technologies. TAs were initially focused on learning strategies related to teaching, particularly classroom management.

Things went better than I had ever dreamed. The students seemed to be learning in an unbelievably diverse number of ways, it has been extremely difficult to categorize them all. Even though I wasn’t studying it, the TAs and students reported that they learned more I the projects than form other parts of the course. I can believe that because they certainly had a lot to say in the debates. (F1, Post-Project Interview)

They learned a lot. You saw what they were capable of, they were focused on a biology topic for two straight hours and were enjoying it. That is why these types of projects are so successful. This material will stick with them. (F2, Post-Project Interview)

Student’s short-term skill-related goals (successfully debating, learning about the topics) were similar, even though long-term goals varied. Long Term Job/Career goals such as desire to teach impacted some of the students, TAs, and F1 to reflect on teaching during the project. In this study, a few students mentioned how biology could relate to their future careers. However, several of the students were not sure of what their careers would be.

Short-term goals, such as a TA successfully introducing a project topic appeared to out-weigh long-term goals such as completion of a research program. TAs demonstrated that their primary motivation was their goal to do a good job, particularly in the eyes of the students. Not seen in any subjects was a shift in concern from self to concern in others.

The combined impact of interest and goals effected whether subjects engaged in surface or deep forms of learning. The deep approach of learning was impacted by interest in the task, whereas subjects citing extrinsic motivation from other course
participants demonstrated surface learning. Data supporting subject interests and goals were often indirect, meaning that subjects did not directly state what their interests/goals actually were until prompted in interviews.

Numerous factors impacted motivation to learn, with positive and negative motivators influencing all subject groups. Subjects generated the qualities of material that they found to be motivational, focusing on qualities such as significance. Topics related to ethical considerations and direct human applications were cited as being more motivational because they were important. Students referred to a "coolness" factor, related to motivation, that it was cool to be debating important issues. Interest related closely to attitudes in that students were proud of what they knew. This theme of pride/ownership/membership repeatedly appeared in the data, such as students bringing friends to class, TAs telling co-workers about the course, and faculty expressing pride in course traditions. As will be discussed, the content itself was also a motivator.

Students repeatedly mentioned the significance of motivation influencing what other students learned.

Um, it wasn't really an issue, everybody was pretty eager and grasped the concepts pretty quickly. (S3A, Post-Project Interview)

Students equated interest with their ability to complete the project. This study suggests that interest related to TAs and faculty outcomes as well.

**Attitudes and Beliefs**

*Attitudes and Beliefs* about aspects of teaching and learning impacted subject behaviors, and due to difficulty in discerning between these factors in the data, were grouped into the same sub-category. Attitudes and beliefs were characterized by general feelings and perceptions that subjects had toward aspects of the study in which they were involved.

Attitudes impacting learning included attitudes toward the *Project*, *Course*, *Course Participants*, and *University Culture*. Subjects exhibited changes in attitudes toward project, often shifting back and forth between overall positive and negative impressions as the project changed.

Student attitudes toward the *Project* included attitudes toward long-term aspects of working with group members and public speaking. Individual students working on the genetic technologies project expressed both positive and negative views of group work,
and while most expressed liking the debate itself, they were divided on whether group work on a weekly basis was beneficial. These results will be discussed further in the *Project Design* section.

Similarly in the context of the genetics technology project students discussed developing attitudes, however those attitudes varied with some students only liking the issues aspects of genetics, and others focused on the applications or recent developments.

Students preferred teaching approaches that they perceived as beneficial for learning. As a result, students stated preferences for lecture and the debate over the textbook and weekly laboratories from which they perceived learning less. These results will be discussed further in the *Course Structure* section.

TA attitudes toward the project focused on demands on their own teaching and student response. Attitudes were part of the diverse group of factors that influenced TAs intentions and behaviors.

I think they learned a lot about current issues, I mean everything came up when they actually did the debate. And they definitely got at all of the ethics associated with it, and yet they still had to understand enough about the science to be able to get in an talk about the ethics. It was a very up to date current topic, I think they got a lot out of it. (T2, Post-Project Interview)

Faculty attitudes toward the project revolved around aspects of student achievement.

I think the project went very well. It was a rocky start, largely due to my picking two overlapping topics, and the TAs miscommunicating some of the project requirements. Despite that, the students appeared to have learned a lot more about the genetic technologies than I expected. The students appeared to really enjoy the project and it was a great experience listening to the level of discourse they were capable of in the debates. (F1, Post-Project Interview)

Subjects' changing attitudes toward the project impacted views of the *Course* in general. Positive attitudes toward the project did not necessarily translate to positive views about the course in general. Some of the subjects discussed discrepancies in other parts of course in relationship to the project.

...the tests were too difficult. (S3C, Post-Project Interview)

I don’t think I got a lot out of the labs. (S5A, Post-Project Interviews)
Subjects did not state without prompting that their attitudes toward Course Participants affected their behavior. However, other data suggested that these attitudes commonly impacted behaviors, particularly as subjects spent a great deal of time discussing their opinions of other participants in the formative and post-project interviews. Students with attitudes that other students were not serious enough about the course tended to be resistant to adopting their suggestions and views. TAs who viewed students as potential threats to their control were initially unwilling to give students more control over their classroom learning. As previously discussed, these attitudes toward others changed. These changes in attitudes impacted both teaching and learning behaviors in the course.

A few subjects demonstrated that their attitudes toward University Culture impacted their behaviors. This included the perception that only certain student types studied on campus (including the library and computer centers). Additionally some of the students initially referred to the university as a training ground for employment, and a resulting attitude that baccalaureate core courses were superfluous. Few students (undergraduate or graduate) had a clear understanding of the role of their education or the organization of the university in general, and possibly as a result, their attitudes toward the university were often negative. Faculty also had attitudes toward the directional changes in the university culture, anticipating continued financial and facilities limitations, as well as increasingly under-prepared undergraduate and graduate students. Additionally, the faculty viewed university culture as not employment-oriented in mission, a sharp contrast to students and TAs.

As stated, subject beliefs were difficult to discern from subject attitudes. Variables grouped under the beliefs category often overlapped with those in the attitudes category. However, it common that subjects would have specific attitudes augmenting learning (such as students enjoying working with group members on the project), and beliefs inhibiting learning (such as beliefs that group members had limited intellectual abilities), and vice versa.

Beliefs included Self-Efficacy, Other's Abilities, Support From Others, and Aspects of Control. Self-schemas, or declarative knowledge about self, impacted learning. These self-schemas were impacted by project participation, with many subjects expressing positive changes in how they viewed aspects of their own behaviors.
This study does not indicate that initial individual self-efficacy (instead of group) is always an indicator of learning. In this study, students were placed in situations where they indicated low self-efficacy, particularly at the beginning of the project (week one) and the week prior to the debate (week five). Some of the students expressed concern about being able to complete the project.

Oh, no, I don’t know anything about genetics, this is going to be really tough. I mean there’s a bit in the (text) book about our topic, but I’m not really sure what it all means or how we’re going to be able to talk about this stuff. (S3C, Week 2, Formative Interview)

A few of the students said that they were having trouble finding material on their topic.

I’m just not finding a lot of things I can use. I think we got the tougher topic because I am finding a lot of websites with information on cloning, but not a lot on our topic. (S5E, Week 2, Formative Interview)

TAs and faculty began the course with a set of “baggage,” or concerns that often limited teaching experimentation and flexibility. These concerns included concerns about controlling student behaviors and appearing competent to others. However, concerns also enabled rapid identification of classroom problems, indicating that concerns were both positive and negative factors impacting teacher learning. There were a number of factors that influenced TA implementation of the genetic technologies project, including:: concerns over content, frustrations about student population, and confusion over the teacher’s goals.

Subjects’ changing beliefs in Other’s Abilities impacted their own behaviors. Students who initially thought that group members were incapable of completing tasks did not share construction of knowledge as readily as when they later developed appreciation for other’s skills. Similarly, students were reluctant to ask their TAs for assistance unless they believed they had adequate teaching abilities.

TAs linked what they thought about student abilities to how they had taught during the course.

It made me think a lot about how important it is to set up the context, this brings back the prep, I spent a lot of time trying to I’d try to let them know where we had come from, where we were, an where we were going essentially. I think a lot of students, my impression was that this was really helpful for the students. I saw a number of students make positive comments about the process. (T4, Post-Project Interview)
T1 primarily mentioned that students needed guidance and deadlines to be able to successfully complete the projects.

It's been a battle just trying to get the students to arrive on time and be quiet (laughs). They need rules, guidelines, so they know what behaviors are expected. (T1, Post-Project Interview)

TA beliefs about student abilities impacted TAs learning various teaching strategies. Generally, as per directions by course faculty, TAs followed the procedures outlined in the Monday preparatory sessions, minimizing difference in content coverage and assessment between the sections. However, four of the five TAs described the genetic technologies project before giving students an opportunity to list and describe what they knew. These TAs also encouraged their students to use the textbook to answer the questions. When later asked why they did this, there were varying responses. The first reason given was that it was easier to present the activity in this manner.

I thought that this way just flows better. I was going through the overhead on the activity (procedures), and it was easy to continue and describe the project. I felt that the students really needed to understand what they had to do, and this was the best way to do this. (T2, Post-Project Interview)

Another reason for altering the activity was TA concern that students would have difficulty completing parts of the activity on their own.

Well, I wanted to give them a bit of help. It is the first week for them and I didn't want to scare them with things they didn't understand right at the beginning of class. (T3, Post-Project Interview)

The one TA who followed the activity as described in the prep session stated

It went well. The students had a tough time coming up with a list of genetics issues, but once they thought about it, they knew more than they realized. These stories are always showing up on TV and in the newspapers. (T5, Post-Project Interview)

When asked why he followed the activity the way it had been presented in the prep session, T5 mentioned that he thought it was interested in seeing what students knew about the technologies.

Student responses to the questions in this activity reflected TA intervention. The first section asked for basic background information about genetic technologies.
Advancements in science and technology have led to the development of a number of amazing genetic technologies. List several of these new technologies, including a brief description, and the ethical issues associated with each new technology. (Student Activity Manual)

<table>
<thead>
<tr>
<th>Genetic Technology</th>
<th>Description</th>
<th>Ethical Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloning</td>
<td>Replication of sheep</td>
<td>Clone humans</td>
</tr>
<tr>
<td>Hybrids</td>
<td>Crossbreeding</td>
<td>?</td>
</tr>
<tr>
<td>Fertility</td>
<td>Making the perfect baby</td>
<td>Messing with nature</td>
</tr>
<tr>
<td>DNA Testing</td>
<td>Investigations</td>
<td>Mistakes</td>
</tr>
<tr>
<td>Gene Splicing</td>
<td>Test tube basis</td>
<td>Religious concerns</td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloning</td>
<td>Producing a replica from the original animal</td>
<td>Religious issues, human rights</td>
</tr>
<tr>
<td>Gene Therapy</td>
<td>The changing of genes to make the perfect person</td>
<td>Superior race problems</td>
</tr>
<tr>
<td>Drugs</td>
<td>Medicinal Uses</td>
<td>If its right</td>
</tr>
<tr>
<td>Forensics</td>
<td>Use of DNA to solve crimes</td>
<td>Invasion of privacy</td>
</tr>
<tr>
<td>Medicine</td>
<td>Use of DNA to diagnose illnesses, deformities in babies</td>
<td>Do we need to know?</td>
</tr>
</tbody>
</table>
Student lists of technologies only included technologies discussed by their TAs. T2 discussed the possible negative ethical and consequences of genetic technologies. The subject students group in that section wrote down similar responses. T3 discussed how genetic technologies may "run against nature's course" and that "mistakes are irreversible." These direct quotes appeared repeatedly in the student's responses. What the student groups wrote down had words that matched TA comments and text, but did not necessarily link concepts coherently.

The adding of genes to a person and also to unborn babies. Mistakes are irreversible. Germline gene therapy is illegal. (S3, Pre-Project Activity)

TA beliefs in student abilities impacted the way they taught and students learned.

Student, TA and faculty expectations for learning related to the project initially varied widely. These variations altered over the project, with most subjects identifying
the outcomes of complexity of issues and learning from others at the completion of the project. However, the belief in the importance of other outcomes still varied widely. Interestingly, these variations were as great within subject groups as between subject groups. Instead of faculty, TAs, and students holding distinct, almost hierarchical views of outcomes, perceptions crossed course-related groupings.

Students researching the science behind genetic technologies topics understood the topics so they could make decisions using other belief systems. Students stated that their time for teaching and learning was impacted by beliefs in support from others within the course. Students also discussed the importance of believing that they would receive Support from Other course participants in altering their own behaviors. Students indicating that they thought they would receive limited assistance felt that they had to learn entirely on their own.

Subjects from all three groups discussed how their beliefs in Aspects of Control over their own behaviors impacted what they decided to do. TAs noted that they were less likely to spend time on aspects of planning and grading if there were specific requirements from those tasks. Similarly, students and faculty focused attention and time on aspects of the project (notecards, lecture) that they felt they had the most control over.

Subjects repeatedly demonstrated the importance of a perception of control, or self-determination, on their behaviors. Students and TAs discussed that they were unlikely to put as much effort into learning if their roles were dictated to them by other course participants. Faculty discussed continual problems of developing aspects of the curriculum without control over lecturer or TA selection (as discussed in the Institutional Factors section).

Student, TA, and faculty beliefs diverged and converged at different times during the project. This included subject confirmation that public speaking was a major factor impacting student emphasis on the project.

This type of project works because the students have to get up and present in front of the class. They'll work harder on this than they will on a paper. Students have a vested interest, their abilities are on display. (F2, Post-Project Interview)

Changes in beliefs did not always appear to impact behaviors, including teaching behaviors. For example, although some of the TAs spoke repeatedly of the importance of having students learn about genetic technologies on their own, their teaching
suggestions and actions focused on providing students with definitions and a conceptual framework. TAs noted in interviews that they were increasingly realizing what students were capable of, but only one discussed altering teaching to accommodate student abilities. Even if TA perceptions altered teaching, not all changes had a detectable impact on learning.

Identity and Values

One of the most difficult to characterize of the groups of factors impacting subject’s learning was that of personal Identity/Values. "Identity is not a static object, but a creative process; hence crafting selves is an ongoing – indeed a lifelong – occupation." (Kondo, 1990 [p.48]) The factors that emerged which appeared to lead to different categories of identity impacting learning included Experience/Age, Cultural Traditions, Gender, and Personality. Individual identities became apparent in the project, where the long-term collaborations between participants led to increased communication and dependency.

The Experience/Age of the individual subject appeared to be a large component of some subject’s identities. Older than average students and the single older than average TA repeatedly remarked on their age as a factor setting them apart from other course participants. These students perceived that their background experiences and goals were what set them apart. However, it also appeared that concern about age itself and the response of other course participants was a factor. Age impacted F2 participation due to proximity to retirement.

A few of the students also demonstrated the impact of their Cultural Traditions on what they chose to learn. Students from agricultural families focused on genetically engineered plants. Students from forestry backgrounds concentrated on government regulation, an active concern related to logging in the Western states. Cultural identity was important for two of the students that identified themselves as belonging to a particular ethnic group. Cultural traditions appeared to be strongly linked to moral sense and ultimately sense of self in many of the subjects. The few students with cultural identities that differed from the majority of their classmates brought different perspectives to the debates.

Within the context of this study it was not possible to tease out whether there were distinctions between self-identity and societal identity, or whether these distinctions would have impacted learning. Gender played a role in student subjects. Women used
exuberant expressions like “awesome” and “wonderful”, different words, more mention of babies.

Female students repeatedly offered reasons for why they were not good in science (learning style, aptitude, etc). Male students frequently discussed the roles of others in their limited course success. Both men and women described debate and argument as a way of learning. Both genders also appeared to rely on faculty as a source of knowledge.

General Personality traits were also a component in learning. Self-described “quiet” students did not appear to be as impacted by group members as other more gregarious students. Similarly two of the TAs primarily worked on their own. However, to muddy the waters, it was not clear that differences in the extent of social behavior necessarily led to different learning. These subjects may have learned from different sources, such as observation and reflection. As will be discussed in the course participant section, interactions impacted learning, but they were only one subset of a variety of factors impacting learning.

Perspective of personal power was an aspect of personality. Dominant “organizer” individuals in groups did not see themselves as part of group dynamics problems. Other subjects viewed themselves as culpable in any developing group problems.

Personalities, including degree of motivation and responsibility appeared to impact group interactions.

You have all of these different personalities, some people kind of just read the (campus newspaper). Here we are five strangers, so we all start kind of equal. Even like the table dynamics are kind of interesting because you come into a new table and its like a different country. (S5A, Formative Interview)

Subjects repeatedly mentioned personality traits of other course participants as factors impacting course dynamics.

In interviews, students stated that they believed verbal participation was important, and that participation included attending class, asking questions, listening, doing assignments, and comprehending. Students indicated irritation at individual classmates who asked repeated questions. Student social norms included limited questioning, with older students not necessarily conforming to these norms. Interviewed faculty had a more limited role of student participation, focused on questioning/answering or note-taking, not as broadly defining participation.
Subjects values included Educational, Cultural, and Personal. Educational
decisions are impacted by moral evaluation, or weighing something on a good/bad scale
(Fitzgibbons, 1981). Words indicating moral judgments included: ought, should, must.
Moral judgments reflected individuals' ethics. Look for examples of ethical egoism,
ethical relativism, and assessment of reasonableness.

Students (and other subjects) viewing topics/learning as important and valued
those learning opportunities. This was an aspect of perceived value. For example,
students valued understanding news items.

I have learned a lot about genetic technologies that I did not know ever
existed. That's probably the part I liked best. (S3E, Written Debate
Response)

Disposition for thinking can include curiosity, questioning, adventureness, broad
scope, clear reasoning, organization, and time (Tishman, Perkins, & Jay, 1995). In this
study these characteristics were seen in some subjects, but the different ways
personality could be impacting thinking could not be distinguished in the data.

Culturally-based ethical and religious beliefs also appeared to impact the way
students studied and utilized project material. Even though most students indicated that
they had learned a great deal about genetic technologies, some of the students stated
that their basic opinions about the use of the technologies remained unchanged. They
confirmed that those decisions were based on moral or ethical beliefs.

Some of the students were asked specifically in follow-up questions if their beliefs
impacted their learning. S2A, with an agricultural background, echoed ideas that he had
expressed in formative interviews.

When we talk about government regulation, the question has to be,
regulation of what? I mean they already regulate like crazy, or they try to,
you know, what comes to your table. I think we debated more about
regulation than the technologies. (S2A, Post-Project Interview)

Each of the different TAs emphasized different aspects of debating. T1
emphasized formal debate structure, T2 emphasized making detailed notecards, T3
emphasized developing distinct roles in the debate, T4 emphasized citing scientific
sources of information, and T5 emphasized the importance of telling compelling stories.
TAs appeared to be providing helpful advice, more than leading students to a right
answer or behavior.
Other students provided personal examples of how genetic technologies could relate to their own lives. For example, S3E stated that a parent had cancer and then explained how gene therapy could relate to this situation.

Take for instance, cancer. This has been historically treated in four ways, no treatment, surgery, radiation, and chemotherapy. If you have any friends or family with cancer, you know that these treatments are very difficult, and people are taken to near death. Now gene therapy, and this is from the National Cancer Institute, gene therapy can kill cancerous cells. There are treatments being developed for melanoma, which is skin cancer. Researchers say its too early to tell if these treatments are effective yet, but so far, there are no negative side effects. (S3E, Debate)

T5 had emphasized the value of providing examples in a human context to his class, and several of his students followed this advice.

Students in the debating groups and the audience became very quiet when a student, speaking in a very low voice, shared a personal perspective.

I am from a country, Thailand, which does not have the wealth of this country. I had friends die very young. If a country has the money, the science to cure a disease, there is a responsibility (pause, class is completely quiet). That is all I have to say. (S3D, Debate)

Subjects also demonstrated that Personal values impacted how they researched topics and approached relationships with other course participants. Student S4B, who had taken the BI 101 ecology/environmental science course, repeatedly related the project topics to personal environmental values.

Should we be altering the foods and crops that they produce more for the increasing human population or wouldn’t it be better to consider our world is overpopulated and cut back on births and take care of what we have? (S4B, Written Debate Question)

Similarly, S1E drew on personal beliefs that genetic technologies tampered with a design established by "a supreme being" (S1E).

Also with genetic engineering, the seeds are the same. If a virus or fungus comes along, then there can be a major crop failure. If there is no diversity, there is less chance of survival. Insect pests can develop resistance. When genes are designed to give crops a competitive advantage, these plants may be hard to get rid of. Genetically engineered cotton plants, there was a problem with the process and the plants dropped their cotton balls and died all together. There are people, either religious or vegetarian like seventh day Adventists or Buddhists
who do not want to eat certain foods. Muslims and Jewish people have rules for the foods they eat. There are also vegans, who do not eat any animal products. What if a plant contains animal genes and proteins? With genetic engineering, we are almost making natural foods extinct. What if the natural plant or animals had better qualities? (S1E, Debate)

Some of the students stated that they had already formed opinions prior to the debate, based on personal belief systems.

I thought that the con group won the debate. But that may be just because I already thought genetic engineering is unethical. (S1C, Student Debate Critiques)

I think they had many good arguments like possible finding the cure for AIDS, cancer, and other genetic diseases. Overall they did very good. If I didn’t believe that gene therapy is morally wrong, I would agree with the group because they provided better arguments. (S2B, Student Debate Critiques)

I felt that the debate was a tool for us to learn more about genetics. However, it seems to me that it turned out to be a disaster. People were attacking one another and not the issues. The room was very tense and people were getting offended and taking things personally. Comments were made that shouldn’t have. I feel that if people stuck to the topics and weren’t taking everything as a shot against them things would have been a lot better. In the future, I feel it might be better, instead of a debate, to have group just give short presentations of certain areas you assign them. That way they are getting a chance to show you what they have learned and not yell at others for doing so. (S3B, Written Debate Response)

The students emphasized more aspects of ethical considerations in their written questions than they did in the oral debate.

Would you still feel that it is best not to disrupt the natural course of life if your best friend’s life could be saved by genetic therapy? (S2E, Written Debate Question)

Is the mistreatment of animals any worse to genetically engineered animals than those animals bred for slaughter? Are they morally different? (S3A, Written Debate Question)

The mix of formats associated with the project and research may have impacted how students expressed their knowledge and views.
Background Knowledge

Subjects demonstrated that a wide variation of sources of background knowledge impacted learning, including: Biology Courses, Other Courses, Cultural Experiences, Work Experiences, and Media. Biology courses that impacted learning included prior courses in the BI 10X series, other University courses and Grade 7-12 classes. Students, TAs, and faculty discussed applying content knowledge and teaching strategies introduced in prior courses. This was particularly the case for subjects who had participated in previous BI 10X courses. Some of the students related what was being debated to other topics from their own backgrounds, including previous BI 10X courses.

If plants can withstand insects, what happens when insects die and other animals can't eat insects (the food chain we talked about in BI 101)? Their point that companies have a monopoly of herbicides and plants. So does Microsoft, but Microsoft has benefited society by doing so, won't these companies? (S1E, Written Debate Question)

What about the animals that thrive in these farm ecosystems? We saw the effects of one missing link in BI 101. (S4A, Written Debate Question)

TAs and faculty were strongly influenced by antecedent conditions, including information about student abilities, participation, and behavior problems. TAs who had taught in BI 101 had developed ideas about how students would perform during the project.

The three TAs who had taught the previous term, had ideas about how the students would search for information based on their teaching experience with the BI 101 salmon project.

I think they would use the library and the Internet, yes, definitely the Internet. That was pretty much their primary source of information for the salmon poster. (T2, Post-Project Interview)

Oh, I think they will all go to their computers for information, won't they? They seem to be pretty comfortable finding information with the computers. Most of my students referenced websites for their posters. (T3, Post-Project Interview)

One of the TAs stated knowing less than some of the students about the genetic technologies could be challenging.
T5: I was familiar with the things in the book, and the things, some of the things discussed in lecture, but uh some of the things the students came up with were outside of all of those realms, germline, gene therapy.

F1: How did this affect managing the debates, was it an issue knowing whether or not it was valid?

T5: It worked because I told them they had to have citations, so all I could say was do you have a reference for that? And all they could do was give it or say no, and it was obvious during the debate that their argument was weaker if they didn’t have the source. It did make it a little bit tough to not be an expert in genetic technologies. (Post-Project Interview)

Conversely, the TA who had not previously taught in the biology courses had fewer expectations for personal and student behaviors.

Well this is all new to me. I’m not sure yet how I will be teaching, and will have a better idea a few weeks or so into the term. (T1, Pre-Project Interview)

Well, from last year, I remember the discussions related to Tay-sachs and genetic screening. Also, I’ve heard about new genetically engineered plants and animals in the news, and of course, cloning. (T5, Pre-Project Interview)

Subjects also were impacted by other University biology courses, particularly TAs and faculty who had taken many university biology courses in the past. Only one of the students remembered encountering a project topic in a previous course.

I guess I was most familiar with some of the agricultural aspects, you know the food, the genetically engineered foods. They covered a bit of this in a university class I took up in (different university) so I was a little bit familiar with the medicine aspect, treating genetic diseases, Tay-sachs, and others. (S3A, Post-Project Interview)

When asked if this previous experience influenced the group’s project, the student responded

Well, we did talk about agricultural uses, partly because I already knew a bit about it, yes, I think so, but were assigned gene therapy. (S3A, Post-Project Interview)

Other students utilized specific examples of technologies they had learned about in other courses, and applied those examples to the project topics.
It's impossible to know the long-term effects of a new technology. For example, the steam engine and cotton gin had a major impact on society and the economy. There were certainly opponents and problems, but over the long-term these technologies were extremely valuable. Instead of being afraid or ignorant, we need to have discussions about how this new technology fits into our society. (S2A, answer to opposing supergroup question, Debate)

TAs noted that previous courses in genetics helped them pick up on the project topics rapidly.

Uh, most of it (teaching) was pretty much new to me, I haven't worked with anything genetic. One thing, my experience in biology made it a lot easier for me to understand what the issues were. (T1, Post-Project Interview)

Some of the TAs mentioned the impact of required departmental seminars on their background knowledge.

T3: ...I suppose I haven't really ever run across technologies in my class work, you know it's been a while since my basic biology courses. Um, but I know there are attempts to alter plants in ways that may threaten other plant species.
F1: Where did you hear about that?
T3: Well, it has come up in our department, our seminars discussing problems with loss of native species. These new plants can out compete and displace other plants.
(Post-Project Interview)

Classroom comments suggested that limited TA understanding of project topics may have impacted their teaching. For example, TAs often did not understand specific students questions.

F1: Would you say that you there were aspects of the genetic technologies that the students knew more about than you did?
T4: It varied, I think in general because of my biology background I have a better grasp of genetics, but they definitely were able to learn a lot from their research.
F1: One of the students made a comment during the debate about how genetic engineering may relate to energy shortages?
T4: Some of the questions were a little off task.
(Post-Project Interview)

Only a few student subjects mentioned the impact of High School courses on their learning related to the project. These impacts were primarily related to boosting beliefs in ability to master genetics content.
Maybe, I don’t really remember gene therapy or anything, but I did know about Punnett Squares and other things like Mendel, so I think I started in a better place. (S4A, Post-Project interview)

Conversely, students and TAs discussed not having sufficient prior course exposure in high school or the university to genetics concepts. Faculty also noted that genetics had changed dramatically since they had taken courses, necessitating self-study of concepts.

The impact of Other Courses besides biology courses appeared to impact learning, particularly related to formulating arguments. Other courses, besides biology, that impacted learning were grouped as Science and Non-Science. Students initiated use of examples from other subject areas in the annotated references. TAs and faculty, with recent course-related work in biology followed the students by revisiting ideas from earlier courses. Students who had taken history courses referred to earlier technological controversies such as nuclear energy.

Students in business majors used examples from those courses in preparing debate arguments.

So now you can actually patent genes, which takes control away from people and puts it in the hand of companies. What will happen to less developed countries that can not afford to buy from these companies? Genetic engineering is expensive. How will the costs be covered? Can independent farmers in these countries afford these crops, or will this be under government control? (S5B, Debate)

Cultural experiences included Family and Community experiences. Background knowledge in part came from family experiences. For example, a student from a Family with a forestry background drew heavily on knowledge of forestry practices while researching genetically engineered organisms. Similarly, a TA from a family with strong environmental beliefs and practices, discussed developing tactics to share those beliefs with students. The subject’s Community backgrounds, such as small town vs. big city, Northern vs. Southern state, also appeared to impact learning. The family and community impacts were persistent in subject data, reflecting that tacit learning, learning through extensive experiences, impacted project behaviors.

Students demonstrated the impact of Work experiences on learning. This included using examples such as economic considerations and food labeling from their current and previous jobs. One student (S5C) with experience working at a newspaper
appeared to spend more time researching the project topics than many of the other student subjects.

Subject learning was impacted by Media, including Television, the Internet, and Print Media. Most recognition of genetic technologies at the beginning of the project came from exposure to television. As a result, understandings were brief and primarily dealt with major news stories such as the cloning of Dolly the sheep. Early in the project, faculty, TAs, and students used books, including the textbook, for basic definitions. These definitions provided keywords but limited updated information on the technologies, leading to the development of misconceptions on progress in some of the subjects. As the project progressed, most subjects relied primarily on Internet resources, which led some subjects to focus on specific, dated, and/or incorrect information, while others learned substantial breadth of topics. Use of the Internet initiated further consideration of the topics of judging resources and plagiarism.

Background knowledge of the project topics differed in the three subject groups. Students knew little about the genetic technologies that were the focus of the project, although several had heard of DNA fingerprinting and cloning. Similar to the students, the TAs had limited background knowledge of the definitions, techniques, and recent developments of genetic technologies, although they had more developed ideas of applications and issues from news coverage, discussions with other graduate students, and course work. The faculty had a little background knowledge in the applications and issues associated with genetic technologies, primarily from teaching aspects of genetics, and news coverage.

In the initial week of the course, prior to beginning work on the project, students had heard of a few types of genetic technologies, primarily discussing what they had heard on Television regarding cloning (Dolly the Sheep) and DNA fingerprinting (O.J. Simpson Case). Early in the project, after defining gene therapy and genetic engineering, students thought that gene therapy was commonplace and that few foods were genetically engineered, stating that these views were based in beliefs that medical technologies were advanced and the government regulated technological development. By the end of the study, students expressed that they learned that gene therapy was uncommon but genetically engineered foods were commonplace. None of the student subjects could explain how these (or other) genetic technologies were performed. By the end of the study, various students could explain different aspects of genetics techniques.
The Internet was the primary source of information with convenience cited as the primary reason for its use.

We went to the Internet, it was the easiest. Yeah, I did a general search. (S1B, Post-Project Interview)

I went to Scientific American and I thought it was really nice they were on there (the Internet). (S5A, Week 4, Formative Interview)

Some of the students used the Internet to locate journal articles later located in the library.

I started with the Internet and found a list of sources using the library system, OASIS. I went right away to the library and made copies of a few of the good journal articles. (S5C, Week 5, Formative Interview)

It looks like I'll be putting together the activities for the project myself, which will be good because I can try to match them up with the Standards, Benchmarks, etc. They should be done by the end of this week, so I can get them in the Appendix of my proposal. (Researcher Journal)

The impact of previous exposure to Print Media, including newspapers, magazines, and books on initial understandings of genetic technologies and teaching varied by subject group. Students mentioned reading about issues associated with animal rights in the campus newspaper. The TAs who had taken science education courses mentioned that they related information from assigned articles in those courses to their teaching during the project. Faculty drew on general information on genetic technologies covered in the textbook and journal articles when designing the curriculum.

Teaching and Studenting Experiences

All of the course participants had spent extensive time in the educational system and had formulated ideas about teaching and learning prior to participation in the project. Impact came from Previous Similar Courses, Previous Dissimilar Courses, and Concurrent Courses. Subject roles within the project enabled (or forced) subjects into drawing on these past experiences.

From previous similar courses, subjects incorporated Science Representations and techniques for developing Course Participant Relationships. Science representations included ways of viewing science that impacted ways of thinking about and sharing knowledge. TAs and faculty commonly drew on science representations
from previous courses to discuss teaching strategies. However, these examples were often not a close match to understandings of genetic technologies, and subjects sought related examples in genetics.

Subjects also stated using strategies developed in prior course work to interact with other course participants. This included students determining when to ask TAs and faculty for assistance, TAs communicating with irate students, and faculty planning ways to introduce changes in project materials to TAs. A few students noted that required university diversity and discrimination courses had not prepared them for group interactions.

TAs indicated that they had learned about a variety of aspects of teaching due to participation in the debates. Experience affected the responses to this question, as TAs noted the impact of their prior teaching experiences (or lack thereof) on learning about teaching.

This was different than the Salmon Project. At first I treated this project pretty much the same, but then I tried some what the other TAs were doing. (T3, Post-Project Interview)

Tough question. Its hard to say what I learned about teaching from the activity because this activity, because this being my first term teaching, I've been learning from everything. (T1, Post-Project Interview)

Subjects incorporated understandings of Instruction and Assessment from Previous Dissimilar Courses in completing the project. In the final interviews, students discussed examples of instruction and assessment from numerous other courses. This including weighing which instructional strategies and materials appeared to be effective, as well as forms of assessment that appeared to be authentic to the subjects.

Since the project format differed from teaching TAs had carried out in previous courses, there was more of an equal playing field for the TAs in the context of the studied innovation. Relevant instructional strategies from the previous term's poster projects were primarily carried over as a contrast to the debate.

TAs and students drew on Content Examples from Concurrent Courses. TAs were enrolled in a variety of life science and/or science education courses. Students were primarily enrolled in non-science courses. Subjects from both groups attempted to link concepts from these other courses to the project. For example, S5D was taking a political science course.
In the case of third world countries, the US currently stores food until it rots. This is a political issue, not a scientific one. (S5D, Debate)

Students utilized example of *Multiple Pedagogies* from concurrent courses to develop debate arguments. This was represented by incorporating different forms of media (overheads, handouts), with teaching styles (lecture, discussion) in order to match main debate points with a form of presentation.

Subjects also cited concurrent educational experiences in impacting their learning. Impacts included time constraints and comparisons in pedagogy. These pedagogical comparisons included degree of teacher planning and active role of students in the course. Following the project, these ideas were fleshed out with increasing detail on specific roles of feedback, addressing student variations, and so on. Two of the TAs (T2 and T4) stated that the biggest impacts on their teaching were the actual teaching itself and concurrent coursework in the sciences and science education.

My class (teaching) moved a lot of what was external to internal, and I was able to begin to watch what was going on without panicking and worrying about what was going on. When this happened, all of my science ed things began to take a role and it felt like then was when I began to make the transition to start to do something better... I knew that I had made the transition, that I was making connections with people, that I was putting things together, and that I was getting around to helping people, and uh yeah, and when I take other biology classes, I start tying things in from other areas. I was taking behavioral ecology at the time we were teaching evolution, and you always get a different perspective when you have things crossing over like that. I find it is always a synergistic experience, and now when I go upstairs it is no longer hypothetical, I have the experiences at the end of the day to bring to the discussion. And then there is no substitute for that. (T4, Post-Project Interview)

All those things they keep telling you about, start actually happening in your own classroom, and hopefully you are prepared to deal with it. (T2, Post-Project Interview)

F2's previous teaching experiences led in part to the debate format in the course. At this initial planning meeting, F1 wanted to add a presentation technique to address applied aspects of genetics, other than a poster (used in BI 101) or a paper (used in BI 102). F2 suggested "How about a debate?" He continued with a possible scenario of one TA's section debating another TA's section. In a later conversation, when asked if debates had ever been used in the course, F2 answered

Yes, back in the early 70's, during summer term. There were 80 or so students in the courses and we used the lecture hall. And at some point
in the late 60s, early 70s we tried debates during the school year too. There was also the Mary’s river basin study, where each group was assigned a special interest group. It was more of an oral presentation where students researched one point of view. There were other similar types of presentations, the forest study too, but they were not true debates though. (F2, Post-Project Interview)

F2 repeatedly discussed the impact of his previous teaching experiences on behaviors during the project.

It makes sense that someone just starting out in teaching would have a lot to learn about just about everything. When you’ve been around as long as I have, you’ve seen it all, done it all, and just have to keep adjusting the finer points. (F2, Post-Project Interview)

Background teaching and studenting experiences impacted subject learning in the context of the project, in that previous ideas and behaviors allowed subjects to approach the content and pedagogical techniques that were new to them. The shared experience of acting as both learner and teacher during the project impacted numerous aspects of subject learning, including learning about other course participant’s roles and beliefs, as well as communication skills. Subjects had previously established models of science, teaching, and learning. The project enabled some of the subjects to challenge and/or build upon these models.

Communication Skills

The archaic definition of communication is to share in common and to participate. Communication skills impacted subject project participation, and as a result, learning. These skills included Writing and Speaking. Writing skills included Assignment/Curriculum writing, writing For Self, and using the Computer Use. The ability to write impacted student performance on the annotated references and notecards. One student noted embarrassment over anyone seeing misspelled words. Other students did not realize that they lacked writing skills.

Inability to generate and follow directions related to Assignments/Curriculum was a continual problem that some subjects experienced during the project. Students were following and editing directions, TAs were following and editing directions, and faculty were creating and editing directions. As students generated directions for group members, several expressed difficulty in communicating intentions.
Students noted have difficulty with the written assignments. This was particularly the case for the individual annotated references, which students wrote alone.

It was hard to sum up an article in a paragraph. (S3D, Week 3, Formative Interview)

Problems arose when students tried to summarizing and citing Internet resources.

So, what do you put down, the address? Our TA wasn't sure. (S3B, Week 3, Formative Interview)

Student's written assignments, particularly the annotated references, included misspelled words, grammatical mistakes, and misconceptions. TA beliefs in their students' intellectual abilities were negatively impacted by the grammatical mistakes in the annotated references. TAs had begun grading the annotated references, and all expressed concern over the general poor quality of the writing styles, spelling, and critiques.

They were definitely challenged by this assignment. They could really benefit from a crash course on grammar and spelling. (T4, Week 4, Formative Interview)

My class was really struggling with trying to explain the basics of the technology. Their paragraphs really were not set up in any context at all. (T2, Week 4, Formative Interview)

Some of the students assisted other students in their groups during writing assignments.

Um, one of the guys in our group came up with the format (for the group summary). I think he’s written papers for class before. (S2E, Post-Project Interview).

There was TA concern over basic writing styles and paper structure. Some of the students had submitted papers written in a first person conversational style, and others did not cite references within the text.

It's pretty clear that they (students) have not done any scientific writing. I mean, some of the papers do not even have any citations in the text of the paper. There's no way you can figure out what the actual source of their information is for that fact or figure. (T2, Week 5, Formative Interview)

Students had pronunciation issues, for example one student was discussing somatotropin, but his inability to pronounce the term seemed to embarrass him, even though the point being made was a good one.
Other difficult words included somatic, congenital, and the scientific
types of organisms. I never thought about the difficulty of pronunciation
when we decided to have students make oral debate presentations.
(Researcher Journal)

F1 also noted in the researcher journal that the students' writing in the annotated
references matched their apparent understanding of their topic in the formative interview.

If a student had a poorly worded, confusing, or possibly copied summary
of the reference, the interview didn't go much better. At first, I though I
was just seeing difficulties of writing style, but now I'm wondering if some
students are just not as motivated to find information to the point where
they can talk about it. (Researcher Journal)

Some of the language students used in written assignments appeared to be
copied directly from the original reference, often without appropriate usage, suggesting
that students did not understand the terms.

Genetic engineering is used to describe modern techniques in molecular
biology. Genetic engineering involves harnessing the natural biological
processes of microbes, and of plant and animal cells, for the benefit of
mankind. It has opened up important possibilities in many industries.
This article is a good source of general information on the subject. (S5B,
Annotated Reference)

During a later formative interview, S5B did not know what a microbe was or what
molecular biologists studied. Plagiarism became a repeated concern throughout all of
the written project assignments.

Subjects from all three study groups used a form of notes For Self. These notes
included words, sentences, and drawings that reminded individuals of particular tasks or
concepts. Subjects generated more of these notes as the project progressed. Some of
the students used their style of writing detailed notes when developing their debate
notecards (Figure 4.1).

Student writing skills related to Computer Use also appeared as a factor that
impacted class performance, particularly related to using e-mail and word processing
programs.

I don't really use computers much, e-mail or anything, so ___ did the
typing. I pretty much did the research and thought about how to put it
together. (S5E, Post-Project Interview)
Several of the students mentioned that they had assistance from their group members in word processing.

The whole word processing thing isn’t really my thing, so ___ (S1B) gave me some help with that part. (S1E, Week 4, Formative Interview)

Verbally students expressed themselves very differently than in writing, use quotes versus inflection to indicate emphasis or error. They had difficulty in pronouncing words, but could often spell words. The researcher began bringing paper to formative interviews so students could write words or draw pictures. Some of the student expressed that they preferred writing over speaking.

Speaking skills impacting learning included dialogue with other Course Participants, Debating Experience, and Pronunciation. Although speaking skills were a component of other course activities and lecture, the project increased the degree of oral communication between course participants and required different aspects of speaking.

Ability to discuss science was a requirement for conveying information to other Course Participants. Conversations about science occurred in both the formal course settings and during informal meetings. Aspects of speaking skills are explored further in the subsequent factor category of Course Participants, including types of dialogue used by different subject groups.

Few of the subjects had Debating Experience, but those few individuals in the class contributed to subject understandings of debating techniques. None of the student subjects had debating experiences, but lack of experience added to concerns about successful public speaking.

Students had limited experience in communicating about science, and all participants had limited experience communicating about genetic technologies. As a result, Pronunciation was an issue for all three groups. F1 frequently checked pronunciation with F2 and other faculty. TAs checked pronunciation with each other and faculty. Many students did not check pronunciation prior to debating, but judged other students (by laughing and written comments) if they mispronounced a term.

Although students were impacted by writing and speaking skills, it was not determined in this study whether (or how) reading skills impacted learning about the genetic technologies. This was due to limitations in the methodologies. Since subjects did report changes in how they read technical literature, background reading skills may have been important. However, students may also have used alternative media or
researched specific aspects of technologies that were easier to read to compensate for background reading deficiencies. Alternatively, students may have had adequate reading skills for the project, with a few students extending those skills into the science literature. Further research would be necessary to elucidate the role of reading skills on student learning in the BI 10X series.

Learning Skills

Learning skills impacting subject learning included Thinking Skills, Self-Regulation, and Obtaining Information. Thinking skills that appeared to impact learning included Reasoning, Critical Thinking, Creative Thinking, and Problem Solving.

Subjects repeatedly used Reasoning (if, then) to formulate arguments and Critical Thinking skills to explore why certain arguments had merit. Creative Thinking skills included visual-spatial thinking, which can be in the “minds-eye.” For some students, particularly those from disciplines other than science, shifting thought processes to learn to interpret images and search for themes in text were particularly challenging aspects of researching the project topics.

Problem-Solving skills were utilized by subjects to deal with situations that arose during the project. F2, with the most teaching experience in the course was frequently called upon by TAs and F1 to solve class problems related to content and instruction. Students solved many of their project-related problems within their groups, turning to TAs or faculty when they were unable to come up with their own solutions (such as distinguishing between project topics or citing Internet references).

Self-Regulation behaviors that impacted learning included Preparation and Reflection/Maintenance. Preparation involved developed organizing structures. These aspects of preparation ranged in subjects from students developing a detailed outline of the steps to take in locating a journal article in the library to TAs developing a script for introducing project requirements, to faculty scribbling notes of the order to present information in the preparatory session. Not all planning was recorded, some planning occurred verbally between participants, as between group members in the hours before the debate. Although types of preparation varied enormously, the impact of limited preparation showed clearly in limited learning and project success. Subjects did adopt some of the preparation skills of other participants. TAs shared overheads, students copied note card formatting, and faculty incorporated similar lineage of ideas in lecture as those outlined in magazine articles.
Reflection, as previously discussed, gave students an opportunity to learn about themselves and maintain desired behaviors. For example, S1B reflected on her own learning.

I would probably remember this the most because it sticks in your mind and it is the most influential and I liked it a lot. (S1B, Post-Project Interview)

Research participation influenced reflection, as will be discussed in the subsequent Research Participation category.

The final group of variables related to learning skills related to individual’s abilities to Obtain Information. This included abilities to find resources at the Library and on the Internet. Students who knew how to use the library assisted other students in finding materials.

We met at the library. I hadn’t been there since all the work, and it is really different. Anyway, (S1B) knew where everything was and we found a few articles and worked in one of the study carrels for a few hours before we split up. We got quite a bit done, even though we goofed around a lot too. (S1D, Week 4, Formative Interview)

The researcher utilized library resources that had suggestions for minimizing plagiarism (Pechenik, 1988).

Some students mentioned that they had difficulty in locating web resources.

I didn’t find much related to my topic. (S2B, Post-Project Interview)

Many of the students had difficulty locating information on the Internet related to the debate arguments regarding governmental regulation of genetic technologies. Only two of the 25 student subjects specifically asked questions related to whether or not the government should control the technologies.

Is the safety of genetically engineered foods in question? Why? What’s wrong with them? Should labeling be provided for consumers? (S4C, Written Debate Question)

Who should get to decide how we regulate genetically engineered foods? (S5C, Subject Underline, Written Debate Question)

TAs used the Internet to check students references and project information.
They were checking student accuracy (T1) and trying to learn more about the genetic technologies (T2 and T5). All three of these TAs mentioned that they spent hours visiting these web locations, but when asked if they were doing anything differently in their teaching, replied "not really" (T2). T3 and T4 had limited departmental access to computers, and both mentioned that this impacted their ability to review the websites.

Topics that F2 researched using the Internet (such as Monsanto genetically-engineered organisms) were repeated during the course by F1, TAs, and students. The questioning began with a request for information about this topic.

That story points out so many different aspects of the new genetics, the corporate role in developing, patenting, and marketing technologies. It is an ingenious decision to market both the pesticide and the pesticide-resistant crops. (F2, Post-Project Interview)

When asked, F2 stated reading about the topics while searching for biology information on the Internet.

External Conditions

Factors classified as external included instances subjects had limited individual control over. These factors ranged from those the subjects were not aware (such as structure of the content) to factors subjects repeatedly referred to (such as interactions with other course participants).

Structure of Content

Aspects of the structure of the content covered in the course, including the Project Topics and Other Course Content, impacted learning. Characteristics of the project topics that impacted subject learning included the Varied Nature of Concepts, Media Coverage, and whether the topics were Recent vs. Older. Generally students cited that content was the most significant aspect of learning, TAs focused on teaching. F1 focused on content, F2 on teaching.

The Varied Nature of Concepts associated with the project topics led to differences in learning. Within gene therapy, there was generally less controversy in the American literature over whether the procedures should be performed for an individual with a life-threatening disorder. With genetically engineered organisms (particularly plants), students did not perceive benefits as necessarily out-weighing societal risks, and
it was easier to imagine the technology being banned. Additionally, the gene therapy topic was more succinct, a few definitions and classes of basic techniques.

For the topic of gene therapy, the technology was the focus of interest, such as developing a new vector. For genetic engineering of other organisms, the application is the focus. Limitations of topics impacted types of knowledge or conceptual understandings that could be acquired. Students researching gene therapy appeared to use technical terms about the technology's procedures more frequently than those researching genetically engineered organisms other than humans.

I learned that they have different things like lipids and viruses to carry the DNA to the transplanted cells. But the scientists haven't found a way to get the DNA to produce so the patients don't have to get repeat treatments. (S3A, Week 5, Formative Interview)

One thing I have learned is that all genes have three sections. A promoter that tells when and how much and a coding sequence that tells which protein and a termination sequence that stops the process. (S4C, Week 5, Formative Interview)

Many of the students in the study struggled with explaining the process of gene cloning, but those students who had researched gene therapy had a more accurate description of the process than those studying genetically engineered organisms.

A DNA strand is cut into pieces to obtain the genes. Then vectors, either plasmids or bacteriophages, are used to inject the gene into the bacteria. Bacteriophages are viruses that infect bacteria with a gene. Its only a matter of getting the genes into the vector. For plasmids, the recombinant DNA is made by adding the new gene to the vector. The bacteriophages are fixed by injecting the material into it and then splicing the DNA. (S4C, Post-Project Interview)

Although students who had researched genetic engineering may have used a few of the terms correctly, the entire process was generally described out of order or incompletely.

First, the gene must be acquired. Then its put into a virus or a vector and the virus is put in with bacteria. The virus injects genes into bacteria and the bacteria reproduces it very quickly and you get many of the desired viruses. This process is called bacteriophage. The vector is part of the DNA where this process takes place. (S2D, Post-Project Interview)

Students researching genetically engineered organisms found more information on issues and applications associated with the technologies and focused topics like limited safety testing.
Something that I have learned about my topic is that there has not been enough testing on GE foods yet to determine if all of them are safe. (S2D, Week 5, Formative Interview)

Not much is really known about genetically engineered foods, they are changing the genetic structure and don't know exactly what is going to happen. It could have some major consequence down the road. (S5C, Week 5, Formative Interview)

Many of the students studying genetically engineered foods discussed the need for labeling, another topic commonly discussed in available popular literature.

In my research I have learned that there is a very heated debate as to whether the food should even be sold, some groups are simply fighting to have all genetically engineered foods labeled. (S2A, Week 5, Formative Interview)

One thing I have been learning from this project is that there are a lot of foods that I eat on a daily basis that have been genetically engineered. But the FDA is unclear about labeling, so as a consumer I have no idea that my food has been altered. Some examples of foods are Kellog's cornflakes, Gardenburgers, and Frito Lay cornchips. (S1C, Week 5, Formative Interview)

Students assigned to the topic of genetically engineered organisms discussed additional potential negative aspects of genetically engineered foods.

Some negatives include the inserting of recombinant DNA to alter a product. This can cause severe allergic reactions due to the fact that the rDNA can come from an allergen-containing food. (S5A, Week 5, Formative Interview)

I have learned about dangerous side effect of genetically engineered foods. I learned how a genetically engineered fish can grow and cause competition with natural fish for food if they escaped and that would cause the population of natural fish to decrease. (S5E, Week 5, Formative Interview)

I've learned that many people are very against genetic engineered foods because of their religion. They are appalled that genes from pigs can be in their carrots. (SSD, Week 5, Formative Interview)

Fewer students discussed the potential benefits of genetically engineering organisms than the potential negative aspects, reflecting in part the amount of coverage of the negative aspects that they found through Internet research.
I have learned that you can engineer plants that will kill bugs if they eat the plant, with bacteria, like Bt. (S4E, assigned to gene therapy, researched genetic engineering, Week 5, Formative Interview)

Genetic engineering in plants is done to help them grow bigger, more colorful, stronger, and more pest resistant. (S2E, Week 5, Formative Interview)

Prior to the debates, few students stated that they learned both negative and positive aspects related to their genetic technology, and provided examples.

I have learned that genetically engineered foods could possibly enable us to feed the world’s poor. Also that new foods are in the works such as no-caffeine coffee. These foods could also create new allergens. Third world countries are protesting uses of GE foods because of expense and corporate financial tricks. (S2B, Week 5, Formative Interview)

Advances in genetics were intertwined with politics, religion, and economics. These issues would continue to expand and impact student’s lives in the forms of adult human cloning, germ-line gene therapy, and increasing complexity of genetically engineered organisms.

Biglan (1973) classified subject matter as having three dimensions: hard-soft, pure-applied, life-non-life. Project topics, similarly had this dimensionality, and as a result, had numerous insertion points for individual subjects with different interests.

*Media Coverage* of the project topics impacted subject access to information. Students in the genetic engineering group were more focused on negatives due to media coverage of topic until the week six Tuesday lecture. A few news stories permeated the debates, particularly the stories related to GE-related deaths. Media also included popular movies. Students had little awareness of older science fiction, but a few were influenced by the movie *GATTACA*.

Subjects in all groups did not fully comprehend the genetic technologies techniques. This was in part due to limited need to understand the techniques in communicating other ideas (such as applications and issues), but is was also related to the extensive time it would take to perform certain techniques in the classroom setting, as well as an artifact due to the way popular journal articles are written. Most subjects, including the researcher, referred to review articles in magazines such as *Discover* and *Scientific American*, never directly reading about the details of the techniques in science journals. Instead science journals were sought for current information about applications, particularly related to human diet and disease.
Some of the students indicated difficulty locating information on their topics from sources other than through the Internet.

No, there were not really many magazines out there, I think some people (in our group found them), but we mostly used the Internet, it was so easy, you know exactly where to look, it goes so fast. (S5B, Post-Project Interview)

Some of the students cited difficulty in using internet resources.

I found very little information on xenotransplantation, I found a few Internet sites, but the information on those sites was very limited. And a lot of it, this is another problem with the Internet, a lot of it you just don’t know, with books you know how recent it is, but with the Internet, I’ve seen stuff where the link is from 1985. You look at the bottom and it says AP Press, 1985. (S4D, Post-Project Interview)

Several students discussed difficulty in finding material covering all sides of their issue

Mostly I did magazine articles because there was so much in magazines about it. And a lot of it, this is kind of interesting, I found a lot of things against, everything I found was against genetic engineering, so when I heard we were going against, I said Whew! A girl in my group said all she could find was things for it on the Internet. Eventually I found a few things for it so we could be prepared to be responsive on both ends of it, but it was interesting that we found such extremes of information. We mainly used the Internet, but we found a couple of magazine and newspaper articles on it. (S1A, Post-Project Interview)

Most of the student groups also used library resources, primarily as a back-up to Internet sources of information that appeared to them to be inadequate, or simply due to possessing more background experience using books.

Um, library sources. We spent a lot of time at the library looking at genetics books and we found like three that were really useful, but a bunch of them were just not helpful at all, and they had pros and cons in them, so we were really happy about that. Not too many people went to the library, I think most people used the Internet. Yeah, we started with the Internet but we didn’t think it was very in-depth and we were confused as to what was gene therapy and what was genetic engineering and a lot of it was on cancer and AIDS technology. (S2C, Post-Project Interview)

We mainly used journals and books. There were some really good books in the library. There were, I went the first day of the assignment and found four books, four brand new books that were 1997 or 1998, and um, some of it was a little too specific, bacterial stuff, that was a little beyond me. It seems like the most popular source was the Internet. They said, I
found this great website and its awesome and all of this stuff, but I don’t like websites this much. (S2B, Post-Project Interview)

The resources began focusing students on specific topics, such as the genetic engineering of plants.

... discusses how several research groups and biotech firms have genetically engineered corn and other plants to manufacture antibodies. The scientists hope to cheaply mass produce antibodies that can treat cancer, stop the spread of infectious diseases, and even stop tooth decay. Using plants for genetic engineering in this case is a good idea. Using plants is a good way to stay away from the ethical questions that may arise. This could new idea could aid in the health of humans. (S5A, Annotated References)

Another aspect of the content that impacted learning was whether information was Recent or Older. Older information, such as that associated with established genetics principles of dominance/recessiveness, or production of Bt corn had more published information available in print and electronic formats. This information also tended to be more accurate. By contrast, more recent information, such as gene therapy trials or genetically engineered mammals were covered in less detail, and were more likely to be misreported or rife with bias.

It was different to try to find usable resources, there was a lot of bias and sometimes you couldn’t tell where a site was coming from. (S2E, Post-Project Interview)

Subjects from all three study groups were unclear of how advanced technologies were prior to the project, and the scattered nature of information on recent developments led in part to prolonged confusion about the project topics.

Some of the students mentioned that gene therapy was still in the early stages of development. This contrasted with student responses to the pre-project activity questions and earlier formative interviews, when most students commented that genetic technologies were in advanced states of development. This indicated that some of the students were learning more about the progression of gene therapy.

Case Western Reserve University School of Medicine is optimistic about artificial chromosomes surviving and replicating itself in cells. The genes are placed in the chromosomes and then observed to learn more about how they really function. This article is positive about gene therapy leading to a correction of gene disorders in the future. Although their is a
long way to go, genetic experts have come farther than they have ever been. (S3A, Annotated Reference)

However, a majority of the students were still confused about how far genetically engineered organisms and gene therapy had progressed. In 1999 genetically engineered foods were already in widespread use in the US and gene therapy was still in early stages of development.

With the new technologies, we may soon have genetically engineered food on our grocery shelves and not even know about it. (S2D, Annotated Reference)

Many diseases that were uncurable now have cures made from understanding the specific genes which need to be targeted. (S4B, Annotated Reference)

This article raises many concerns and questions about genetic engineering. Genetic experts are breeding plants with genes from animals and bacteria – components that would never have “entered” plant genetics. This introduces many new possibilities for things going “awry.” Due to the lack of constraints, the long-term results are unpredictable. This article, written in 1996, uses more negative spin on genetic engineering. (S2A, Annotated Reference)

In this study, faculty and TAs developed content knowledge, particularly aspects of the project topics, such as definitions, applications, and issues, in order to keep up with student learning, possibly indicating that this type of curricular innovation, in which content and pedagogy are in flux, may address the missing paradigm.

Other course concepts impacted learning through Multiple Representations of knowledge, Linked Concepts, and Application. Subjects in all three groups related that they learned more about specific course topics because of a variety of characteristics, or Multiple Representations of those topics. Some students referred to remembering particularly stories, others specific illustrations, and others concepts that related to their own interests, including the project. Different subjects related to specific representations. For example, in response to the post-project interview question on protein synthesis, some students recalled information from a laboratory puzzle depicting the process, where as others referred to the poster they constructed themselves. The type of representation appeared to impact learning related to debate topics in that students who primarily focused on illustrations of their technology had more limited information than those incorporating text more extensively. France (2000) discussed the need to use models to make aspects of genetics visible and comprehensible. Models were in an intermediate position between observed reality and the theory
explaining that reality. Teachers utilized a variety of models, including: flow diagrams using words or formulas, diagrammatic representations of techniques, and illustrations to represent microbial methodologies. Most of the students had learned the two categories of gene therapy from the textbook description, but also stated that they had found the terms while researching their topics.

Not surprisingly, the degree of Linkage between Concepts in the course itself also appeared to impact learning. Those topics covered in lecture, laboratory, text, and the subject's own research (such as gene insertion) were generally represented in a more detailed manner by subjects than topics covered in only one or a few parts of the course (such as PCR - polymerase chain reaction). Certain lecture stories which emphasized the link between historical development of science knowledge and current issues appeared repeatedly in conversations held by subjects from all three groups. For example, the lecture introducing the American eugenics movement of the twentieth century and its implications for twenty-first century genetics was linked in lecture and adopted widely by other participants.

Some aspects of the content simply appeared to be more difficult than others. For example, few subjects ventured far into research on techniques for treatment of specific diseases, or genetically engineered bacteria. Many studies were rich with models and statistical analyses. F2 discussed that certain genetic concepts were difficult for students to grasp.

F1: What do students appear to have the most trouble with during genetics?
F2: Inability to think in proportions, back to basic math. Problems with dominance and frequency, proportion relates to these, also probability. Probability is a very hard concept. In order to do the various problems, students need to be able to understand fractions, and they haven't got it yet. When asked the best way to become a millionaire, people say the lottery, they don't understand the basic probabilities.

(Post-Project Interview)

The Applicability, or "practical" nature of particular topics also appeared to correlate with subject learning. Much more attention was given by subjects in their project research to topics with direct application to human health and welfare, than research with applications to other organisms or furthering the scientific inquiry process. This stress on the "racy," controversial and interesting topics (to the participant) impacted the depth of learning about underlying genetic technologies techniques.
Additionally, subjects focused on learning course policies and procedures that were directly related to their own perceived success.

The practical aspects of the technologies impacted how they could be debated. Students also mentioned the possibility that some topics or arguments were easier to debate than others, something the faculty had not considered when developing the project curriculum.

I think we had a really strong side on the debate, first of all because I talk a lot, but also because what we were technically set up to debate is very debatable, because all that is really left about genetic engineering and regulation, is whether or not to regulate the research, because anything they put out has to go through the FDA, several steps, and the EPA, they have to go through that, so look, anything that hits your table should go through, you can’t argue that, how can you say regulate research? There isn’t much to argue for that, how would you do it? (S5D, Post-Project Interview)

Just as ideas in science typically begin with researching observed phenomena, followed by research into aspects of mechanism, subjects began researching the easily observable aspects of genetic technologies such as sales of genetically engineered foods and vaccine gene therapy trials. However, the basic underpinnings of these technologies, the historical development of techniques, were more challenging to subjects, and were typically developed later if at all. Multiple representations, linked concepts, and application of those concepts in the project may have enabled different groups of learners to master some of the material.

Project Design

The design of the genetic technology project itself impacted what subjects learned. This included aspects of the Format of the project and sources of Supplementary Information. As discussed relative to the data presented thus far, this innovation differed from other aspects of the course, and these differences impacted learning. The nature of the project appeared to impact learning as it required investigation, a form of inquiry.

Aspects of project Format that impacted learning included Participant Roles, the Research Requirement, the Debate, forms of Assessment, and Time Considerations. The project structure required specific Participant Roles, or individuals to interact in specific ways, and these resulting interactions impacted what subjects learned. Students assisted one another outside of scheduled class times to prepare group
summaries and debate arguments, TAs spent more time listening to students and reading their work, faculty spent more time discussing content with students.

Roles in the course impacted what each of the subject groups learned about the project topics. Students were given “free reign” to develop understandings of genetic technologies with limited guidance from the curriculum.

When I was first heard about genetic engineered food, I had no idea what it was about, but as I did my research I learned a lot about it and was really glad to do this topic because now I am aware of the dangers of genetically engineered food. (S1D, Post-Project Interview)

This led to exploration into many aspects of genetic technologies in developing the annotated references. Later, as students began to focus on the debates, emphasis focused on clear definitions and descriptions for the introductory remarks (project requirement), applications for the pros, and issues for the cons.

TAs shared information with one another. T1 designed a debate form and all of the subject TAs used a version of this form (Figure 4.14).

___(T1) came up with this form, and you know I really like it. I was going to just have them (the students) write on a piece of paper, but this is much better. (T3, Week 6, Formative Interviews)

While preparing the curriculum, and the project in particular, faculty focused on issues. Learning about additional aspects of the topics, and more depth about the issues, occurred in response to TA concerns, student questions, preparing lectures, and listening to the debates.

There were similarities in learning between the three subject groups. All three groups learned the definitions and general progress made related to the project topics. This was largely due to the initial project topic ambiguity and student confusion over topics, as expressed in their annotated references.
The Research Requirement portion of the project engaged all of the subject groups in locating and assessing information on genetic technologies. As previously discussed, all subjects engaged in locating, summarizing, and critiquing genetics technologies information.

The Debate portion of the project put pressure on students to prepare to speak in public, on TAs to manage student interactions during the debates, and on faculty to learn new content to assist students with debate arguments. The debate itself involved dialogue, which impacted learning. Dialogical learning often focused on a teacher using
classroom questioning to encourage students to argue different aspects of issues. In the project, students played an active role in directing a dialogical experience.

The format of the debate, in which it was important to anticipate questions and understand opposing views in a competitive setting "forced" participants in all three subject groups particularly the students, to learn content. As the other supergroup attempted to undermine arguments through examples, the best defense was a good offense through presentation on detailed and substantiated information.

Students commented on the relationship between their learning and the debate format.

I felt participating in an active argument made it work in more than anything else could have. (S2D, Written Debate Response)

I learned that with a debate in which you are given or assigned a pro issue or a con issue, no matter what your belief, you can still gain valid information and make for a great argument! (S4A, Written Debate Response)

Some of the students purposely researched topics they did not know a lot about because they thought that would be an advantage during the debate.

We focused a lot of ours on plants and benefits like that, because no one knew much about crops and no one could refute what we were saying. We kind of had an edge, it was like look at all of these benefits that you are eating, and they couldn't really say anything, they were ready to debate, you know cloning or changing mice. (S5B, Post-Project Interview)

No, I've used the computers for finding information, I hadn't done a poster (salmon), and I had never been on a debate team before so that was kind of nice, and I think that debating sounded easier than a presentation because in debating its easier to just talk. (S1A, Post-Project Interview)

Students commented that the debate stakes were high, and that this impacted the tenor of the debate.

I felt that the debate was more of an attack — a not let finish speaking style, and possibly needed some rules prior on interrupted. (S3E, Written Debate Response)

The debate itself was fun, especially a couple parts where it seemed to get out of hand, and you could tell that people were getting a little too involved. I think that we as college students, need to know what is happening in our world because we can make a difference and some of
us might even be involved in something that we debated in class. (S4B, Written Debate Response)

TAs also perceived that aspects of the debate had an impact on student interest and success.

Oh yeah, I love this idea for a debate because they were so motivated by the fact that they were going to be speaking in front of other students that the points didn't even matter, and I think they learned so much looking through the material on their own, that I like that idea. ... and they learned so much when they had to get in front of the class. I mean you can't do it with every topic, you can't do it all term long, but you can especially choose a topic where they have to make a choice, I really like that with college-level students because I think it made them think about something they had never thought about before. (T2, Post-Project Interview)

TAs were called upon to mediate and respond to that information during the debate, and both TAs and faculty had been questioned over content as students prepared to debate. All TAs mentioned learning more about the debate topics, largely due to listening to the student debates.

Well, I learned more about genetic engineering, and gene therapy, especially some of the newest news stories that the students talked about during the debate. (T3, Post-Project Interview)

Um, well it refined my understanding of what genetic engineering, or gene therapy is, how it works. I never really got much of that as an undergraduate. And I haven't really looked at it since then. It was interesting to take polls in my classes to see what students thought, whether they were for or against it. I guess I was a little surprised to see how in favor of regulation it was. That's kind of the mood of the whole country right now: less government, less government, but let's keep the regulations on. (T1, Post-Project Interview)

Some of the TAs mentioned that they had learned more about the content from the debate than they had from university courses they had taken.

I learned more about the technologies than I knew before. One of the things about the genetic courses on campus is that the technologies are geared more towards the basics, analyzing quantitative models. In this case they were placing genetic in the context of the real world and really understanding the importance. (T4, Post-Project Interview)

One of the TAs mentioned that it was difficult to remember what she had learned from the debate.
Um, the things that I didn’t know about genetic engineering were when they gave specific examples of products that had been put on the market and pulled off the market and then had problems. Like they brought up the Flavr Savr tomato and some cotton thing, I don't remember that now. So the specific examples were interesting for me to sit and listen to, and sometimes when one side had brought something up and it was obvious the other side hadn’t heard of that before. Gene therapy, I'm trying to think about what they focused on now, because I heard so many. It was interesting with the gene therapy thing to hear their views. (T2, Post-Project Interview)

Faculty also reflected on the impact of the debate. F2 assessed project success in part on student interest, but noted that this interest was not unexpected.

Pretty impressive isn’t it. They are spending two hours listening to each other talk about genetics, and they don’t even seem to mind it! I think we’ve got a winner here. (F2, Week 6, Formative Interview)

I don’t think there were any surprises. This course curriculum is like a wheel, or maybe more like a Möbius strip. Nothing is really new, it just seems new. (F2, Post-Project Interview)

Students and TAs discussed ways in which the project Assessment scheme impacted their own learning. Some students stated that they put more effort into the project because of the requirement that they speak in order to receive points. A few students stated that they would have put more effort into the project if it had been worth more points. However, the same students put minimal effort into other aspects of the course as well. TAs spent more time grading student work and listening to students in order to assign grades.

The type of assessment, assembling multiple artifacts that demonstrated mastery of the project topics, resembled a form of portfolio-type of assessment. Although the project was worth a small percentage of the overall grade (6%), students spent a great deal of time working on the various components of the project, with some students reporting spending more time on the project than on studying for the exams. The reasons for this ranged from the project being more interesting, to concerns about public speaking, and pressure from group members.

A few students noted that the assessment structure of the course impacted group dynamics.

Grading in a group means that people who work hard have to work that much harder to help the people who don’t. I don't think it helps anyone
more, we have to keep getting down on then, and in the end everybody does different things, and then we copy it. (S3B, Post-Project Interview)

TAs had addressed this question while answering previous pre-planned questions. Different activities associated with the project included grading, learning about genetic technologies, leading the debate, and addressing new student concerns.

Like we were discussing, there was a different type of grading, more to read and more subjective than the right or wrong questions in the other labs. (T4, Post-Project Interview)

T2 indicated that she was learning more by listening to her students and reading their assignments.

I mean, things came up that I hadn't though of before. But the things they turned in, the summaries, were not as eye-opening as the material presented in the debate. I definitely learned things from the debate. Some of the groups brought up examples, especially with the genetically engineered food, things pulled off the market, things I hadn't heard about before. (T2, Post-Project Interview)

TAs mentioned specific aspects of sequencing student assignments, including the importance of having students turn in their annotated references early so misconceptions could be identified and completing the project early in the term.

It was pretty good. I especially liked having those annotated references to look over to see what was going to be coming up and to guide them towards the correct issues. And that's what clued me in to all of the confusion over just what genetic engineering means. (T2, Post-Project Interview)

The annotated references were most useful on that, but there were still some problems in the summaries, so those were useful too in identifying student problems. (T1, Post-Project Interview)

The project impacted participant *Time Considerations*, as there were many activities associated with the six-week innovation. Most topics were covered less than one week, where as the project stretched over six weeks. Even though subjects were not constantly focusing on the project, the sequential student assignments (pre-project activity, annotated references, group summaries, debates, notecards, exam) meant that subjects were repeatedly refocused on the material. Students stated that they were able to go into more depth on the project topics than other course topics, even if they spent minimal time preparing each assignment.
Student opinions on the structure of the project were generally positive. "I think it was laid out pretty well, pretty clear-cut." (S2D) Other students mentioned that the time-intensive nature of the project made the course more challenging.

I think it's a good idea to have a project like this because otherwise the class wouldn't take much effort. If there's not a lot of work, then it kind of makes people not want to study, with the projects and stuff you think, hey I need to keep on top of it, even though it's a 100-level you have to put the time in. (S4C, Post-Project Interview)

TAs also discussed the importance of giving students time to work on the project.

I liked having it at the beginning of the class, the whole set-up for the quarter was much better than having it at the end, I really appreciated that. The way that everything sort of fell out. It could be a little tighter, to lump, because they were waiting for the day or two before it was due to do the work, when you draw it out there is just more time between those big chunks. (T5, Post-Project Interview)

Most of the TAs discussed spending more time on the genetic technology project than on other course activities, engaged in a variety of novel tasks. These tasks included grading the annotated references, group summaries, and debate notecards.

Um, reading the annotated references took more time, especially when I tried to check up on some of them. But, I wouldn't say that it was taking up a horrible amount of time. (T1, Post-Project Interview)

TAs indicated that they generated handouts and overheads more frequently for the project activities than they did for other laboratory and recitation activities in the course.

Well with both the projects both terms we made little grading sheets for them and trying to inform them what we would be looking for on overheads, and that's something we don't do during the normal activities. (T2, Post-Project Interview)

TAs stated that they did not have do much library or computer researching related to the topics, however three of the TAs (T1, T5, and T2), had checked student references and/or searched for additional information on the topics.

Um, well yeah, I went over the techniques and stuff in the book, I didn't do much in terms of my own searches on the internet, or the library, but I did check up on a few things that came in the references, about three or four internet sources I checked on and one thing in the library I actually looked up. (T1, Post-Project Interview)
Yeah, initially it took a little more time because I had to make sure I had the layout, it was a little complex, but then once they got started on their own it took a little less time, I think it balanced out. They were becoming the experts and I was just sitting back. But like prep-wise, I'd say I got pretty excited about it and that makes it easier to put in time, so I don't remember putting in lots of time, but that was probably because it was something I was interested in, so that I was interested. I checked some students references and then would do my own personal interests and then would bring that into class and tell that story, I was just looking into the references because some of it sounded real cool. (T5, Post-Project Interview)

One of the TAs thought the project activities actually took less time to teach because students were doing much of the work.

No, I actually thought, if anything, that it was actually less labor-intensive because what your objective was to get them rolling and to be a resource. They didn't seem to have any trouble executing that in most cases, it was give them the assignment and it was off to the races. (T4, Post-Project Interview)

The long "life span" of time students worked with one another, interdependence of students on one another's assessment, and size of the groups meant that students were given strong incentives and opportunities to develop ways in which to work with one another.

As the course progressed, TAs primarily learned aspects of the project topics, such as definitions and issues that were closely related to their teaching. TAs were attempting to clarify the ambiguity regarding the project topic definitions and answering student questions as to how to best debate opposing supergroups. TAs indicated learning little about the techniques, but did express that they had learned more about the applications and new developments through listening to their students debate.

Supplementary information impacting learning included information from the Project Directions, Textbook, and Lectures. TAs and students were impacted by the form of the project directions. Subjects from both groups were impacted by the initial ambiguity of the Project Directions, particularly the distinctions between genetic engineering and gene therapy. The introduction provided an overview of the project.

In BI 102 we begin with six weeks of genetics, followed by two weeks of evolution, and two weeks of animal behavior. This week you will begin a six-week in-depth examination of a genetic technology (human gene therapy or genetically engineered organisms). This project will culminate in a debate over whether or not the government should prohibit (or
severely limit) the specified genetic technology. There are several assignments that will help you find and organize materials for this debate. The primary objectives of this project are to provide the opportunity for in-depth research of a complex biology topic and an opportunity for application of that research to decision-making concerning a current and controversial topic. (Pre-Project Activity, Appendix E)

TAs had to reiterate specific directions related to the project directions in later activities in response to repeated student questioning.

The note card was a little tricky because I wasn’t sure exactly what questions were going to be asked and so um, I’d probably say about an hour to go through my notes and research materials. I picked out the stuff that other people were talking about and that the TA had mentioned, and that (the TAs comments, helped me out a lot. (S1B, Week 6, Formative Interview)

As previously stated, additional ambiguity existed related to distinguishing between the two project topics in the initial directions. Two of the TAs noted that students mentioning the project topic conflict had influenced them to look up information.

It was so student-driven, I think the biggest thing for me in terms of work was trying to figure out all the ways that they could misunderstand the directions. What was genetic engineering? What was gene therapy? Those were most of the things that I had to deal with, they really didn’t have to do it, what might be ways they could differentiate between the two questions. (T4, Post-Project Interview)

The thing with the 37 people dying from Tryptophan, well its kind of on the borderline of the definition of genetic engineering, I think it was the gene that was inherent in the bacteria, but they amplified the copies in the bacteria so it would produce more and doing that and there were a couple of other tweaks they did to it that ended up producing a byproduct that was toxic. No I had two or three people mention this in their annotated references, I had warning on that one and researched it. (T1, Post-Project Interview)

Students revisited the Textbook to prepare the portion of the debate introducing the basics of each technology. Faculty referred to the textbook at the completion of the debates to assist in writing exam questions on material that was available to all students, irrespective of assigned debate topic.

The textbook definitions were clear, but not consistent with the project requirements or more recent developments in genetics, adding to confusion over how to utilize key words for Internet searches. The groups used their textbooks to “get the definitions right” (S4C, formative interview), but demonstrated confusion over
distinguishing between what was possible, and what may be possible in the future related to genetic technologies.

TAs also used the textbook to initially find project topic definitions.

I think I mean the first thing I did before the recitation that we discussed the project, I read the book, because I don’t think I could have sat there and defined any of it, I mean I would have had some understanding of it, I just wouldn’t have been competent enough to even introduce that recitation. I mean the first thing I did was read those pages in the book, and then I felt, oh yeah, I played around on the Internet a bit at websites and I felt confident enough that I could at least lead them to look for information. (T2, Post-Project Interview)

Faculty primarily used the textbook to see what information the students had access to, and to judge whether that information was dated.

Lecture confirmed knowledge and linked students concepts to a broader picture, and provided additional specific examples. Lecture impacted subject learning. Students utilized examples from lectures in their debate arguments, TAs drew on examples from lectures to assist students, and faculty researched topics that could assist students with arising misconceptions.

The order of lectures relative to the debate also impacted subject learning. With information on genetic engineering techniques and the benefits/problems associated with recombinant foods presented in the Tuesday lecture, most students debating those topics could refer to those topics. By contrast, those students debating human gene therapy, which was primarily covered in the Thursday lecture, primarily referenced their own research and the textbook, with lecture references limited to the American Eugenics movement, which had been discussed the previous week.

Lectures introduced information in a manner that differed from the textbook, the activities, and other resources. Particular visual representations presented in lecture, such as an artist’s rendition of a tomato containing a human fetus, appeared in later student conversations about the impact of genetic technologies. Additionally, stories appeared to be repeated and by students, TAs, and faculty, particularly the American eugenics movement and the cloning of Dolly the sheep.

Students linked their research to material that had been presented in lecture, including the procedures of gene cloning and the American eugenics movement.

As we saw in lecture today, DNA is cut by restriction enzymes, the genes are combined with vectors, plasmids or bacteriophages, the recombinant
DNA enters the bacteria, and the bacteria produce proteins. This had led to much more dramatic changes than have ever been seen before by conventional breeding. There has been genetic engineering of tomatoes; potatoes, and corn, but there is still is a lack of regulation, especially in labeling. (S5D, Debate)

That's all real exciting and everything, but (class laughs), but we have to think of our future. What will we do with a whole generation of look-alikes? Now there is cosmetic gene therapy, which will cause new problems, a society of genetic dos and don'ts. For instance, in that movie from lecture, GATTACA, people's lives are determined by the genetic make-up they are born with. So, what's to prevent future generations from selecting some people over others for important jobs, or whatever? (S4D, Debate)

Lecture also clarified some of the project topics and altered subject's perceptions of the range of issues associated with a particular topic.

This is one of the most important issues that we can debate. We know from lecture that genes are the blueprints of every part of an organism. We can transfer genes from any organism to any other organism on Earth. There are many examples of foods that have genetically altered, including potatoes, tomatoes, and soybeans (shows poster of cut-out magazine pictures). These are all examples of types of foods that have been genetically engineered. As consumers, we are already seeing these plants on our dinner tables. (S1A and S1B, Debate)

Students in the genetic engineering groups were more focused on negatives due to media coverage of topic until they heard the Tuesday lecture of week six. Some of the students researching gene therapy understood the controversies and which cells were being modified, but were less clear on how sperm and eggs would be modified until after the lecture showing microinjection. The illustration and accompanied story were linked by students to their own library research.

Students in general replied that they liked the lectures. Since the researcher was one of the lecturers and was concerned that students may not want to criticize her teaching, follow-up questions were used to determine the reasons for the responses.

S5B: I'm not a biology person, but I've been talking about the class with my friend who is in zoology. I really, really love the class, for lecture mostly.

F1: What do you like about lecture?

S5B: Oh, everything, especially being able to talk about biology, now I know something, and the music, you really seem to enjoy teaching and what you are talking about. (Post-Project Interview)
Students in lecture indicated spending more time outlining class notes and readings. This behavior may have linked to behaviors related to completing written project requirements.

The amount and type of exposure to particular information appeared to impact whether it was learned. Students researching gene therapy frequently mentioned the distinction between germline and somatic cell gene therapy.

Gene therapy is mostly involving somatic (non-reproductive) therapy at present, instead of germline which affects reproductive cells. (S3D, Week 5, Formative Interview)

I have learned that while most people think somatic gene therapy is all right, a lot of people are opposed to germline gene therapy because it would have lasting effect on future generations. If you were to correct a genetic disease in one person using germline gene therapy, it would be corrected in their children and their grandchildren, and so on. (S4C, Week 5, Formative Interview)

Some of the students who had researched other genetically engineered organisms knew the definitions of gene therapy, but not as thoroughly as the gene therapy groups.

Germline gene therapy is the study of sperm and egg. Somatic therapy is the study with other parts and organs of the body. (SID, Post-Project Interview)

Other students researching genetic engineering could not define germline or somatic cell gene therapy despite its mention in lecture, the textbook, and the debates.

Somatic deals only with genes that are already there. Germline deals with introducing different genes from other organisms – that is more controversial because in reality, that's a new organism when you put different genes in. (S1C, Post-Project Interview)

Actually being assigned the topic appeared to carry more weight than lecture, the textbook, or listening during the debates.

Similarly, students who had researched genetic engineering verbally listed numerous reasons to genetically engineer plants.

Increased yield production, pesticide control, nutritional value is better, better storage life, increased quality, new possible species, also shorter growing seasons. (S2A, Post-Project Interview)

Resistance to insects, resistance to round-up, faster growing potential, more produce, like bigger apples, new strains that can survive diseases,
assuming we can do a better job designing plants than nature. (S1E, Post-Project Interview)

Those students who had researched gene therapy, generally defaulted back to the limited reasons for altering plants that were discussed in lecture.

Faster growth of plants, more crop yields. (S3C, Post-Project Interview)

Increased yield, resistance to pesticides. (S4B, Post-Project Interview)

Actually debating a particular topic linked to knowledge of that topic that persisted to the post-project interview.

Course Structure

The structure of the course itself had an impact on subject learning. This included the Activities, Accessibility, and Classroom Environment. The format of the class impacted learning. On exams, students scored highest on concepts related to the project, followed by those covered in the lectures, the textbook, and finally, laboratory/recitation activities.

Aspects of the Activities that impacted learning included the Sequence and Multiple Pedagogies associated with the course impacted course learning. Sequencing of the project requirements impacted a variety of other factors, including reflection. Subjects appeared to build ideas based on sequential reflection as the course progressed.

TAs were spending more time on course activities following the project, including asking more questions about the evolution and animal behavior content. Faculty were also linking project topics to other content in the course. During the animal behavior unit, F1 researched and lectured on recent research.

Due to the nature of the project design, culminating in the debates during the sixth week of the term, learning was spread out over the entire project, with different learning occurring at different points in the term.

Variation of teaching led to a variety of learning opportunities. Some subjects focused on utilizing text, while others preferred lecture, or locating their own information on the Internet. The project enabled students to select the form of teaching that they gleaned information from.

Students were shown, using the course schedule, that the genetic technologies lectures covering material directly related to the debate were conducted the week that
students were debating. Students were asked to comment if it was “O.K.” that the lectures occurred at that time. Many students commented that it was beneficial because they had an opportunity to research the information before it was presented in lecture.

I think it was OK cause it gives us a chance to learn on our own. (S2D, Post-Project Interview)

Um, well I guess it depends if you want people to be forced to go outside you know, to other resources for information, or that can just scrape by and just listen to lecture and regurgitate stuff back. (S3A, Post-Project Interview)

Other students thought the simultaneous debates and lectures reinforced emphasis on the material.

I like the same time, because it went with what was going on. And plus when you did it, people had most their research done, so if you did it any earlier, I think like people would just be like O.K. this was in lecture, we’ll talk about this. I think the same time was good because it helped focus us for the week and it kind of reinforced everything we had been learning. It was like O.K. we’re doing this right, we’re on-track. (S2C, Post-Project Interview)

I don’t think it hindered our research at all, it was reinforcing. (S5D, Post-Project Interview)

The few students who suggested that the lectures could have been earlier thought it may have helped them learn the information sooner.

Yeah it probably would have helped to have lecture earlier, any information you can get is good and the book is, good for definitions, I don’t think it was bad, I don’t know if it would have changed the way we did anything. It might have worked better if it was before. (S1A, Post-Project Interview)

When asked more specifically about the sequencing of the lectures and the debate, TAs noted that the lectures appeared to support the students’ own research.

Did lecture help? I think it did. I think it was good to have it right beforehand. I mean in my debates, I heard things they had gotten out of lecture. They’d already done most of the work on their own so it was a nice familiar way for them to hear about what they were learning about. And if it had been after the debate, they would not have wanted to listen to that in lecture. And if it had been too early, then they might not have done as much work on their own, I don’t know. I thought it was good the way it was presented. (T2, Post-Project Interview)
F2 also discussed the role of selecting the right sequence of genetics topics so students had an understanding of the basics necessary for comprehending the current genetic technologies.

Begin with a lower level of and move to a more refined level when you revisit the material. Maybe start with a brief intro to history, revisit it after students have learned about DNA. So students can understand Mendel's work, that the alleles coding for pea color actually have differences in their base sequences. Really learn Mendel, because students have background knowledge. (F2, Post-Project Interview)

*Multiple Pedagogies* impacted subject enthusiasm and motivation. Different students stated that they found different aspects of the course to be engaging during the project, including the debate itself, working with other students, lectures, talking with their TAs, and locating information in the library. TAs and F1 cited different aspects of teaching as motivating, such as watching the debates, working with students, working with one another, researching the topics, and developing materials.

Different types of teaching led to different types of learning by participants. In this study, a similar range of learning tasks was observed, but it was not possible to tie these types of learning as succinctly to a particular type of teaching. For example, during the preparatory sessions faculty modeled to TAs the way in which specific activities could be presented to students. Some of the TAs mimicked or imitated these techniques, another memorized the directions, and another practiced ways to present the information differently. Subjects in all three groups, when presented with a specific type of learning, approached learning that material or skill in widely varying manners. Some of the students related the project structure to their abilities to learn.

S3A: Its not my personal learning style, but I think overall it was very effective. I'm all for projects, I think it is always very time intensive and you need low student numbers but I think the best ones need a lot of guidance and supervision form the TA or professor to make sure you're on the right track.

F1: What is your learning style?

S3A: I'm a visual learner and do best with pictures and such, but I did learn from the debate, especially listening to the other students.

(Post-Project Interview)

Even though students were directed to consider laboratories and recitations other than those related to the project, and the assigned text readings, students did not address these aspects of the course without prompting.
F1: Did you use the textbook for any part of your research.
S4B: No not really.
F1: How about for your original definitions of somatic cell and germline types of gene therapy? (Shows subject copy of group 4 pre-project activity artifact)
S4B: Yeah, I guess for that, but not much else. We spent most of the time using the computer.
(Post-Project Interview)

F1: Which of these activities (pointing to activities other than the project-related activities) did you consider to be most effective?
S1E: You mean the ones I learned the most from? They were pretty much the same, none of them stick out in my mind right now although I could have done without the busy work.
F1: Which activities had busy work?
S1E: Oh, you know, the ones with counting or drawing or reading graphs, that kind of thing.
(Post-Project Interview)

In later course evaluations (Appendix M) students in the course generally rated the project-related activities favorably, but had many suggestions for improving the non-project related activities. Both faculty also discussed the way activities, lectures, and the text readings fit together in the course.

I thought the project activities were the most successful, in part because the students were debating about the same topics that were being discussed the same week in lecture. Students were able to elaborate on lecture topics! I was unhappy with many of the other course activities, particularly the paper and pencil activities. More students than ever were filling these out at home. (F1, Post-Project Interview)

F1: (Show copy of syllabus) Which of these activities was the most successful? The least successful?
F2: Most of the activities have stood the test of time and have been revised repeatedly. You would want to maintain the coverage of the three topics. The bigger section on genetics reflects its importance.
F1: What other things would you recommend for the curriculum?
F2: Something in at least one lecture or part of the course that challenges the best students. Lecture needs to be different from chapter readings. Lecture has a different flow, the visuals. Field trips have the advantage of stimulating all of the senses: sight, sound, touch, etc. In lecture, you have maybe sight and sound.
(Post-Project Interview)

Occasion setters are opportunities to reset the educational experience by focusing attention on a particular event, process, or concept. During the project a few of these occasion setters emerged. For example, a student began to discuss researchers
as people with common concerns as the general public after attending a lecture
discussing Nancy Wexler’s research and family history of Huntington’s Disease (HD).
Lecture stories, TA personal stories, and the debate itself were the primary occasion
setters.

Accessibility of course participants within Office Hours and through Internet/E-
Mail affected subject learning. All of the subjects interacted in TA and/or faculty Office
Hours. These interactions ranged from brief greetings, to long project-related
discussions, to research-related formative interviews.

T5 discussed his interactions as primarily assisting students in their work on the
project through reminders and advice.

I acted mostly as a reminder, that they had things due, but secondarily
had a chance to talk to about ten students in-depth one-on-one, either
after class, or during my office hour, and they were really having a hard
time with their arguments part of it. (T5, Post-Project Interview)

In response to how a follow-up question on the amount of time he spent with students,
F2 discussed the importance of meeting with students.

You need to spend time with the students because they are the core of
the course. Students have the same problems from one term to the next.
(F2, Post-Project Interview)

F1 also indicated that spending time working with students was one of the most important
aspects of her job.

The number of students in the course, coupled with only a small percentage of
those students interacting with faculty, or TAs in office hours could lead to a skewed
opinion of course events. Formative interviews late in week four were revealing that
students were learning a great deal more about their topics than they had written about
in their annotated references. The TAs, who were at the time currently grading the
references, were expressing dismay over student abilities to write, research, and
understand genetic technologies. The researcher noted that this indicated that TA
perception of student knowledge was temporally offset by the static nature of the
interaction (grading a paper). Additionally, the subject TAs had stated during formative
interviews that most of the students and groups who had asked for assistance needed “a
lot of help” (T1). F2 also was not clear of how far students had progressed in the
research, although he indicated that “I have been getting a few questions, e-mail and
students coming by, asking about their research." I was much more aware of the subject students' progress than other students in the courses due to the formative interviews.

For all of the subjects, use of the Internet and E-mail communication was a relatively new phenomenon. Although faculty and some of the TAs and students had used previously computer technologies, the project expanded emphasis on using the Internet for research purposes, and handling large numbers of e-mails from other course participants. Students who did not know how to do Internet searches reported having initial difficulty in finding information. Students, TAs, and faculty discussed using e-mails to clarify course directions in a timely manner.

Students spent a great deal of time in the post-project interviews discussing how their group worked together on the project. Several students noted that using e-mail made it easier to complete the project.

Yeah, the e-mail made it very easy to send information back and forth, to put together the summary. (S1B, Post-Project Interview)

The Classroom Environment impacted learning, including Class Size and the course's Cooperative Philosophy. The Class Size had an impact on subject learning. With lecture sections exceeding 250 students, laboratory sections at 40 students, several TAs and multiple course faculty, there was a increased complexity of personalities and backgrounds impacting the learning community.

Class size impacted the logistics associated with designing the curricular innovation.

Regarding logistics, F2 suggested a lecture hall close to the lab and recitation rooms for the debates. However, we quickly determined that it would be unlikely to have the room available at the necessary times, and that we would need to use our own classroom spaces. The next idea was to have laboratory and recitation sections scheduled for the same time debate each other, but the possible 50-minute time slot appeared to be too short of a time to give 80 students a chance to contribute. Finally, we agreed on having debates within the regularly scheduled laboratories, giving 40 students a chance to debate during a 1-hour and 50-minute period. (F1, Researcher Journal)

Class size also impacted the forms of assessment of student outcomes. Assessment of individual student outcomes (annotated references, notecards, and debate participation) was limited to the project, with assessment of many other course topics limited to multiple choice exams.
Another aspect of the classroom environment was a difficult to group, but pervasive set of variables described as Cooperative Philosophy. Students from two of the groups discussed the difficulty in assembling outside of scheduled class meeting times.

One thing about the out of class work, my group was really adverse to meeting outside of class. We had it arranged so everyone would do their own thing, bring it to class, and I would put it all together and synthesize it, you know, together. But I would have preferred this to meeting outside of class, you know we all have different schedules and it is hard with five to six people to pull together... No one had enthusiasm to say hey guys lets all meet, even though I guess there was that hour after class where we could have, but we didn't. (S5B), Post-Project Interview

Subjects frequently discussed the importance of being able to work freely with other course participants.

Course Participants

Results from the pilot study suggested that different interactions between the subject groups impacted learning in a myriad of ways. These interactions were grouped as Peer Interactions (Student-Student, Teaching Assistant-Teaching Assistant, and Faculty-Faculty) and Other Interactions (Student-Teaching Assistant, Teaching Assistant-Faculty, Student-Faculty). These categories reflected different styles of interactions with peers and other participants.

Student-Student interactions occurred in their laboratory and recitation groups, in lecture, and outside of the classroom, socially and in other learning contexts such as working on the project and studying. Initially, students were doing most of the research for the debate on their own, without the assistance of their TAs or faculty. As the project progressed, many students began working with each other to obtain information, particularly to complete the group summary and prepare for the debate.

As discussed, students taught each other how to research a topic and basic computer skills such as using e-mail to send document attachments. Students also learned specific concepts from other students, often repeating information initially located by a group member in the debates and post-project interviews, or talking about topic another student has researched. Some students took a “parenting” or mentor role toward others. Similarly, some students stated that they “…learned most from other students” (S3A).
Students working with groups reflected on many of these aspects of group dynamics, including: managing differences in participant interest and ability, establishing depth of inquiry (into project topics), dividing tasks, judging valid procedures and ideas, accommodating ambiguity (uncertainty of roles and assignment.), dealing with confrontation, dividing the labor, integrating ideas, and presenting ideas.

It took our group a little bit longer to do the research thing. Our group really didn’t stay on top of things compared to other groups, and the interactions weren’t, it was pretty much you had to do your own thing, rather than working together. It was probably about 15 hours, but it would have been less if everybody had helped. (S4D, Post-Project Interview)

Conflict arose repeatedly related to dealing with each of these aspects of group learning, and the resolution of these conflicts was an aspect of student learning. A few students mentioned that aspects of group interactions negatively impacted project completion.

I typed it all. I hate working in groups, I hate being at the mercy of other people. We couldn’t get together to meet so when we finally did I said, e-mail everything to me and I’ll type it up and the last one made it about 9 p.m. and I had to get it together by 6 a.m. the next morning, it was due at 8 a.m. I had to make the corrections, and I did the introduction and the conclusion and plus a paragraph in there about xenotransplantation. (S4D, Post-Project Interview)

Even students who had issues working with other students in their groups throughout the project, mentioned a positive aspect to group work, sometimes expressing excitement when recalling participation in the debate-related activities.

S5D: Yeah, I don’t generally like working on group projects, but it didn’t turn out badly, luckily I had there was only one person who was dragged along, he didn’t show up for classes, and we were really worried about that. But basically, everybody wanted to put something into it, had ideas and wanted...you know we had two debaters, me and another guy, and we wanted to make these points you know, and use certain facts, like yeah we could use that, so we got excited about it, the argument point. Generally, we worked well. I had a fun group in that we were loud and laughing most of the time, probably scared everybody else, so it was fun.

F1: So overall do you think your group worked well together?
S5D: Well it was fun for a lot of it, like I said, I had a real squirrelly group so we, I think we learned a lot, it made lab more fun. It was nice to be with your people, you knew your people and everything.

(Post-Project Interview)
Differences in the characteristics of the five studied student groups in the study, including homogeneity/heterogeneity of individual's characteristics, dissonance/consonance, and relatedness, led to different group strategies and impacted time spent on the project as well as the depth and breadth of learning outcomes.

You can have cliques, where two people don't talk with everyone else, that makes it hard to get work done. (S5C, Post-Project Interview)

Individuals were impacted by aspects of the group, such as composition, roles, and group assessment. Students sometimes disagreed with the degree of impact the researcher believed group members had on their learning.

F1: Would you say that your group members had a major impact on your learning during the project?
S5C: Well, no, not really. I would have still done the work and everything. I mean it was easier that we got along, but we lost one of the guys in our group and it didn’t seem to matter.
F1: Why was it easier that the rest of you got along?
S5C: Well we could agree on who would do what, divide up the group summary.
(Post-Project Interview)

The researcher sought data from multiple sources to attempt to resolve these potential conflicts.

Group roles varied as the project requirements changed and students developed relationships with one another. These roles included recorder, reporter, checker, encourager, observer (Johnson, Johnson, & Smith, 1991), and organizer. Some of the roles were more fixed than others. For example, the organizer ("leader") role was fairly consistent throughout the duration of the project, whereas students frequently shifted roles as encourager.

Well, I mean I was kind of happy the group didn’t help, I mean when they took over it was kind of like lets find an easy way out, and we kind of like to go in depth, so it was like O.K., well we’re going to do what we want. (S2C, Post-Project Interview)

The degree of fluidity impacted learning, in that students not acting as organizer of checker appeared to have less access to group research and decision-making. Interestingly, students in organizing and checking roles were frequently acting as teachers in the classroom, but outside the classroom, at the library and learning center, students with other group roles also adopting a teaching role for fellow students.
Some of the student groups represented both traditional and cooperative group characteristics, shifting over time from a more "traditional" group structure at the beginning of the project, to a more "cooperative" group structure by the time of the debate.

This study indicated both positive and negative impacts of small groups on learning, as well as differences in groups in the way group members functioned with one another. Those groups that adopted roles in which everyone had a distinct and not-integrated function, appeared to learn less from one another than those groups that adopted roles in which the roles were more fluid. The difference from the studies in the meta-analysis may relate to the wider degree of variables characterized in this study as impacting learning, as well as students determining their type of grouping rather than having pre-determined relationships.

Group pressure to perform in a particular way was a factor impacting the time students spent on the project. Although not stated as a factor during formative interviews, several student subjects only initiated research after repeated prodding from group members.

Well, some people in the group just wanted to leave. Some of us are thinking of getting together later to work on this. (S1D, Week 5, Interviews)

Additionally, this group pressure had occasionally had a negative impact on learning, increasing group dissonance, at times speeding group members quickly through difficult material without conceptual understanding, and leading students to adopt misconceptions from another student. Most research focuses on positive group impacts, particularly on affective domain or skill development. Little focus is placed on whether students learn content more effectively, with discussion of increased depth, but little investigation of accuracy. This is a particular concern if each student starts with different knowledge and is learning from others with incomplete conceptions.

Relationships between students in the groups changed as the project progressed, with several students reporting that they felt much closer to group members after the debate. These changes were also evident through observations of student discourse. Students expressed interest in other's students comments through questioning and affirmative remarks. Limited interest was reflected through not including individuals in decision-making or artifact assemblage. This study suggested that group work could have both positive and negative impacts on short-term attitudes and beliefs,
with reflection potentially leading to an overall longer-term benefit of learning about self and others by the time of the post-project interviews.

Different student groups impacted one another. Initially, a sense of competition between groups developed as they prepared to debate one another and individuals reported that they wanted to perform better than students in other groups. In this study, self-described “spies” adopted ideas from other groups prior to the debate, and students reported learning from others during the debate.

I actually learned a lot from the other group’s debate. (S3A, Written Debate Response)

S5D mentioned strategies for debate, the other supergroup’s topic, and specific areas of interest.

I learned a lot about the plants, I actually have to say, it wasn’t even ours, but I learned a lot about the human genome project and the gene mapping, that was really cool. I was a lot more into the question about should you use animals for testing, I had thought about it before, but I’ve been thinking more about it. And then that thing in the news about the soybeans, I thought hey we know all about that! (S5D, Post-Project Interview)

The student-student group interactions differed from interactions between pairs. Students working in pairs often had distinctly different roles than they played in the larger classroom groups, engaged in different tasks, and incorporated a different type of discourse. Students working in the learning center were less formal in tone and repeatedly challenged one another’s authority.

We were just able to talk about things, and to have that type of relationship was important. (S1E, Post-Project Interview)

Much of the learning in the course may have occurred in the informal non-classroom setting, beyond the eyes of the researcher.

Teaching assistant – Teaching Assistant interactions altered TA learning, and in some cases, subsequent student learning. Although some of the TAs had taught together previously, their only close interactions at the beginning of the term revolved around the preparatory sessions and studying for a shared statistics class. Course interactions at the beginning of the term were classified by the researcher as formal and limited. TAs generally obtained information on their own outside of the context of the
prep sessions, with those returning to teach in the course occasionally working with other TAs to collect information.

As the term progressed, TAs spent an increasing amount of time with one another discussing the project and other aspects of the course. The initial reason for these interactions was TA concern about their teaching and student perceptions of their teaching. This was evident as TAs began exchanging overheads, handouts, and ideas on how to manage the project. TAs were often not aware of the extent or impact of interactions with other TAs. TAs did not initially state that other TAs had impacted their teaching “No, not really” (T4).

This may have been in part because most of the meetings between TAs were unplanned and between other scheduled events such as the time between teaching and attending class. Additionally, TAs were reluctant to discuss themselves as part of a team of teachers, but spoke of their own autonomy and individual concerns in the classroom. This changed slightly as TAs mentioned similarities of concerns to other TAs in the post-project interviews. When asked directly about sharing of materials, TAs stated that those materials were important.

I mean the handout was useful for ideas on how to design my own. We didn’t talk much, but left our overheads by the copier. (T2, Post-Project Interview)

It was very nice of (T1) to share his debate rule sheet. I used that the week before the debate so that students would know how the debate would proceed. (T3, Post-Project Interview)

With additional questioning, TAs did not mention impact of discussions with other TAs as impacting their own teaching or learning.

TA interactions were both similar to and different than student interactions. Similar to student interactions, TAs demonstrated fluidity of roles within the group, with some of the TAs acting as organizers, others as encouragers, reporters, and observers. Some of the aspects of group dynamics were also similar, such as judging valid procedures and ideas, presenting ideas, accommodating ambiguity (uncertainty of roles and assignment.), and dealing with confrontation. However, TAs did not develop as many aspects of group dynamics as students, such as integrating ideas, as they were not working consistently with the same TAs to the same degree over the course of the project.
Faculty-Faculty interactions with one another had many of the characteristics of the interactions between other pairs of peer participants. Roles fluctuated, and the task at hand impacted the dynamics of interactions. Faculty worked separately during most of the curriculum development phase, but worked together while addressing new concerns that unfolded as the term progressed.

As the project processed, there was increasing emphasis on managing differences, dividing labor, and judging valid procedures, while during the project dynamics shifted to accommodating ambiguity, dealing with confrontation, integrating ideas, and presenting ideas. The breadth of interactions between the faculty more closely mirrored student interactions than student interactions, possibly because faculty and students had to work with their peers to successfully navigate the project. With interdependence, all group members must succeed for the individual to succeed.

Faculty spent extensive time discussing the course and coming up with ways to address student and TA concerns. This focus on the project requirements mirrored student group discussions, while discussion of how to teach the material in lecture and the prep sessions mirrored TA conversations on teaching.

At this point we decided the debate would be a good project and joked about how good we were getting at “this curriculum design stuff.”
(Researcher Journal, Curriculum Planning Meeting).

Following the week 5 lecture on human genetics, F1 was concerned that the lecture had not gone as well.

I really like the eugenics topic, but the lecture didn’t seem to flow. I had to backtrack and cover basics about chromosomes and karyotypes not covered in earlier lectures, and clarify multiple allelic and polygenic traits that the students seem to be still having trouble with. Also, I wanted to address how genetic screening was performed, to set up that we have the technology for another type of eugenics movement. It just didn’t come together as well as I expected. (Researcher Journal, Week 5)

F1 discussed these concerns with F2 who had attended the lecture.

F1: That lecture didn’t go as well as I thought it would. I don’t know, maybe...

F2: You covered a lot of material, remember sometimes you need to focus on a few important ideas, too much was going on, too many words, not enough story. It’s like the movie, about Mozart, too many notes. (both laugh)[see beginning of this chapter for movie reference] (Week 5, Formative Interview)
Following up on this discussion, F1 re-worked several of the rest of the term’s lectures to a more story-like format, with emphasis on key concepts.

Student – Teaching Assistant interactions occurred in the activities and office hours, as well as occasional interactions in lecture, the library, and the learning center. An unresolved question prior to this study was the degree to which students impacted TA learning and vice versa. By the post-project interviews, both groups had demonstrated an impact on one another, although most of that impact was observed or developed through follow-up interview questions instead of accumulated through subject self-reporting.

Most students had not mentioned their TAs frequently in the formative interviews or earlier questioning in the post-project interviews. The exceptions were students in T5’s sections. Students in T5’s section mentioned that he had shared a personal story with them and that this story impacted their views on the topic.

My TA brought up that he was totally against using animals for research, but the drugs that are helping his Mom are developed using animal research. You may care a lot for the animal, but it’s your Mom. We’re dealing with really big issues and sometimes it’s important to bring it back and think about yourself and others, like genetically engineering food for people in China instead of just thinking about overpopulation. (S5D, Post-Project Interview)

When asked specifically about whether their TAs were helpful, some students responded positively, based on TA assistance in clarifying project procedures and their ability to let the students work on their own.

Yeah, because for the things I was going over I found things on cloning, not a lot on humans, but there was a lot on things like Dolly and that was the first things I looked at or came across before we were assigned things. So when I found out we were doing that he made it real clear that if you were doing genetic engineering, you were not doing humans, so he made it easy. (S1A, Post-Project Interview)

She really encouraged us to think about this ourselves I think she’s a really good TA and she really helped us a lot and she helped give us ideas and helped redirect us if we went off the pathway and she did an excellent job of like making us think for ourselves. (S2B, Post-Project Interview)

Many students indicated that their TAs did not play a major role in their successful completion of the project, although most mentioned having received guidance from their TAs at some point.
My recollection is that there was very little TA involvement. I think she just, like there was an assignment that we had to do an annotated bibliography at one point you know and she made sure we had it. (S3A, Post-Project Interview)

No I think for the most part we worked independently, I can’t remember anything that he really came in and said. I mean on the summary, he mentioned a lot like focus on this, don’t focus on the humans, cause I think I had that on my paper. He was just really good about telling us when this was due, when that was due, you should have this done, you should be doing this by now, and then I think we had time in class. If we had questions we asked him. (S4A, Post-Project Interview)

Some students mentioned that TAs played a role in what occurred during the debates.

We did have that God debate and _____ (T5) said if you don’t have research, he said lets talk about the research. (S5A, Post-Project Interview)

Students in group 5 mentioned that there were qualities in their TA, especially listening skills, understanding of topic, and interest in biology, which impacted their own learning in the course.

We did go to _____ (T5) if we were confused about something, _____ (T5) is really good, I mean he really understands what we’re talking about and so he is able to give you a good answer and can say well lets look at it this way, so we always found that, you know we weren’t afraid to ask him because he never made you feel stupid when you asked him a question. He’s so passionate about botany, you know his plants, you see, we know that now! (S5A, Post-Project Interview)

I think we worked together a lot, but if we didn’t know something, we’d say, hey, let’s ask _____ (T5). (S5C, Post-Project Interview)

Students in the other four study groups made far fewer comments about their TAs, but those comments were generally positive in nature.

I think we pretty much did things on our own. I went to T4 once just to make sure we were straight and arrow on the right path, but, just to check that we were doing everything correct as far as his guidelines. The TAs are great, I was so afraid to take science, this is the last of my bacc core, so, but its been a lot of fun, I really like the lectures. (S4D, Post-Project Interview)

Students repeatedly stated that their TAs were a “last-resort” resource, the person you went to the few times your group members could not figure something out. Almost paradoxically, the students generally described their TAs as either extremely
proficient or lacking in teaching skills. This apparent contradiction, that students viewed TAs as of peripheral importance, but highly competent, was resolved in part through the observations that students received assistance from their TAs at critical junctions in the project, such as corrections on topic focus on the annotated references or specific ideas on ways to make arguments during debate preparation. Additionally, students closely repeated what their TAs stated, sometimes weeks after the statement was made, such as students in T3’s class repeating the phrase “Mistakes are made” (T3). Personal stories and ideas from TAs were incorporated into written artifacts, the debates, and the post-project interviews.

TAs were observed changing the direction of group and classroom discussions, including the debates, with specific comments.

You know, you should figure out what you need to debate, whether or not you’re missing information. You can use the computers if you need to search for additional information. (T2, Week 5, Debate Prep Activity)

I would focus on figuring out who is going to do what. So each of you have something different to do during the debate. So, you ___ (student name) could do, say, part of the introduction, and you, ______ (student name) can do the rebuttal, however you want to divide it up. Just make sure that everyone has something to do. (T4, Week 5, Debate Prep Activity)

TAs led student discussions at the beginning of activities, but most of the time was spent on students working with one another, with TAs answering group’s specific questions. Possibly as a result, repeating student answers, asking for elaboration, and using student names did not appear to impact learning. However, correcting (or not correcting) student answers did appear to impact student learning. After the graded annotated references were returned, most students were aware of how far the technologies were developed, in part from TA grading and in part from other group members.

I learned that genetically engineered foods are being consumed in mass amount by a population that is unaware they are consuming them. (S1B, Week 5, Formative Interview)

Additionally, TAs corrected students that were studying the wrong topics.

This article introduces the idea of artificial human chromosomes that have been developed at the School of Medicine. These artificial chromosomes
provide different ways to study gene therapy and treat genetic diseases. (S2B – assigned genetic engineering, Annotated Reference)

This reference refers to human gene therapy, not genetic engineering of organisms other than humans. This is the topic of the other 4 groups. Focus on genetically engineered organisms.” (T4, Subject’s underline, Graded Annotated Reference).

TAs also negatively impacted student learning. One TA (T3) did not pass on information about the confusion over distinguishing between genetic engineering in humans (gene therapy) and genetic engineering in other organisms, or that cloning was not the same as recombination of DNA to the students. These points of confusion persisted with in some students during the introduction portion of the debate, but fellow members of the supergroup, opposing debaters, and audience members corrected these apparent misconceptions through comments and questioning. As TAs were learning content along with the students (and faculty), they were also susceptible to misdirection and misconceptions.

Although TAs impacted many aspects of student learning, the impact varied by student, and did not indicate that all students adopted similar views or beliefs as their TA. Some students challenged their TA’s comments and recommendations, and chose to develop different ideas.

TAs also did not mention students as impacting their own learning without prompts. Primarily TAs stated that their own research, prior coursework, and preparation impacted their learning. However, TAs repeatedly brought up concerns about how to deal with specific students disrupting teaching. As the project progressed, TAs mentioned that they were learning more about the content because they were attempting to grade project assignments and/or find ways to assist their students. TAs mentioned that students included topics in their papers that they were not familiar with. T5 mentioned that he had not previously heard of xenotransplantation, which had been covered in a group summary paper.

Genetically engineered organisms are being developed as sources of organs. The transplantation of organs into humans is called xenotransplantation. No xenotransplantation has so far been successful in the long term, most patients survive only a few hours, days, or months at the most. (S5, Week 5, Formative Interview)

TAs discussed the nature of their interactions with students. These interactions varied with each TA. T2 noted that the interactions depended on the student and that
she learned from many of her students about the debate topics and skills such as Internet use.

Well I think they know how to do searches on the Internet better than I do because they were finding actual finding real journal articles on the Internet and that's not something I've explored as much. They are better at it than I am. So they, here I am telling them go to the library to find journal articles, and then they're turning in the actual articles off the internet. And I'm telling them to do it this old way, and they're like looking at me like, I'll just do it off the internet, and I'm saying no, go to the library. It's a new way of finding information, and they could have taught me, instead of me telling them go to the library. Now I know. (T2, Post-Project Interview)

Observations suggested that TAs were adopting ideas, skills, and beliefs based on interactions with their students. In interviews, TAs discussed content that they had read in the student's writings or heard during the debate more frequently than concepts from their course backgrounds, lecture, textbooks, or their own research. Additionally, some of the TAs reported adopting particular computer research skills from their students. All TAs reported changes in their beliefs about student abilities based on working with students in the classroom.

TA – Faculty interactions occurred in the preparatory sessions as a group, and one-on-one in informal, but frequent, meetings throughout the term. TAs formed a critical link between students and faculty during the project. Early in the term, faculty were primarily lecturing and demonstrating how to teach and elaborating on course procedures. As the project proceeded, and problems arose, TAs began sharing increasing amounts of information with faculty.

Despite discussing similar concerns, such as ambiguity of project topics and plagiarism, TAs were focused on what they needed to do in order to be able to manage their students, and faculty were focused on what students needed to learn. As both focuses were important, TAs and faculty both contributed to successful solutions of course dilemmas. Even though the researcher/faculty had been a TA in the course, TAs were able to provide a more detailed assessment of problems with implementing the new project.

Prep sessions were the setting for the majority of meetings between TAs and faculty. A TA stated that the prep sessions were more useful in preparing for the shorter laboratory and recitation activities than the long-term project.
The Monday morning meetings have been really useful for the other activities, but with such a large thing going on over several weeks, it didn’t fit into the Monday meetings very well. (T1, Post-Project Interview)

One of the reasons given for the limited value of the prep sessions was the difficulty in predicting problems since it was a new aspect of the curriculum.

Well because it was a new project, it was hard to anticipate questions. So the big thing for them became differentiating between the genetic technology topics, you know if you were teaching the exact same thing next year, that was something that could come up at the meetings, so that we had thought about it before the students asked us, but it is hard to anticipate when you haven’t done it before. (T2, Post-Project Interview)

I’m not sure what could have been done differently, with this being a new topic. Possibly more discussion of what everyone was planning on doing each week. (T3, Post-Project Interview)

When specifically asked what could have been addressed more specifically related to the project, the common answer related to detailed descriptions of the topics.

A heads up ahead of time, like the difference between germline and somatic cell gene therapy. And then some of the most popular websites that have certain genetic technologies. A list of things to be familiar with. (T5, Post-Project Interview)

The only change that I really see that needs to be made is that the topics need to be defined clearly on paper during the first week. The topics and the actual debate question. Um, the other thing that might be useful is to make a more clear definition of what the group summaries should be, um. Cause if that is given in their course packet, or something like that, it will make it a lot easier for them to understand what to do. I thought I had defined it pretty clearly to them but I ended up with a lot of different formats. Giving definition, pros and cons, that it should be a group project. I had a few groups hand it in where each one in the group wrote a half page or a page, and the material ended up overlapping. (T2, Post-Project Interview)

One of the TAs indicated that more information in the prep session on how the project fit in with the larger curriculum goals would be helpful.

The prep sessions for me seemed just fine. I’ve been through the content area and felt pretty comfortable with the material. Because I’m doing the prep session, then I’m doing my own things then I’m doing a re-prep. If I don’t get it out of the prep session, then it’s hard for me to separate what I did from what was given to me. One thing that would have been good was to see how it all fit together with the rest of the course, how it all connected together. (T4, Post-Project Interview)
None of the TAs discussed the other prep-related exchanges, such as hearing questions/comments from other TAs, sharing overheads and handouts, or designing the layout of the room for the debate. However, when asked if these events impacted their teaching, all TAs responded affirmatively.

Both F1 and F2 agreed that the prep sessions were critical for preparing TAs to teach and to make any needed changes to the activities.

We seemed to make a lot of decisions and project corrections in the prep sessions. I especially remember the prep the week of the debate, and how everybody contributed to arranging the room and discussing how they could encourage audience questioning. (F1, Post-Project Interview)

You can't run a good course without somehow preparing the TAs to teach. Look at how much they struggle over some of the material on Mondays (day of the prep session). You don't want them doing that with their students on Tuesday. (F2, Post-Project Interview)

F1 wrote about the types of information that was shared in the prep sessions.

TAs asked about the breakdown of the points (five for participating in the debate, five for the notecards, and five for being an active audience member). One of the TAs asked how the audience would be actively involved. I suggested that they could take notes on the debate in progress, but to think about it so we could decide on audience participation during the next week's prep session. There was also confusion over what the notecards would contain. I suggested that the notecards should contain what the students planned to talk about during the debate, and turned in at the end of class. T1 expressed concern that students would not fully participate and that the debate rules did not emphasize participation. After the prep session we worked together to modify my debate rules to create a slightly different debate guide (Appendix M). T1 wanted to distribute the rules to every one of his students, but I suggested that copies of the rules be placed in plastic covers on the tables so all students in the course had access. (Researcher Journal, Week 5)

Problems associated with the project were often discussed between a single TA and either F1 or F2 in office hours, and then with all of the TAs and faculty in the prep sessions.

They are really both forms of genetic engineering, or altering an organism's genetic material. Generally, we refer to altering human DNA as gene therapy, and altering other organism's DNA as genetic engineering, but this is an artificial distinction and may be confusing to students. (F1, Prep Session)
TAs learned by watching the faculty model behaviors. As will be discussed, TAs reflected on lecturing techniques. Similarly, TAs appeared to adopt particular ideas and skills from the faculty and other TAs that they believed would be effective, such as the use of media in the classroom.

F1 and F2 differed in their perceptions of how interactions with TAs had impacted their own teaching. F1 thought that the TAs had contributed ideas that impacted her teaching.

I found out about problems with the project from the TAs. Sometimes TAs were relaying their own concerns, and sometimes they were relaying student questions. Also, by attending the labs, I could see what TAs were struggling with so I could discuss problems with ____ (F2) and we could make changes in the prep sessions. (F1, Post-Project Interview)

F2 did not perceive TAs as impacting his teaching at that point in time.

F1: To what degree, if any, do you think you learn from the TAs and students?
F2: The first few years, quite a bit, but the last few years, not so much. To them something is a new idea, but it has probably been tried, not new to me. (Post-Project Interview)

F2 perceived TAs as a conduit of the curriculum, and a director of the student's activities.

F1: How much of the teaching are the TAs doing in the course?
F2: Not much, more of a director of the activity, most of the teaching going on is peer teaching because this is how it is set up. If there is a really slow group, than the TA can help. The TAs have to learn that they don't have to spend equal time with each group. A good TA gets to know the students and spends appropriate time. Their role is facilitation, more than a teacher in the traditional sense of a lecturer. They need to spend more time to keep certain students on task.
(Post-Project Interview)

Faculty views of TA roles impacted the interactions between both groups. However, the project shifted those roles over time, with TAs and faculty sharing pedagogical ideas.

Student - Faculty interactions occurred primarily during lecture and office hours, meaning that the majority of the hundreds of the students in the course did not have conversations with faculty. Many of the subjects in the study would not have ever had a conversation with the researcher/faculty under “normal” conditions. As only approximately 20% of students held any type of conversations with the two faculty, those
few interactions held a great deal of significance in shaping faculty beliefs about students and the curriculum. Part of the limitation in faculty-student interactions was due to limited time to allocate to hundreds of students.

Students primarily questioned faculty about course policies and procedures, such as making up missed activities and re-scheduling exams. Additionally, students sought assistance after receiving low midterm grades. As a result, most of the student learning from meeting with faculty revolved around course procedures and policies, as well as basic note-taking, studying, and test-taking skills. As the project progressed, students also sought assistance with locating information and specific content questions.

Faculty learned a considerable amount from students about areas of genetics technology research that they were interested in and/or did not understand. Even though the sample of students visiting office hours was skewed and not necessarily representative of all the students taking the course, some information could be gleaned from the discussions. Faculty learned specific content in trying to answer detained student questions (such as distinguishing between in vitro and ex vivo methodologies).

F1 altered lectures after interacting with specific students during office hours.

A student not in this study stopped by to review aspects of DNA and protein synthesis. In the course of our conversation, the student revealed that she was so interested in the material because she had cystic fibrosis (CF). We talked briefly about the disorder, but I admitted that my knowledge was limited to the little that I had read in textbooks. I offered to find information on current research related to CF, and in the process of researching websites, decided to discuss CF in lecture. I carried the print-outs from the websites with me in my computer briefcase for the remainder of the term, but did not see that student again, as she became quite ill and had to withdraw from the course. (Researcher Journal)

Additionally, changes in the project were often made to reflect student comments made directly to faculty. As evaluations were not viewed until the project was long completed, student feedback in the offices, hallway, or after lecture, was critical in faculty decision-making.

Student – Teaching Assistant – Faculty interactions occurred in the lectures, some of the debate, and occasionally in discussions in the biology wing. Students, TAs, and Faculty met together each week in lecture. Although the nature of the large lecture was as a multimedia performance, scripted from beginning to end, rather than an interactive discussion, students asked occasional comments (4-8 per lecture), and the lectures sparked a great deal of discussion between each group of course participants.
Even though subjects did not interact through conversation during lecture, students and TAs often responded collectively (laughing, groaning, etc.), and often discussed lectures, particularly teaching style and recent research, after lectures.

I liked the part about the cloning, do you really think we will clone a human soon? (S5D, Week 6, Formative Interview)

They (students) seemed to be losing it a bit during the part about the gene copying. (T2, Week 6, Formative Interview)

TAs also discussed the relationship of the lectures to the student debates.

The students had most of their information and what you covered was kind of like a reminder or review for them. (T3, Post-Project Interview)

Although faculty sat in on some of the labs/recitations/debates, their role was to observe and there was limited direct interaction with students and TAs. After the debates, the TA and faculty, along with a few students stayed after to discuss the debates. These discussions did not usually occur after course activities, and were also distinct in that students, who had just “taught” played active roles in the conversations.

That was great! ...I’ve learned about gene therapy, of course, ... And I’ve learned how common genetically engineered foods are on the market today. I didn’t realize how common these foods are in the supermarket already. (S3B, Week 6, Post-Debate Discussion)

Student and teacher thought processes and views of one another may differ considerably, but this may not be evident in a lecture setting. Instead, students and faculty may see one another as possessing similar beliefs and interests.

TAs and faculty entered the project with a set of abilities related to teaching. Arguably, students also entered the project with similar teaching characteristics, and developed some of them, particularly group teaching characteristics, due to interactions with TAs and faculty.

Students, TAs, and faculty mutually bought into the project goal of learning. The students did not remember being told what the project goals were, but reconstructed what those goals were during the post-project interviews, based on their own project experiences.
I have learned a lot about genetic technologies that I did not know ever existed. The debate made you look at both sides of the debate and consider both sides of the argument. (S3E, Written Debate Response)

Subjects in all three groups repeated the idea that all participants were engaged in and affected by the project, indicating an awareness of the importance of the project in overall course-related learning.

Sometimes one group started considering a concept or skill, but another picked it up and made it into something that could be transferred across subject groups. For example, students initially considered how to judge a reliable resource within a group. A TA listened to the group's concerns and developed an overhead with information on how to judge resources, which was later adopted by other TAs and seen by the faculty and most students.

After the genetic technology project, students were vociferous in ideas regarding improving multiple aspects of the course, speaking to their TAs and faculty. This may reflect the degree of involvement students had in changing the project itself.

During the genetic technologies project, students were primarily responsible for mediating their own social interactions. Peers impacted one another's learning. Hierarchies occurred within and between subject groups, but were flexible based on individual needs. For example, subjects sought different assistance from different participants, based in part on perception of ability and perception of role.

Interactions between all three subject groups also indicated that the process of conflict resolution can be shared by all three participant groups, if there are avenues for communication. Even a series of mishaps can lead to learning, and possibly a degree of change and uncertainty provides a spark for a wide range of learning.

From the surface there appears to be almost a chaotic breadth and depth of learning occurring due to subject interactions, but upon closer examination, there are threads of interaction within participants, linking the knowledge of one person to the next, or acting as a conduit for learning which sparks different outcomes in different individuals. These threads, or types of dialogue in the classroom, represented communication in a general sense.

The interactions in Table 4.14 represent types of dialogic pattern. Ideas could be expressed in numerous formats between participants, and the nature of these formats impacted how individual subjects learned.
Interactions between participants varied depending on which groups were represented in the interaction. For example, TAs tended to give directions to students, whereas students were more likely to provide demonstrations to other students.

### Institutional Factors

All three groups interacted in various ways in different contextual settings, including lectures (Faculty, TAs, and students), preparatory sessions (Faculty and TAs), and laboratories (TAs and students). Institutional factors impacting learning included **Facilities and Atmosphere**. Facilities, or the actual settings in which some of the learning took place, were broken into the categories of **Classrooms/Equipment, Library, and Computer Centers**.

The classroom facilities and the equipment available in those facilities impacted subject learning. The layout of the biology wing, with classrooms and offices in close proximity to one another, resulted in course participants interacting closely with one another.

Learning in all three groups appeared to be impacted by the proximity of classrooms and offices. Faculty interacted frequently with one another to discuss course progress and strategies, even though work schedules were quite different. TAs spent time discussing course concerns with one another and faculty in their offices before and

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**Table 4.14: Types of Participant Interactions Observed in Studied Course.**

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directions</td>
<td>One participant indicating to another what should be done</td>
</tr>
<tr>
<td>Demonstrating</td>
<td>One participant showing another what should be done</td>
</tr>
<tr>
<td>Planned Stories</td>
<td>One participant representing knowledge though a narrative with a particular point</td>
</tr>
<tr>
<td>Question and Answer</td>
<td>Participants ask questions and provide answers</td>
</tr>
<tr>
<td>Evaluation</td>
<td>One participant judging the ability, behavior, or knowledge of another participant</td>
</tr>
<tr>
<td>Assessment</td>
<td>One participant provides feedback on another’s performance</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>One participant discussed process of teaching and learning with another</td>
</tr>
<tr>
<td>Conversations on Course Content</td>
<td>Participants carry on dialog about something related to the course</td>
</tr>
<tr>
<td>Conversations on Non-Course Topics</td>
<td>Participants carry on dialog about a topic unrelated to the course</td>
</tr>
<tr>
<td>Person to Person/Personal</td>
<td>One participant indicates a personal relationship, through gesture, greeting, or comments</td>
</tr>
</tbody>
</table>
after teaching. Students met to work on projects and discuss other course material in the available rooms, particularly the biology learning center. As a venue for course participant interactions, the design of the biology wing had a recurring impact on subject learning (Figure 4.15).

Figure 4.15: Map of Biology Wing.

The space and furniture in the classroom used for the debate were movable, and their rearrangement led to a series of conversations between TAs on students and their own role relative to the debate. In the prep session for the debate (week 6), TAs rearranged the room to accommodate the debate format. The TAs began moving the tables around to create a separate debate and audience area. T2 mentioned that the debaters would probably rather sit down, and the other TAs helped her move tables up to the front.

The week 6 prep session was the first in which the TAs directed the discussion with questions and suggestions. TAs and faculty were dispersed throughout the room during this prep session, sitting on, or leaning against tables (Figure 4.16). T3 asked how she should grade the debate presentations, and the other TAs discussed how they would handle students who were shy or unprepared. F2 and I offered suggestions, but
left final decisions to the TAs. The TAs discussed how the 20 debating students would fit around the tables, access the overhead projector (if needed by students), and having tables for the audience members so they could take notes. All the TAs agreed with the table and chair arrangement and mentioned that they would sit in the back of the room with the audience while moderating (Figure 4.17).
Figure 4.16: Usual arrangement of recitation room.

Figure 4.17: New Arrangement of Recitation Room.
Students utilized the course's learning center to work with group members. Students and faculty were negatively impacted by slow computers and network connections. Students left the debate preparation activity to find faster computers for research and faculty noted spending less time researching debate topics due to slow web connections.

Yeah and we got together after class Tuesday in that room down the hall. Nobody knew what was going on, so we figured out who was going to do what. One of us is going to have to put it all together later, but we all are pretty much doing different things anyway. (S4B, Week 4, Formative Interview)

Having computer equipment available enabled faculty to alter instruction quickly to address problems associated with the project. When F1 and F2 found out that students were having difficulty finding material, they decided to add information on finding and reviewing information to a laboratory activity.

We can use the computers and make a lab of it. (F2, Week 2, Formative Interview)

However, the type of computers available in the classrooms created problems when used for Internet research. When asked what other factors may have limited student learning during the projects, T4 indicated that the McIntosh computers were a problem.

One thing that day was that the speed of the computers, it definitely was too slow and student groups just left. (T4, Post-Project Interview)

We need to do more research, and these computers are slow as hell. We're going to get together later at the computer lab and work on this some more. (S1E, Week 5, Formative Interviews)

The problems of Internet access had not been realized in other activities that primarily relied on computer programs.

TAs used the biology wing to communicate with other TAs. T1 also discussed the incident with the other TAs who were in the biology wing (TA office and biology learning center), and other TAs began to check for evidence of plagiarism.

Use of the facilities changed as the term progressed. Only a few students stopped by office hours the first few weeks, primarily to ask about switching class sections. The biology wing was "very quiet" (researcher journal), with the learning center
empty, and students and TAs leaving as soon as classes were completed. By the
project, the biology wing was full of course participants from 8 a.m. to 8 p.m. on the
weekdays, many working in small groups or supergroups on the project.

Campus Library facilities impacted student, TA, and faculty learning. Participants
from all three groups utilized library resources in relationship to the project. TAs and
faculty discussed the importance of access to journals, as well as opportunity to observe
and interact with students outside of the classroom settings. Some students and TAs
discussed the importance of access to material in printed text form, rather than
electronic. Some students also discussed having difficulty finding information at the
library, and limited assistance from reference librarians.

Um, no I don’t think there was a problem, we met at the library and kind of
divided up what we were going to do, what we wanted to talk about, and I
can’t quite remember, I think we did that before we were assigned
specific topics. We kind of all looked for information, and if someone
found something we could use, we just wrote that address down. (S1A,
Post-Project Interview)

The researcher went through some of the preliminary research conclusions with
the students to get their feedback. These questions/answers were specific to each
subject, and diverse in nature, and a small subset of this data is provided here. In
general, the students confirmed the researcher’s categories of learning, including the
significance of the campus library.

F1: (showing students an early version of the list of categories of
learning) Which, if any, of these categories describes things you
learned about during the project this term?
S1B: (studies list, laughs) Well, probably pretty much all of them if I think
about it. I mean (points to the project content column) especially
about genetic engineering. But probably working with other
students in my group (pauses and points to institution column).
What does that one mean?
F1: That there are bigger, broader factors like university facilities or
university culture that impact learning,
S1B: There’s the library, I used that a little for research, things like that?
(Post-Project Interview)

Some of the students discussed limitations in the quantity or quality of library materials
(“...everything was checked out or missing” S5D, Formative Interview).
TAs, using the library to locate materials for the courses they were taking, noted that they met their students and had discussed the course and non-course-related topics.

Students and TAs reported the importance of campus Computer Centers in providing a setting for group meetings and access to the Internet. Many of these subjects did not have a computer in their homes and relied on computers in the library and a variety of other campus locations to find information.

Everybody pretty much used the computers on campus, except one girl had one at home. (S1B, Post-Project Interview)

Atmosphere included the Student Community, Science Department, and the Faculty/College. The campus Student Community included issues and topics widely talked about and published in the campus newspaper or on the quad. Topics included concern about discriminatory and racist interactions between students as well as animal rights. Both of these areas of concern repeatedly appeared in the debates as well as lectures and office hour discussions. A few students and TAs discussed being careful of what they said due to concerns about offending students.

Influenced to a degree by repeated articles in the campus newspapers about animal rights, several of the group summaries addressed aspects of animal rights and the ethical treatment of animals used for food and research.

The animals that are used for transgenic face shorter lives, suffer, and sometimes are slaughtered for human consumption. This addresses a safety issue. A spokesperson for ethical treatment of animals says "the capacity to splice human genes into animals proves that humans are merely part of the animals world – nothing more. (S1, Group Summary)

Also these transgenic animal experiments are cruel. These experiments are designed to increase growth, weight, and body fat, but they can also increase the stress on the animals. Also, in these animals there is more health problems due to illnesses and increased development of abnormalities. (S5, Group Summary)

Animal right issues also figured prominently in the debates. A protest rally against the use of animals for research had been held on the campus' main quad during the previous week (week 5).

There is another side of genetic engineering, putting human genes into animals to produce desired proteins. This can result in highly increased production of human proteins, which are currently produced in tissue
culture. These animals would not be treated differently than a dairy cow. If you wear leather shoes, you know, these animals would be treated like kings and queens compared to other animals. The cost of new proteins could be one-third to one-thirtieth of tissue culture. (S2A, Debate)

These are some of the truths about genetic engineering. Regarding animal rights, if it wasn’t for animals in research, we wouldn’t be here. If you are from Africa, you do not have the technology to have this debate. There are large numbers of people dying in Africa, these technologies may save people from dying of disease. If we have the technology, if we do not sacrifice animals, people would continue to die. Here we kill animals for hunting, for fun, and other uses, what about killing animals to save human lives? (S2D, answer to audience question, Debate)

Student, TA, and faculty subjects all had conversations in the formative interviews about some aspect of the animals rights posters, demonstrations, and/or campus newspaper coverage.

The Science Department provided support for the BI 10X courses by continually attempting to acquire funding for staff salaries, facilities, and equipment. As a result, departmental activities impacted all course participants to some degree. Although faculty discussed this more frequently than other subjects, TAs discussed that their concerns about continued support through their assistantships impacted the time they spent teaching.

Aspects of the Faculty/College culture impacted faculty learning. Budget considerations at the college level had a direct impact on the resources available to the department and BI 10X courses. Large-scale innovations, requiring significant changes in facilities, equipment, and materials, were not probable, and faculty focused on utilizing existing resources.

Related to budget, there were issues of staffing the BI 10X courses. Lecturers were assigned from other courses, without control of the course coordinator (F2). When asked to list factors impacting teaching and learning in the BI 10X courses, F2 cited the faculty who were assigned by the college to give part of the lectures for a term.

F1: In recent years, what constraints were there on teaching and learning?
F2: People put in the program, you need to meet their schedules, their abilities, their needs, their priorities.
(Post-Project Interview)
Sequencing of the project had occurred around the lecture topics and recitation activities of one of the lecturers (not a subject in this study), and the innovation may have been different with more sequencing flexibility. Faculty were the only subjects demonstrating knowledge of the impact of budget and staffing considerations on the courses.

The university had a historical emphasis on teaching and learning. In a graduate guide published by the university and used in a seminar for graduate students for over 20 years, evaluation was represented as dominating classroom interactions. Only the faculty appeared aware of this historical context of the existing curriculum, although evaluation concerns continued to impact curricular innovation.

Other Commitments

Subjects had multiple roles in addition to coursework that impacted the time and goals related to learning. Factors changed as the roles of participants changed. Students balanced studies, jobs, families; TAs balanced research, teaching, and coursework, faculty balanced research, teaching, and service. These roles were categorized as Employment/Degree, Health, Family, and Activities.

Subjects representing all three groups had Employment obligations. Several students had jobs, TAs had laboratory research commitments, and faculty had service commitments. Student's jobs often conflicted with coursework.

T5 indicated that time constraints associated with finishing his degree limited the time he could spend on teaching.

I didn’t always spend as much time on this as I would like, this being the first time I had my paper due at the same time, trying to graduate. (T5, Post-Project Interview)

Students were impacted by their own Health. Two of the students missed classes due to illness. As a result, they missed due dates and opportunities to interact with group members.

Students also had Family considerations, including caring for their own children, or visiting a sick relative. Some students, away from home for the first time, went home on weekends to be with family. This impacted the time available for studying and socializing with other students.

Other Activities, such as hobbies and sports also impacted subject learning. Some students noted that they researched topics that they were more interested in due
to their relationship to gardening (genetically engineered foods) or sports (enhancement gene therapy).

Although not often discussed in the research literature on undergraduate learning, commitments outside the classroom often precluded learning. These commitments may be having an increased impact as more students are classified as "non-traditional," with job and family commitments.

Research Participation

Subjects were impacted by participation in the research, through increased Reflection, Time Considerations, and altered Relationships with Participants. TAs and faculty noted that participation in the research impacted the amount of Reflection upon their own teaching and learning. Although they did not state this explicitly until prompted in the final interviews, TAs asked the researcher more questions about teaching during the project, and faculty spent more time talking about the project than other course activities.

All students responded that participating in the research had been an interesting experience. Student answers to the question on interactions with the researcher were briefer than previous answers. Most of the students stated that they had enjoyed the opportunity to be a part of the study.

This was a lot of fun. At first, my group members kind of dragged me into it and I figured it was going to be a lot more work than I had time for, but we (indicating F1 and herself) just have talked a few times. This (post-project interview) has really been the longest part. I guess I kind of enjoy talking about myself (both laugh), although probably a lot of this isn't too useful for you. (S5B, Post-Project Interview)

Students replied that they did not believe they were acting differently because of involvement in the project. When asked if they learned anything because of participating in the research, most students stated that they had not, but a few students replied that involvement, particularly in the post-project interview had given them a chance to think about their activities in the course.

It's like another chance to think about what is going on in the course and what I have been doing. All of the things that have gone well, and not so well, you know like working with my group and the debate. (S2C, Post-Project Interview)
The researcher asked several of the students if they knew what the research was about. Most of the students responded that they thought the researcher wanted to figure out ways to improve the project and the class.

Well, that you are trying to find ways to improve the course. Wasn't the project new? So you were trying to figure out how to make it work better. (S2E, Post-Project Interview)

A few of the students stated that the researcher wanted to find out what they had learned about the project topics “Well, what we know about genetic advancements.” (S4A). None of the students mentioned that the researcher was interested in aspects of learning other than the project topics, the factors that impacted that learning, or how interactions with other course participants impacted learning. Additionally, at this point in the interviews, none of the students mentioned the researcher’s dual role as teacher.

The TAs initially indicated that participation in the study had not had an impact on their teaching or learning. When asked more specifically if they learned anything because of participating in the research, most of the TAs stated that involvement, particularly in the post-project interview had given them a chance to think more about their teaching.

I have been reflecting a little bit more term, because of those classes and maybe from us talking. I wish I had written more down, but I did think about it. My goal has always been to make connections for students, because I enjoy seeing those connections and its great that all of these disciplines can go together. (T4, Post-Project Interview)

None of the TAs mentioned learning more about content due to participation in the research study.

F1 believed the study had impacted all aspects of her research and teaching.

Because of the research, I have learned a lot about what it means to research a course that you are teaching, the constant attempt to discern empirical data from anecdotally based conclusions. I definitely learned a lot about genetics in general, and the project topics more specifically. Although I have been pretty comfortable working with the other TAs in the past, I think this project and the research has made me more comfortable in interacting with the students. Also, in the long run while taking a closer look at the data, I will learn how to improve my teaching. (F1, Researcher Journal)

There were definitely short-term effects in my teaching, in that I was able to hear about some of the things going on in the course from the subject
TAs and students. I'm not sure how much different this would have been if the study had not been in progress, because students and TAs who were not participating in the study also saw problems with topic confusion, assignment procedures, and assessment. In the longer-term, I anticipate that this research will have a very large impact on the course, and other BI 10X courses, as well and directing future research. (F1, Post-Project Interview)

F2 did not believe the study had impacted his behaviors.

We've been talking like this for years, how many years have you been here? (both laugh) I haven’t been doing anything differently because of your work this term. (F2, Post-Project Interview)

When asked whether they had thought about these aspects of altering course design before, students initially replied “Nope, not really” (S4C). The researcher followed-up by questioning students who were analyzing aspects of course design to determine whether the research had led to this reflection.

F1: Did my conversations with you during the course affect your thinking about how the course was structured?
S3A: I think it was mostly working with my group and seeing how they responded. I'm able to succeed in most classes, but I think they have difficulty in some situations.
(Post-Project Interview)

Research participation also involved an increased Time Commitment for all involved. The research limited the amount of time F1 had for non-research related course activities. Although subjects did not state that the time was a concern, the researcher notices that subjects participating in the study talked with the researcher after class, where as other subjects often talked with other course participants.

Through repeated interactions, the researcher's Relationship With Participants changed over time. Additionally, students and TAs indicated that their behaviors with other course participants were sometimes altered after formative interviews.

Characteristics of Factors Impacting Subject Learning

The reviewed research and pilot study that informed this study suggested that a variety of discrete factors could impact student, TA, and faculty behaviors. This study elucidated a comprehensive set of variables impacting learning. Unexpected was the extensive similarities of factors impacting the three subject groups.
Cases were developed related to the factors impacting how subjects learned specific content. These cases were originally developed related to the definitions of the project topics, and were expanded to include a wide variety of content. The cases demonstrated the impact of subject interactions on learning, the breadth and depth of content, and aspects of content that appeared to impact learning. For example, the topic of eugenics originally appeared in the data during a week five lecture. The topic was utilized by some of the subjects during the debate and mentioned in the post-project interviews. The eugenics case revealed that subjects referred to that content as a demonstration of the interactions between science, technology, and society. As a contrast, animal cloning was very pervasive in the data from the pre-project activities, but was mentioned less frequently as students distinguished animal cloning from gene cloning. The cloning case revealed that in the post-project interviews, some of the students still confused animal cloning with gene therapy, particularly if they had been assigned to genetic engineering.

Similar to the content case studies, case studies of different skills and techniques were developed to search for new variables and trends. For example, all data related to the skill of locating project topic information were accumulated. The resulting case suggested that a primary factor impacting the development of this skill was a direct interaction with a course participant, particularly those in the same subject group. F2 shared websites with F1, T1 shared Internet search techniques with T3, and S5C assisted S5D in locating journal articles in the library. Additionally the case on locating project topic information suggested that all three groups were engaged in this process simultaneously. A case was developed for the technique of reflection to assist the researcher in determining if particular aspects of data collection impacted subject reflection. The reflection case indicated that that F1 and the TAs reflected on teaching after having difficulties during instruction and that students reflected on their learning immediately following the debates. Additionally, the researcher specifically reflected on the research process after reading science education literature.

The types of conditions observed in this study represented a spectrum of contexts. Factors interacted with other factors to promote or inhibit changes in knowledge or behaviors. Factor interactions made it difficult to tease out specific categories.
What subjects brought into the project (Internal factors) impacted all aspects of learning to some degree. F2 noted that the main factor impacting continual changes in the BI 10X curricula was the constant change in students.

Curriculum development is the key. The content does not change that dramatically. Course procedures do not change that dramatically. There is a continual process of change, refinement. Students change over time, that’s why the course needs to change. (F2, Post-Project Interview)

There were extensive internal differences in individuals that impacted the way they approached the context and concepts of learning. These differences included intention (what), motivation (why), and processes (how) in the context of the environment of learning (Meyer, 1995). Repeatedly reflection on teaching and learning emerged as a factor impacting subsequent learning, in part that indicated that subjects (along with the researcher) were developing understandings of their intentions, motivation, and processes.

Another point of complexity in the data was that different factors could lead to similar outcomes, such as different reasons for why T1, T2, and T5 researched project topics. Conversely, similar factors led to different outcomes, such as students motivated by fear of public speaking either learning strategies to remember a script or developing overheads.

Factors impacting subject learning shifted throughout the project. This indicates that there may be factors impacting learning that were not identified by the researcher as their transient nature would make identification difficult, even with the frequent data collection. An additional difficulty is that it can be very difficult to tease apart factors impacting learning, meaning that some factors may have been masked by others.

One question repeatedly arising related to higher education is the role of non-intellectual factors (learning beliefs, behaviors, emotional reactions). The non-intellectual factors were as prevalent a predictor as the intellectual in this study. Although this study did not seek to weigh the degree of impact of specific sets of variables, it did support that numerous non-intellectual factors impacted subject learning.

A repeated, but easy to overlook occurrence in the data was that non-learners impacted learners. A non-learner is an individual not actively learning similar material at a given point in time, such as a student completing an assignment for a different class or F2 preparing for retirement at the end of the project. Subject’s beliefs and behaviors
impacted one another irrespective of whether they were engaged in similar learning tasks.

Different approaches to learning could be linked to differences in levels of understanding: deep active (explanation and justification), deep passive (summarizing accurately, but little evidence), surface active (describes main points but not argument itself), and surface passive (a few isolated points or examples) (Entwistle, 1995). Even when students in the genetic project engaged in learning at what could be represented as a “surface passive” level, that learning could relate to other, deeper learning at later dates or learning in other individuals. In other words, a subject’s passive learning could lead to deeper understandings in other individuals.

Differences in modes of learning, either “surface” or “deep,” also impacted subject learning. Students using “deep” and “active” meaningful learning modes appeared to construct more elaborate knowledge structures than rote learners (Peasall, Skipper, & Mintzes, 1997). These differences were evident in degree of generative thinking, types of explanations given, questions asked, metacognition, and approaches to tasks (Chin and Brown, 2000).

Students and TAs became quickly engaged in the project appeared to have a variety of changes related to cognitive outcomes, learning strategies, and the affective domain. Even TAs and students who were unclear as to how to proceed within the project, were successful in learning as long as they remained engaged in the course and interacted with peers. Design and implementation of strategies and plans were impacted by interest, and learning occurred regardless of whether those plans were successful. This related back to metacognition. Student and TA views of their own learning were tightly interwoven with their individual views of motivation, morality, and action.

Factors Limiting and Augmenting Learning

This study did not seek to assign significance to the variables impacting learning. However, the data suggested that some factors augmented learning (“positive” impacts), where as other factors inhibited learning (“negative” impacts). Examples of some of these factors impacting student learning are presented in Table 4.15.
Table 4.15: Sample Factors Augmenting and Limiting Student Subject Learning.

<table>
<thead>
<tr>
<th>“Positive” Impacts</th>
<th>“Negative” Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group member background knowledge</td>
<td>Incorrect directions from TA</td>
</tr>
<tr>
<td>Textbook for topic information</td>
<td>Ambiguity of topic descriptions in manual</td>
</tr>
<tr>
<td>TA feedback on graded summaries</td>
<td>TA not marking annotated reference errors</td>
</tr>
<tr>
<td>Facilities for Group Meetings (Learning Center, campus library)</td>
<td>Inaccessibility of fast computers</td>
</tr>
<tr>
<td>TA assisting in debate preparation</td>
<td>Group member wanting to leave early</td>
</tr>
<tr>
<td>Campus publicity on animal rights protests</td>
<td>Limited personal time commitment</td>
</tr>
</tbody>
</table>

TA learning was also impacted by a variety of factors. A small sample of these factors are provided in Table 4.16.

Table 4.16: Sample Factors Augmenting and Limiting TA Subject Learning.

<table>
<thead>
<tr>
<th>“Positive” Impacts</th>
<th>“Negative” Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactions with students in office hours</td>
<td>Limited prep session time</td>
</tr>
<tr>
<td>Listening to debating students</td>
<td>Ambiguity of topic descriptions in manual</td>
</tr>
<tr>
<td>Lecture attendance along with students</td>
<td>Students not listening or responding</td>
</tr>
<tr>
<td>Materials from other TAs</td>
<td>Time constraints</td>
</tr>
<tr>
<td>Informal discussions with faculty</td>
<td>Limited motivation to alter teaching</td>
</tr>
<tr>
<td>Previous teaching experiences</td>
<td>Beliefs in student abilities</td>
</tr>
<tr>
<td>Reflection due to involvement in research</td>
<td>Limited orientation to assessment</td>
</tr>
</tbody>
</table>

Quotation marks are used to indicate that some of the negative impacts may have eventually become a positive impact. For example, initial topic ambiguity led to greater understanding of project topics. Also, some factors had both positive and negative aspects. For example, concern over student evaluations and comparisons with other sections had some TAs altering practice to “keep students relatively happy” (T4). This augmented learning (increased office hour contact with students) as well as inhibited learning (decreased point deductions and less detailed corrections).

Some of the factors impacting one group had an indirect impact on another group. For example, limited prep session time negatively impacted TA learning of...
rational for teaching strategies, this led to TAs not following strategies (such as reminding students of due dates), and students not effectively budgeting time for researching topics. Many factors impacting learning appeared to not be isolated to single subjects or even single subject groups.

Interactions During Innovation

The genetic technologies project altered content and teaching within the BI 102 course. Project-related activities involved different instructional and learning strategies than the laboratories, recitations, and lectures. These changes, and the uncertainty and ambiguity associated with the changes, impacted the interactions between course participants. As already woven into this summary, there was considerable evidence of subject learning being impacted by interactions with other course participants. Initially during the project these interactions were fairly limited. Interactions increased between all groups as the project progressed, with the most interactions occurring during the week of the debate. This section explores these interactions in the context of the learning described in this chapter. In Chapter 5, these interactions will be set in the context of existing research on learning communities.

All subjects began the project with limited background knowledge about genetic technologies. Early in the project, student learning was largely impacted by their TAs, TA learning was largely impacted by faculty, and faculty learning was largely impacted by researching information. As the project progressed, these dynamics changed, with different subjects becoming authorities, or sources of information and skills. The roles of teacher and learner became quite blurred as subjects searched for ways to successfully complete their tasks in the course. Subjects sought help for some aspects of learning more than others, which influenced the impact of interactions on learning.

Early effects of TAs on student learning were often as negative as they were positive related to the project. TA input was often misleading (emphasis on specific points about genetic technologies), incorrect (project directions), or inadequate (not correcting papers). Students were researching topics on their own, seeking technical assistance from group members, and limiting TA involvement. By week 4, TAs began to spend more time researching topics and preparing classroom materials. By week 5, students were consulting with TAs on debating techniques, and by week 6, TAs were primarily observers and learners as the students debated.
Once the faculty designed the curriculum before the term began, they were not extensively involved in the project during the first two weeks of the course, besides prep sessions and F1's data collection. Interactions with students and TAs were primarily centered on course procedures and policies. By week three, concerns over topic ambiguity, student questions concerning the annotated references, and TA questions about grading drew the faculty back into the project. By the debate, both faculty were enmeshed in the project, assisting students with project papers, working on grading with TAs, researching information, modifying lectures to address conceptual concerns, and learning from students during the debates. Roles were actively shifting as the term progressed.

Instead of a “top-down” form of instruction, where faculty teach TAs, and those TAs teach students (Figure 4.18), the teaching role repeatedly bounced between subject groups during the studied project.

![Figure 4.18: Traditional Model of “Top-Down: Instruction.”](image)

In other words, the researcher's initial belief that faculty would primarily design curriculum, TAs would implement that curriculum, and students would learn from that curriculum oversimplified the complexity of events that occurred during innovation.

In order to better understand the interactions between the subject groups, a simple model was developed to represent the settings for learning (Figure 4.19). This
model would allow interactions to be juxtaposed over the various subject groups and locations of interactions.

Figure 4.19: Model of Interactions Between Subject Groups.

The main circles (yellow, red, blue) represent the student, TA, and faculty subject groups, and the settings of interactions within each group. Students interacted in collaborative groups in lab, the library learning center, etc. TAs interacted with one another in their office, copy room, prep sessions, etc. Faculty interacted with one another in their offices, prep sessions, etc. The overlapping space indicating the Student-TA interactions (orange) represent the labs, recitations, and office hours. The space indicating TA-Faculty interactions (purple) represents prep sessions and office meetings. The space representing Student-Faculty interactions (green) represents office hours and F1 formative interviews. The center space marked Student-TA-Faculty represents the shared settings of lecture and the course materials.

Data on interactions between the three subject groups were incorporated into the interaction model. An example is the interaction between groups related to the definition of project topics (Figure 4.20). The ambiguity associated with the two debate topics of
gene therapy and genetic engineering demonstrated the complex interactions occurring within the course.

Initially, Fl had selected the topics with only limited background knowledge and a brief search of the text and Internet for information. After discussing topic selection with F2, Fl developed the activity and the topics were printed in the manual. In week one, the TAs read the manual, and in prep heard about the two topics. The TAs looked up additional information on the topics, primarily in the textbook, and presented that information in the week 1 recitation to students. Students completed the activity and began work on their annotated references. By week 2, a student recognized similarities between the two topics and in laboratory, shared this concern with T1. T1 thought further about the topics and confirmed the overlap. T1 talked to F1 at the end of the week, who then researched the topics further, affirmed the ambiguity and discussed possible solutions with F2.

F1 and F2 decided to discuss the topics in the week three prep session. In the prep session F1 presented how to distinguish between the topics and the TAs decide to write the topic definitions on the chalk board. Additionally most of the TAs prepared overheads with the topic definitions. In the week three recitation, TAs discussed the possible topic confusion. Students talked about the distinction in their groups. Two weeks later, some of the student group summaries still demonstrated confusion regarding the topics, and the TAs noting this, told F1 in her office and by e-mail. F1 included more information on the topics in the week six lectures, and stressed aspects of gene therapy and genetic engineering that would appear on the final exam. In the week six debates, student super groups discussed the distinctions and overlap of the terms. By the post-project interviews, all subject could give clear definitions of the two topics. Representatives of all three subject groups had acted as both learners and teachers regarding this one aspect of course concepts. What could have led to lingering misconceptions, was corrected by the end of the project.
Figure 4.20: Learning Interactions Over Debate Topics.

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>F1 selects topics</td>
</tr>
<tr>
<td>2</td>
<td>F1 discusses topics with F2</td>
</tr>
<tr>
<td>3a</td>
<td>Topics are in activity manual</td>
</tr>
<tr>
<td>3b</td>
<td>Topics presented in wk 1 prep.</td>
</tr>
<tr>
<td>4</td>
<td>TAs look up topics in text</td>
</tr>
<tr>
<td>5</td>
<td>TAs present topics in wk 1 recitation</td>
</tr>
<tr>
<td>6</td>
<td>Students research topics</td>
</tr>
<tr>
<td>7</td>
<td>A student notices topic ambiguity</td>
</tr>
<tr>
<td>8</td>
<td>Student informs T1 in wk 2 class</td>
</tr>
<tr>
<td>9</td>
<td>T1 thinks about topics</td>
</tr>
<tr>
<td>10</td>
<td>T1 discusses topics with F1 in office</td>
</tr>
<tr>
<td>11</td>
<td>F1 looks up topics</td>
</tr>
<tr>
<td>12</td>
<td>F1 discusses possible solutions with F2</td>
</tr>
<tr>
<td>13</td>
<td>Topic corrections discussed in wk 3 prep</td>
</tr>
<tr>
<td>14</td>
<td>TAs prepare overheads describing topics</td>
</tr>
<tr>
<td>15</td>
<td>TAs explain topics in wk 3 recitation</td>
</tr>
<tr>
<td>16</td>
<td>Students write notes on topic definitions</td>
</tr>
<tr>
<td>17a</td>
<td>Some students still confused about topics</td>
</tr>
<tr>
<td>17b</td>
<td>Some students understand topic distinctions</td>
</tr>
<tr>
<td>18a</td>
<td>Group summaries reflect topic confusion</td>
</tr>
<tr>
<td>18b</td>
<td>Students explain topics to group members</td>
</tr>
<tr>
<td>19</td>
<td>TAs observe continued topic confusion wk 5</td>
</tr>
<tr>
<td>20</td>
<td>TAs inform F1 of topic confusion in office</td>
</tr>
<tr>
<td>21</td>
<td>F1 alters wk 6 lecture</td>
</tr>
<tr>
<td>22a</td>
<td>Topics presented in wk 6 lecture</td>
</tr>
<tr>
<td>22b</td>
<td>Students explain topics in wk 6 debate</td>
</tr>
<tr>
<td>23</td>
<td>Students know topic distinction by post-project interviews</td>
</tr>
</tbody>
</table>
Loops of teaching and learning repeatedly occurred related to other aspects of the project. The factors impacting these interactions, and the order of participation varied. For example, students reported to F1 that they were having difficulties finding and reviewing articles in week two. F1 and F2 discussed options, and in week three communicated these student concerns to TAs and presented changes in that week's fruit fly activity laboratory to allow students to use computers for locating information with the TAs available for assistance. Ideas passed back and forth through subject groups as the term progressed (Monsanto genetically engineering plants, Bt Corn, Flavr savr tomato, etc.). With the Flavr Sar tomato story, many participants had small pieces of the story, and the debates provided a forum for assembly of a more compete understanding of the topic.

In some cases subjects in all three groups were learning similar material, but different subjects initiated the learning chain reactions (Figure 4.21). Students initiated concerns over the distinction between project topics, the labeling of genetically modified foods, and tomatoes. TAs brought up the topics of plagiarism, and ways to debate. Faculty brought up the role of corporate interests in genetic engineering.
Figure 4.21: Initiation of Learning By Different Subject Groups.

1. **Students** find information on labeling.
2. **Labeling** in annotated references.
3. TAs read annotated references.
4. TAs talk with other students about labeling.
5. Additional students research labeling.

7. **TA** finds evidence of plagiarism.
9. **F1** discusses with F2.
10. Discussion in prep session.
11. TAs generate ideas to deal with plagiarism.
12. TAs work with F1 to make overheads.
13. TAs discuss plagiarism with students.

14. **F2** finds info on Monsanto.
15. Shares info with F1.
16. **F1** adds Monsanto reference to lecture.
17. Students mention Monsanto in notecards.
18. Additional students research labeling.
19. Labeling major debate topic.

Legend:
- Students
- Teaching Assistants (TA)
- Faculty
- Student – TA interactions
- TA – Faculty interactions
- Student – Faculty interactions
- Student – TA – Faculty interactions
Summary of Results

Data generated in response to the first research question regarding what student, TAs, and faculty learned suggested that (1) there were many diverse variables of learning, that (2) these variables could be summarized in the general categories of cognitive outcomes, learning strategies, and affective domain, that (3) all three subject groups exhibited many similarities in learning of the “new” content and “new” teaching strategies, that (4) at times the variation of learning within a subject group was comparable to that between subject groups, and that (5) learning categories changed over the course of the six-week project.

Results associated with the second research question regarding the factors impacting student, TA, and faculty learning, suggested that (1) there were many diverse factors impacting learning, that (2) factors could be grouped in either internal or external general categories, that (3) all three subject groups were impacted by many of the same conditions for learning, that (4) interactions between course participants impacted learning in all three subject groups, and (5) many of the factors impacting learning related to the process of change within the curriculum.

The genetic technologies project incorporated content, teaching strategies, and participant relationships that differed from others in the course. The process of innovation also led to uncertainty over content and pedagogy. In order to address these aspects of the new project, individuals interacted, and those interactions impacted learning. The variables on learning and the various factors impacting learning were incorporated into a hypothesis of student, TA, and faculty learning. The next chapter describes this hypothesis in depth, as well as the relationship of this study’s results to existing literature, limitations and advantages of this study’s methodologies, and implications for future research.
CHAPTER 5: DISCUSSION AND IMPLICATIONS

Introduction

Addressing this study's research questions led to the general conclusion that in the studied context of a curricular innovation there was an enormous variation in types of student, TA, and faculty learning, as well as a large diversity of factors impacting that learning. This chapter discusses these results in the context of the reviewed literature, with implications for future research. Variables generated in this study were linked together to formulate a hypothesis of learning within the studied course, and this hypothesis is also situated within research on university learning. This chapter continues with addressing questions associated with the role of the researcher, limitations of the methodologies, and broader implications for future research.

Related Research Literature

This section relates study results to research on learning in the context of innovation within university classrooms (as reviewed in Chapter 2). Discussion is organized around the categories of learning and factors impacting learning that were discussed in Chapter 4. Aspects of learning seen in this study may also occur in a course not undergoing curricular change, suggesting the need for additional research on a variety of university courses. Implications for further research are integrated into this discussion.

Cognitive Outcomes

This study suggested that subjects learned about aspects of genetic technologies due to participation in the debate project, including definitions, techniques, applications, issues, and recent developments. Additionally, subjects learned about related course topics within the disciplines of genetics, evolution, and animal behavior due in part to participation in the project. As previously discussed, research on innovation in university courses typically focuses on changing pedagogical strategies. Few studies discuss learning when both content and pedagogy are altered. In those studies in which both aspects of the curriculum are altered, the focus on content is typically limited to a particular subset of concepts, such as controversial issues. Nakhleh, Bunce, &
Schwartz (1995) suggested that an altered chemistry curriculum led to increased student awareness of social issues. Similarly, in this study, subjects from all three subject groups learned about current and potential future issues associated with genetic technologies. Further research is needed to determine whether this diversity of learning is present in a classroom in which curricular change is not occurring, or whether particular aspects of innovation lead to a greater diversity of learning outcomes.

Bradford, Rubba, & Harkness (1995) implemented a curriculum emphasizing science, technology, and society (STS) in an introductory physics course. They concluded that students retained naïve views of science (although details on those views were not provided). In this study, students did develop understandings of the structure of the discipline, historical context, knowledge development, and methods for accessing information. However, these views were simplistic, possibly related to limited discussion and explicit instruction related to the nature and process of science.

Additional research may ascertain whether certain teaching strategies can assist individuals in developing broad understandings of the process of science, or whether a combination of teaching strategies (such as lecture, text, and individual research) are needed to develop science understandings in a diverse group of learners. Additionally, many facets of the content addressed in a course may impact the aspects of science subjects focus on, similar to the impact lecture and text discussion of eugenics had on subject focus on historical development of science knowledge. To add to the complexity, as seen in this study, different learners may respond to different aspects of the content, in part due to pre-existing background knowledge. Instead of focusing on the “magic bullet” teaching strategy that will enhance student (as well as TA and faculty) understandings of science, research may be well-served by attempts to foster teaching and learning diversity.

This study demonstrated that subjects learned about the relationships between science, technology, and society, particularly the significance of technologies, the impact of science on society, the role of societal interests, and various responsibilities and roles. Several studies examined student learning of STS topics. Bradford, Rubba, & Harkness (1995) suggested that students exposed to an STS curriculum developed more naïve views of the connection between science, technology, and quality of life. Their results contrasted with this study in which students appeared to learn that science and technology solves specific problems, particularly medical and agricultural, related to the quality of life. However, students were not clear of the distinctions between science and
technology. Nakhleh, Bunce, & Schwartz (1995) suggested that curricular changes may have altered student views of the interactions between science and society. Bradford, Rubba, & Harkness (1995) suggested that students retained naïve views of the contribution of science to solve social and practical problems. In this study, although students were developing understandings of STS, they also tended to discuss science/technology simplistically as either creating problems or solving problems. In part this may have reflected the focus of the sources of information that subjects used and the often “interchangeable” use of the terms science and technology, as apparent in the term “genetic technologies.”

Bradford, Rubba, & Harkness (1995) also suggested that students developed understandings of the impact of politics and special interest groups on developments in science and technology. In this study, subjects did not appear to develop understandings of the impact of politics on genetics technology, even though the students were asked to argue whether the government should regulate the technologies. However, subjects in all three groups appeared to learn more about the impact of corporations on priorities in science and technology. Similar to the variety of categories representing subject learning of project and related course topics, subjects learned a variety of aspects of science and its relationships to technology and society. Further research is warranted to determine whether a similar breadth (and limited depth) of learning STS relationships occurs in the context of other classrooms.

Students, TAs, and faculty developed more complete understandings of the roles of other course participants. Trumbell & Kerr (1993) assessed TA and faculty beliefs related to innovation. They concluded that TAs and faculty did not have understandings of what students brought to a course. Within this study, subjects learned more about the roles of other participants, including teaching and learning roles, as well as extracurricular activities, over the course of the project. Understanding the roles of other participants may be a key component of university learning. Faculty and TA understandings of students' roles as learners, future teachers, and individuals with specific goals and needs may impact selection of what is taught and the techniques used. Student understandings of the roles of TAs and faculty may impact their own views of teaching and learning. As the introductory biology classroom can be the training ground for future teachers, understandings of the roles of other course participants may be an opportunity to preview future careers in education.
None of the reviewed studies discussed subjects learning about course policies and procedures during innovation. However, policies and procedures were altered in the process of innovation, and the resulting ambiguity impacted learning. Issues associated with managing the often-large introductory classes during processes of innovation may be critical components of successful implementation. Interactions between students, TAs, and faculty resulted in class-wide recognition and correction of discrepancies in aspects of policies and procedures. As consistent understandings of policies and procedures is a basic component of course functioning, further research may elucidate ways to coordinate interactions between course participants.

Cognitive outcomes in this study suggest that authentically assessing student learning can be an enormous task to define and implement. As the genetic technologies project was developed around two particular topics, the generation of other outcomes such as knowledge of specific aspects of STS and the roles of other course participants may have appeared as peripheral footnotes in a term in which research was not occurring. However, students, TAs, and faculty were spending time exploring a broad spectrum of topics, and the participants valued that learning. This extent of cognitive outcomes may or may not be an artifact of innovation, but it does seem to be in keeping with the university charge of developing broad and diverse intellects. Students, TAs, and faculty valued learning even if it was not a component of the final evaluation, which brings into question the process of assigning grades to a small subset of pre-determined cognitive outcomes. Further research is needed on how rich cognitive outcomes can be linked to instruction and assessment practices.

Learning Strategies

Subjects acquired a diversity of learning strategies during the project, including thinking skills, abilities to self-regulate behaviors, abilities to obtain information, communication skills, and teaching skills. Morgan, Carter, Lemons, Grumbling, & Saboski (1995) examined the impact of a learning community on student learning. They concluded that the learning community led to students acquiring more thinking skills (although these skills were not described). Further research may elucidate the variety of thinking skills developed and utilized in university classrooms, including within the context of innovation.

Barrow (1993) studied the impact of a portfolio project and assessment on student learning. That curricular innovation appeared to increase student reflection on
learning, as well as lead to the development of organizational skills. Similarly in this study subjects (including TAs and faculty) developed self-regulatory skills as they managed project-related assignments. Further research is needed to flesh out these skills, including their relationship to dealing with novel content and instructional strategies.

Subjects also developed strategies to obtain information, including locating information and reading skills. Gregory (1992), studying implementation of an STS curriculum, suggested that students developed skills necessary to read about science. However, the reviewed studies did not discuss the impact of innovation on other communication skills (writing and oral discourse) as seen in this study. This may be due to the other courses not requiring extensive written and oral assignments similar to the annotated references, group summary, notecards, and debate. As one of the overriding goals of an introductory science course for non-majors is to prepare those students to be able to understand science topics as consumers and citizens, far more information is needed on how university courses develop (or do not develop) skills related to accessing information. Similarly, TAs and faculty need to develop skills related to accessing information for teaching, keeping up with changes in technologies. Technical support and campus development programs are potentially important facets that were not evident impacts in the studied course.

Students, TAs, and faculty also developed a wide range of teaching skills, including aspects of planning and implementation of activities. Planning included learning content, selecting topics, determining scope and sequence, as well as selecting instructional strategies. Trumbell and Kerr (1993) discussed TA decisions related to topic selection. The researchers concluded that TAs were not satisfied with teaching the "scientific method." Similarly, subjects in this study discussed realizing that other aspects of science, particularly genetics, are important to teach and learn. Trumbell and Kerr (1993) stated that TAs also discussed intentions to provide both broad and detailed coverage of topics. In this study, TAs primarily discussed that students needed to develop broad understandings of science, possibly reflecting their own focus on learning within the course. As many students and TAs will eventually teach in some form, developing teaching skills may be an important process within introductory university courses. This study suggests that a wide range of teaching skills may be developed in different individuals, but further research is needed to determine the depth of these understandings, whether they can be transferred to other teaching experiences, and
whether other introductory science curricula result in similar skills. The potential for developing pedagogical content knowledge within large enrollment courses is intriguing, particularly considering the budgetary and staffing considerations associated with attempts to reduce class sizes.

This study suggests that subjects developed a wide range of learning strategies. Related to the concerns associated with assessing narrow cognitive outcomes, is the apparent difficulty in assessing the development of diverse learning strategies. Many courses have no direct assessment of learning strategies, relying instead on assessment of the outcomes brought about by application of these skills. However, the language of university culture repeatedly stresses the value of developing life-long learners that can think, communicate, teach, self-regulate, etc. These skills are expected to be present and adequate in students, TAs, and faculty despite extremely limited evaluation emphasis. Further research is needed on the extent of this almost incidental, but critical, set of educational outcomes.

Affective Domain

Subjects also developed attitudes, beliefs, and values during the project. Fedock, Zambo, and Cobern (1996) noted that faculty developed positive attitudes toward curricular innovation while engaged in the process. Similarly, subjects engaged in the genetics technology project indicated increased enthusiasm for the project and the course in general. Gregory (1992) stated that the STS curriculum changed student attitudes toward science. Trumbell and Kerr (1993) noted that TAs felt that science was a critical component of a student’s education. Some of the student subjects in their study reported developing more positive attitudes toward science due in part to project participation. As the studied course was the last science that many of the students would take, changing attitudes toward science issues may have been a critical outcome. Research is needed to determine whether changing attitudes lead to behaviors that persist beyond introductory science courses.

Subjects’ changing beliefs related to their own abilities as well as the abilities of others. Prather (1995) stated that faculty developed positive views of their own teaching and the self-assessment process. Similarly, subjects in this study developed more positive views of their own classroom behaviors, as well as their intellectual skills. Subjects also had changes in their beliefs in the intellectual, behavioral, and interpersonal behaviors of other participants. Trumbell and Kerr (1993) noted that TAs
had specific views about student abilities, including doubts that students could learn about science without doing science (as they themselves had done). During the project subjects changed their beliefs about the abilities of others. As discussed, these beliefs impacted interactions between participants. If student, TA, and faculty beliefs in the abilities of students had not “improved,” as they had over the course of the project, they may have reached the end of the course believing that students were capable of far less than their actual potential. Of interest is whether these beliefs subsequently transfer to other classroom situations, or revert back to their initial set point.

In the context of the project, subjects exhibited changes in their values. Barrow (1993) discussed that during the portfolio-based curriculum students demonstrated that they valued learning. Further research is needed to determine to what degree various forms of curricular innovation impact student, TA, and faculty values. This may be particularly important considering that many of the subjects in this study stated that although they had learned about various arguments associated with the genetic technologies, they felt that in times of decision-making they would rely first and foremost on their personal value systems.

Similar to the discussion of cognitive outcomes and learning strategies, assessment of variables related to the affective domain can be extremely difficult and are often lacking from course evaluation schemes. However, difficulty in assessment does not diminish the potential relevance of changing attitudes, beliefs and values in teaching and learning. The affective outcomes can interact with other outcomes, and may be necessary precursors of other learning. For example, in this study students changing attitudes toward group members, led to some students teaching others how to obtain information, which led to subsequent learning of diverse aspects of project topics. Further research into these dynamics between various learning outcomes may elucidate ways to develop scope and sequence schemes for both instructional strategies and desired outcomes.

Internal Conditions for Learning

A variety of internal factors impacted subject learning, including attendance/awareness, interest/goals, attitudes/beliefs, identity/values, background knowledge, teaching/studenting experiences, communication skills, and thinking skills. The reviewed research did not discuss the role of attendance and awareness relative to subject learning. However, curricular innovation may place greater emphasis on
coordination of participant activities. Students who missed directions in class were unable to fully participate in the group summary (and were not as aware of information located by group members), TAs who missed a prep session did not assist students with particular procedures, and faculty who were not aware of issues developing early in the course were unable to address them effectively. Additionally, as subject lives become increasingly complex with other time commitments, attention may become the "deal-breaker" that negates learning. Further information is needed on how changing student demographics, TA roles, and faculty assignments impact teaching, particularly with the potential added time pressures of curricular innovation.

Several studies discussed the relationship of interests and goals to learning outcomes. Barrow (1993) stated that motivation (as a combination of interests and goals) was a major factor impacting successful implementation of the portfolio-based curriculum. Nakhleh, Bunce, & Schwartz (1995) noted that students were impacted by the interests of others, with students discussing chemistry with one another. During the genetics technologies project, subjects learned material that had been researched by other subjects with varying interests. Performance goals, particularly appearing competent, impacted subject behaviors. Fedock, Zambo, & Cobern (1996) noted that faculty apprehension about the success of innovation impacted implementation. Trumbell & Kerr (1993) also stated that TAs felt pressures from students to grade a certain way. Innovation may challenge participant interests and goals, with the resulting uncertainty leading to teaching behaviors and learning outcomes that are distinct from other contexts.

Achievement goals varied from learning to completing a degree to finding a job. Fedock, Zambo, & Cobern (1996) stated that the faculty in the study were concerned about the quality of K-12 education. This focus on learning extended through all of the subject groups. Further research is needed to determine how pervasive performance and achievement goals are in undergraduate classrooms, and whether they inhibit or enhance prospects for curricular change. In this study, subject emphasis on learning as a goal in and of itself pervaded discussions and written comments. This is a potential indicator that an ember of the traditional goal of the university, to engage in learning pursuits, still persists in the day of career-oriented training and student-as-client mission statements.

Attitudes and beliefs also impacted learning. Trumbell and Kerr (1993) described TA and faculty beliefs. TAs were concerned that students were not capable of
understanding concepts like tentativeness, or performing data analysis. Faculty were concerned that students could not handle ambiguity, citing that as a reason for limiting curricular changes. Prior to the genetics technologies project (and through the early weeks), some of the TAs believed that students would have difficulty completing the project-related activities. This impacted the way they taught, and what students were able to learn. However, faculty were not initially concerned about ambiguity. Indeed, the uncertainty associated with the innovation appeared to set the context for altered participant roles, a factor augmenting learning. A certain degree of "risk-taking," including relinquishing specific aspects of teaching control to TAs and students may be a component of successful innovation within introductory courses. Further research is needed to substantiate this and identify systems that support occasional curricular "failures."

Background knowledge from courses, cultural experiences, work experiences, and media coverage impacted subject approaches to the project and subsequent learning. Trumbell & Kerr (1993) discussed how faculty focused on teaching facts, and were unfamiliar with research in science teaching that discussed teaching science process. This contrasted with F1 and F2, who followed research on science teaching and who incorporated both facts and processes into the curriculum. Fedock, Zambo, & Cobern (1996) also noted that faculty reading science literature could impact classroom innovations, but suggested that faculty knew little about K-12 students or the impact of higher education on K-12 teachers. F1 and F2 both had taught high school science and had experience teaching pre-service and in-service teachers. Further research is needed to assess the degree of impact faculty work experiences impact innovation. TA and student teaching and studenting experiences also appeared to lead to a series of beliefs and skills that impacted learning, although it is unclear whether these past experiences impact innovation in other classrooms.

Other studies did not review the role of communication skills, such as writing and speaking, in impacting learning in the context of innovation. Increasing emphasis on alternative content, instruction, and assessment may put a great deal of focus on communication skills. Limitations in communication skills were not readily apparent in other course activities, as students worked in groups and attended large lectures. The project resulted in individual students being heard by large numbers of classmates, as well as their TA and faculty, through the debates. Altering required student behaviors resulted in TAs (and eventually faculty) having to assist students in developing different
skills. This may indicate that curricular changes altering numerous student outcomes put increased emphasis on TAs. Further research is needed on ways courses support (or do not support) TA learning and teaching.

Learning skills included thinking skills, self-regulatory behaviors, and skills associated with obtaining information. Prather (1995) described how self-assessment led subjects to examine a broad spectrum of factors that impacted learning. The process of reflection and corresponding maintenance behaviors appeared to impact subject learning during the genetic technologies project. Thinking skills identified in the study as impacting learning ranged from reasoning to critical thinking, creative thinking, and problem solving. Trumbell and Kerr (1993) stated that TAs and faculty believed that critical thinking skills were developed while doing science research. In this study, subjects developed critical thinking strategies while critiquing other's work. Further research is needed to determine if and how the process of change relies heavily on faculty learning skills as they design curricula, TA learning skills as they determine ways to implement the curricula, and student learning skills as they attempt to complete the assignments.

The internal conditions, those that subjects brought to the classroom drama, were highly varied and transient in nature. Although initial assessment of subject characteristics may help teachers in making curricular decisions, the wide spectrum of variation of these factors, coupled with the discrepancies between self-reporting of behaviors and rapid changes make pre-assessment a daunting task. However, student self-regulatory behaviors may compensate to varying degrees for one-size-fits-all curricula. Further research is needed to ascertain how undergraduate students (as well as TAs) mesh their internal conditions for learning with existing curricula. An additional concern is whether widely varying aspects of background knowledge, including cultural traditions and creative thinking skills should in some way be valued and preserved by promoting a diversity of desirable outcomes within the university. This already may occur to a degree as different disciplines often use different forms of evaluation. However, it is unclear what role introductory courses play in building upon the beliefs, skills, and knowledge of students, TAs, and faculty.
External Conditions for Learning

External conditions impacting learning included the structure of the content, project design, course structure, course participants, institutional factors, course participant’s other commitments, and participation in the research study. The structure of the content itself impacted subject learning. Trumbell & Kerr (1993) suggested that faculty structured curricula to reflect what they themselves were taught, distilling content down to a few take-home messages. In this study, faculty were teaching content that was “new” to them (as well as other course participants). Additionally, students were not expected to learn a few pre-planned concepts related to genetic technologies. Jensen & Finley (1996) studied the impact of a historically-rich problem-solving curriculum on student learning. They concluded that the historically-rich curriculum led to a greater number of alternative conceptions than the traditional curriculum. The range of content covered in the genetic technologies project, including emphasis from historic through future considerations, may have related to the wide variety of conceptions observed in the student, TA, and faculty subjects. Further research may explore whether “new” content in the life science, such as environmental science and infectious disease, may impact a range of participant conceptions.

Aspects of the project design impacting learning included the format and supplementary information. The format of the project differed from the other course activities in the roles of the participants, research requirement, debate, assessment, and time considerations. Trumbell and Kerr (1993) found that the faculty in their study avoided scientific controversy due to concerns associated with student abilities to handle controversy. Faculty introduced and resolved controversy, and avoided critical thinking activities. The research requirement in the genetic technologies project placed responsibility for examining controversy squarely on the shoulders of the students, requiring students to engage in critical thinking as they reviewed resources.

Barrow (1993) suggested that innovation led to reflection. Subjects engaged in a great deal of reflection after the debate, speaking with other participants and writing notes about their experiences. Of interest is how student, TA, and faculty reflection may impact subsequent curricular change.

Assessment practices changed to incorporate the written and debate requirements associated with the project. Trumbell and Kerr (1993) suggested that faculty graded to rank students, and that assessment only incorporated exams. Additionally, TAs had limited understandings of alternatives to testing. During the
project, assessment contained several components other than exams, and TAs engaged in the project weighed the advantages and disadvantages of the different forms of assessment. The reviewed studies did not discuss whether participant roles were altered in the context of innovation, or whether innovation led to time constrictions impacting other aspects participant activity.

Course structure, including the activities, accessibility, and classroom environment, impacted subject learning. Jensen and Finley (1996) suggested that altering instruction was an important aspect of innovation. Fedock, Zambo, and Cobern (1996) dropped their lecture and laboratory format to incorporate a discussion-centered activity. In this study, the course structure enabled the debate to be integrated with written assignments, lecture, activities, and the textbook. All of these course components appeared to impact subject learning.

Prather (1995) studied faculty responses to viewing teaching strategies, stating that faculty benefited from exposure to a wide range of strategies. Within the project, there were a wide variety of instructional strategies, including lecture, laboratories, recitations, textbook readings, written assignments, and the debate. Subjects reflected upon these different strategies, deciding what they believed was effective or ineffective. Morgan, Carter, Lemons, Grumbling, and Saboski (1995) suggested that the smaller class sizes associated with their innovation resulted in higher intellectual skills. By contrast, this study did not indicate that student learning was inhibited by the large size of the class. Instead, the subjects appeared to have a great deal of interactions with other course participants. The reviewed studies did not describe the role of accessibility to other course participants during innovation.

Interactions between course participants impacted learning. Faculty assisted one another with preparing to teach. Fedock, Zambo, and Cobern (1996) described the importance of mentoring and preparation in implementation of an innovation. Similarly in this study, faculty assisted one another, TAs assisted one another, and faculty interacted with TAs to address curricular concerns. Morgan, Carter, Lemons, Grumbling, and Saboski (1995) noted that interactions between students and faculty increased during their innovation, as it did in this study due to research, interest in the project topics, and project-related questions/concerns. Stark, Lowther, Sharp, and Arnold (1997) describing general faculty beliefs and curricular change, stated that student feedback could be a catalyst for curricular change. The increased frequency of student-TA-faculty interactions in the context of the project led to increased opportunities for feedback. This
"simultaneous" feedback may be an important component of continual curricular change, in that the changes are made rapidly and with additional student and TA feedback, rather than waiting for later terms to interpret summative student evaluations and implement changes.

Institutional factors, including facilities and atmosphere, impacted subject learning, either directly or indirectly. Fedock, Zambo, and Cobern (1996) suggested the importance of financial and professional support in the success of an innovation. Stark, Lowther, Sharp, and Arnold (1997) also stressed the importance of administrative support and feeling of autonomy. These factors were also present in this study, although further research is necessary to assess their degree of importance.

Commitments besides course participation, including employment, health, family, and activities, impacted subject learning. Trumbell and Kerr (1993) noted that faculty felt the constraints of balancing teaching and research. Barrow (1993) noted that job and family commitments impacted student learning. Limited attention or awareness due to other commitments reduced opportunities for focusing on project activities.

Participation in the research process led to increased reflection on teaching and learning by study participants. The other studies examining innovation did not discuss the impact of the research process on subject behaviors. This may in part be due to the other studies primarily using pre- and post- innovation interviews or questionnaires, which may not have been as pervasive as this study's classroom observations and formative interviews. The methodologies in this study were actually part of the curricular innovation itself, both impacting variables of learning and being altered by those variables. These interactions are discussed later in this chapter.

Most of the external factors impacting learning related in some way to the curricular changes that were occurring in the studied course. This included changes to the content, classroom activities, interactions between course participants, and research involvement. Although the project design appeared to be the only initial factor impacting learning related to the innovation, the project altered other external factors, which in turn impacted subjects' internal factors. This indicates that changes to a curriculum can have an indirect effect and generate unforeseen demands on teaching and unanticipated learning outcomes. However intimidating this potential diversity of learning may appear to the practitioner and researcher, there are two important considerations. First, ignoring this diversity may undermine attempts to implement curricular innovation, and second,
augmenting variation in individual learners may be precisely the point of higher education. Further research is needed to address these issues.

Summary of the Study's Relationship to Research on University Curricular Innovation

As discussed, this study appeared to confirm some of the findings from other studies, and contradict others. However, the vast differences in the innovations being studied, as well as the research methodologies, suggest that further research is necessary to build a model of learning within the context of innovation.

This research contrasted with the other studies in the exploratory nature of the questions, diverse methodologies, and expanse of identified variables. Most of the reviewed studies relied on interviews and/or questionnaires to assess subject views, skills, and conceptual understandings. The spectrum of methodologies incorporated in this study may in part explain the broader diversity of identified learning outcomes and conditions for learning.

The reviewed studies provide limited information on TAs and faculty and interaction between the three classroom groups. This study suggests that TAs play a critical role in curricular innovation, and that faculty learning is a component of change. Further research is needed to explore the potentially complex interactions between students, TAs, and faculty, particularly within the potentially ambiguous and uncertain framework of innovation.

Hypothesis of Learning in the Context of Innovation

Within a context of grounded theory methodologies, themes were sought that addressed the generated variables in the context in which they were collected. From this analysis, specific themes emerged which encompassed variables generated by addressing each research question. These themes were then incorporated into a general hypothesis that maintained the relationships between variables identified in the study (Figure 5.1).
Pre-Existing Conditions

- Subject Characteristics
- Subject Involvement
- Course Structure
- Institutional Characteristics

Characteristics Of Innovation

- Altered Structure of Content
- Critical Analyses
- Reliance on Media
- Increased Time Spent on Project
- Unstable Teaching and Studenting Roles
- Performance Pressures
- Single Subject Voices Heard
- Increased Reflection

Resulting Learning Community

- Complexity of Learning
- Similarity of Subject Learning
- Subject Interactions Impacting Learning
- Fluidity of Teaching and Learning Roles
- Developing Pedagogical Ideas
- Defining Excellence and Science Intellect
- Importance Of Individual and Discrete Learning

Feedback and Changes over Duration of Project

Figure 5.1: Hypothesis of Learning in the Studied Course.
The hypothesis uses modes of representation (verbal and visual) that can be interacted with, initiating further discussion and inquiry. An obvious problem with developing a figure representing learning is oversimplification of complex events. The point of this figure is to simplify the presentation of learning in the context of innovation to a degree that it can be used in further inquiries that develop an explanation of the phenomena of learning (Gilbert, Boulter, & Elmer, 2000). This study did not seek to present a model for other courses, but instead produced variables for study and consideration in other course contexts. This is in part a summary, and in part a series of questions that lead to the study's implications. It is expected that pieces of the overall puzzle of teaching and learning will be missing, and may be filled in with subsequent research.

The hypothesis is not prescriptive, but instead a conceptual tool against which actual learning can be compared and contrasted (Rowland, 1993). It is general enough to be analyzed and tested by a range of teaching and research practitioners. Through testing it may over time contribute to a greater consensus model (Gilbert, Boulter, & Elmer, 2000).

The point of this study was to characterize learning in the context of innovation within a course with a history of innovation. The hypothesis of learning describes a testable idea of how innovation works within this particular course. References to research on learning are added to this discussion to further clarify the hypothesis. These studies primarily examined university learning, although not always in the context of innovation.

The first theme, Pre-Existing Conditions, included aspects of subjects and situations that were in place prior to implementation of the project. Characteristics of Innovation were particular features of the genetic technologies project that, when combined with other subject and situational characteristics, led to the Resulting Learning Community.

An inherent problem in developing a static representation of learning is capturing the fluid nature of change over time. Learning itself can be characterized as changes over time. The hypothesis simplifies change to a simple equation combining Pre-Existing Conditions with Characteristics of Innovation to produce the Resulting Learning Community.

Each box in Figure 5.1 indicates a superset of variables that can be characterized in multiple manners, including in many cases, along a continuum as
discussed in the previous chapter. A problem with constantly shifting positioning on a continuum is limited ability to focus on a consistent variable between subjects. With further research, these variables may be developed into a mixed continuum model that builds information more fully along each continuum (Henderson, Fisher, & Fraser, 2000).

In order to provide additional information about the hypothesis, each theme and superset of variables will be described in the subsequent sections. As the Pre-Existing Conditions were described in depth in the previous chapter, emphasis will be placed on describing the characteristics of innovations and resulting learning community.

Pre-Existing Conditions

Within this study there were a series of variables impacting learning that were present prior to implementation of the curricular innovation. These Pre-Existing Conditions included: Subject Characteristics, Subject Involvement, Course Structure, and Institutional Characteristics. The conditions were neither intractable or stable, but instead were impacted by aspects of the resulting learning community, as represented by the arrows in Figure 5.1.

Subject Characteristics

As previously discussed, subject characteristics impacting learning included beliefs, knowledge, and skills. These characteristics were linked to one another within individuals and varied widely between subjects. Aspects of the resulting learning community altered subject characteristics.

Subject background knowledge appeared to impact learning. Case and Fraser (1999), assessing chemical engineering students understandings of the mole, suggested that some misconceptions were more difficult to address than others, particularly if it was difficult to clearly define distinctions between alternative conceptions. Limited genetics knowledge may have made it difficult for subjects to distinguish between alternate conceptions during the project.

Subject characteristics also impacted interactions between course participants. Natasi and Clements (1991) discussed that research on cooperative learning with K-16 students suggested that there were cognitive-academic and social-emotional gains, regardless of student backgrounds and abilities. This study suggested that subject backgrounds and abilities did impact learning activities in the context of a cooperative project. Subjects brought perspectives and abilities to their interactions with other
course participants. Further research is needed to ascertain how student, TA, and faculty characteristics compare, and the impact of these characteristics on classroom dynamics.

Subject Involvement

Subject involvement included attendance and awareness, extracurricular commitments, as well as the specific roles played in the course (teacher, learner). Subjects engaged in specific behaviors and activities prior to the innovation. Some of these aspects, such as attendance, were altered by the learning community, others, such as family considerations remained relatively unaltered. Course roles and responsibilities shifted as the project progressed. These variables were grouped into the same superset of student involvement, as they tended to change together in individuals. For example, often students involved in extensive extracurricular activities infrequently attended class, were not fully aware when present, and more likely were passive learners in the student groups. A certain degree of attention and awareness was necessary for subjects to be able to learn.

The maintenance of a certain level of physical and psychological well-being is a necessary precondition for education. College work requires time and concentration. Having the former swallowed up by the mechanics of living or the latter disrupted by frequent intrusions or anxiety makes performing the tasks set by the educational enterprise much more difficult. (Weingartner, 1992 [p.120])

Time commitments associated with family, health concerns, employment, and other non-academic variables limited the amount of attention subjects could focus on the project. Additional research is needed to identify both short-term and long-term impacts of alternative commitments on student, TA, and faculty learning. This may particularly be the case within universities precariously balancing increased enrollments of "traditional" and "non-traditional" undergraduate and graduate students with decreased full-time faculty.

Course Structure

Course structure is a superset of variables including subject groups, classroom settings, course materials, and facilities. All of these variables were present in all of the courses in the BI 10X series. The group structure reduced teaching load on individual faculty, as well as TAs, when students acted as teachers. This division of the labor of
teaching (Diekhoff, 1956) became more augmented by changes to the learning community dynamics resulting from the curricular innovation. Similarly, classroom settings, materials, and facilities were utilized differently after the project commenced.

Lord (1997) presented the same biology information to two sections of non-majors, using two different teaching styles: traditional low-media lecture and laboratory (overheads, full-length movies, demonstrations) versus "constructivist" (use of motivators, short videos, discussions). The author noted that the "constructivist" teaching strategies were engaging and motivating for students. Prior to the genetic technologies project, the course structure included multimedia lectures, laboratories, and discussions. These multiple pedagogies, when combined with the additional project components of the written assignments and the debate, offered multiple teaching strategies for a diverse group of learners.

Limited research exists on how existing pedagogies used in introductory science classrooms impact student learning. Large enrollment courses are often grouped together, despite differences in size, course goals, content covered, reliance on TAs, assessment practices, accompanying laboratories, longevity, and a multitude of other factors. Research is needed to describe whether meaningful differences exist between a 200-student chemistry issues lecture class taught by a single professor utilizing small-group break-out activities, and a 2000-student introductory physics course with lecture and lab team-taught by three faculty, 30 TAs, and two laboratory coordinators. Continual lumping of potential "apples and oranges" classrooms may perpetuate teaching recommendations that exceed available research.

Institutional Characteristics

Institutional characteristics included campus atmosphere, facilities, and other courses. These variables shared a component that was beyond course participant control. As college learning is a cumulative process, prior courses and campus experiences impacted subject learning (Terenzini, Theophilides, & Lorang, 1984). As previously discussed, these impacts were especially evident in the context on the project, in which prior experiences, campus facilities, and campus controversies were utilized by course participants. Teaching and studenting roles were in part linked to settings. Further research is needed to establish how the greater campus community impacts functioning of introductory science courses.
**Characteristics of Innovation**

The curricular innovation involved continually changing aspects of the educational drama, including the roles of the actors, the settings, the motivations, and the script from the first week of the project through the last. The overriding theme binding the supersets of variables comprising curricular innovation is change itself, including changes in content, reliance on media, teaching/studenting roles, performance pressures, and emphasis on individual student involvement. Many of these changes were outlined in previous sections. Particular emphasis will be placed here on explaining formation of the categories relative to innovation.

This study did not seek to compare learning in traditional versus innovative university classrooms. As a result, aspects of learning seen in this study may also occur in a traditional course. Changes to the curriculum associated with the genetics technologies project in the studied course may be established components of other courses. Different curricula may result in distinct categories of change, or reflect in part those seen in this studied course.

An additional change inherent in the studied innovation was the emphasis of time students, TAs, and faculty spent reflecting on teaching and learning due to research participation. Formative data collection and analysis was a component of innovation in the studied course that may be relatively uncommon in other university courses, or conducted in manners that would result in different themes of learning.

**Structure of the Content**

Content acted as a driving force in subject learning, impacting other factors that impacted learning. The characteristics of "new" content in the genetics technology project, including structure and media form, altered subject behaviors. Distinctions between content, such as different topics and characteristics of specific topics impacted "who learned what." These aspects were external to participants and the institution. Content was also a basic thread connecting the three subject groups early in the project. Numerous examples and embedded controversy may have made the project topics more memorable than other course material (Haskell, 2001).

The importance of content emerging in this study counters other studies examining impacts on undergraduate education. Astin (1993) conducted a longitudinal study of the impact of higher education on undergraduates at 159 institutions and concluded that specific factors impacted outcomes.
How students approach general education (and how the faculty deliver the curriculum) is far more important than the formal curricular content and structure. (Astin, 1993 [p. 425])

The structure of the project topics appeared to be an important factor impacting learning, although the importance of content may be frequently overlooked.

Unless faculty continue to teach the same content from one year to the next, they must continually learn new content. However, no one can be an expert in all areas of a field as broad as general biology, indicating that faculty attempting to address emerging fields in their courses will have limitations in their grasp of the content they are teaching. As in this study, that may result in unexpected developments in the classroom. Further research is needed on how faculty and TAs approach unfamiliar content, and whether these approaches are similar to those utilized by students, as suggested by this study. Similarities in student, TA, and faculty learning may have implications for developing courses in which similar aspects of professional development are utilized for all participants. Additionally, although recommendations for practice primarily focus on the importance of faculty learning instructional strategies, research is needed to determine whether learning content is as significant, or even more significant, in a class of adult learners.

Critical Analyses

The project required subjects to critique sources of information and the quality of personal actions, as well as the actions of other course participants. Critical analysis of personal actions, an aspect of metacognition, led subjects to alter practices.

Reiter (1994) discussed the variety of critical thinking skills utilized by college students in dialogical instruction. These included: stating and defending a position, identifying multiple viewpoints, arguing an opposing position, presenting two points of views simultaneously (self-dialogue), and making a final judgment considering the different evidence and perspectives. All of critical thinking skills were represented by different student subjects during the genetic technologies project. Additionally, faculty and students engaged in argumentation over teaching strategies and assessment practices. Arguments were a way to advance learning.

Being able to present coherent arguments and evaluate others, particularly those reported in the media, is important if students are to understand the basis of the knowledge claims with which they are
confronted. Also, in our contemporary, democratic society it is critical that young people receive an education that helps them both construct and analyze arguments relating to the social applications and implications of science. (Driver, Newton, & Osborne, 2000 [p. 297])

Further research is needed on the impact of different aspects of content and pedagogy on development of critical analysis skills in students, TAs, and faculty.

Reliance on Media

Reliance on media included use of computers and journals to locate and present information. Due to the nature of the project’s requirements and structure, all subjects utilized the Internet to locate information, and most of the subjects utilized e-mail to communicate information. Many subjects reviewed science journals, and faculty presented information using computer technologies. These shifts in use of media were time-consuming and led to a degree of access and interactions not previously experienced in the series of courses. Use of media escalated as subjects worked together in the context of the project.

Garner et al. (1991) studied how undergraduate students read different physics texts. Students in the study focused their reading on interesting and sometimes irrelevant details. The relative text placement of interesting details did not impact recall, but the overall interesting nature of the text did impact recall. Similarly in this study, subjects focused on the media that they found most interesting. Typically the source of that information was the Internet.

The pervasive impact of media on aspects of teaching and learning in the studied course may indicate that other courses are being altered by emerging information technologies. As suggested by this study, many course participants may not possess adequate skills to utilize available media. Faculty implementing curricular changes may be adapting to these technologies, in addition to learning content and instructional strategies. Further research is needed on how this may compound concerns associated with curricular innovation.

Increased Time Spent on Project

Most topics in the course were only covered for only a short period of time, often only a few minutes of lecture or a paragraph in the textbook. In their study on undergraduate students, Jensen & Finley (1996) noted little reduction in alternative conceptions (misconceptions) with different teaching strategies. This may have been
due to limited time in which to change conceptions. The six-week project focused participants on particular content and strategies for a much longer period of time than other course-related activities.

Pearsall, Skipper, & Mintzes (1997) determined that a large amount of change in knowledge occurred, and that the changes were incremental. Most of the large changes occurred in the first four weeks of the semester. In this study more changes occurred mid-term, at the peak of the debates. The "building" nature of the assignments and assessment, coupled with increasing lecture and text focus, and increasing subject involvement may relate to the variety of learning occurring at the end of the project.

The length of the project enabled subjects to develop more complex relationships with other course participants. The long "life span" of time students worked with one another, interdependence of students on one another's assessment, and size of the groups meant that students were given strong incentives and opportunities to develop ways in which to work with one another (Cooper, 1979).

This study did not ascertain whether some of the learning outcomes were developed over shorter periods of time than others, although there was tantalizing suggestion that specific factors (such as public speaking pressures) could augment learning in a short period of time. Further research is needed to determine whether specific learning outcomes can be learned quickly, whereas others may be better served by long-term involvement, and which factors relate to the timing of learning. As many university courses consist of far fewer teaching staff-student contact hours than K-12 courses, the role of timing in acquiring knowledge may be an important consideration.

**Unstable Teaching and Studenting Roles**

This category included changing roles due to the project implementation, including students as teachers, and TAs and faculty as learners. More specifically, learning included cognitive, behavioral and affective categories, and teaching included assisting other course participants in learning in some manner. This shift in roles was initiated by the open-ended nature of research into genetic technologies, limited TA and faculty knowledge of topics, and willingness to release control over some aspects of the curriculum. These changes were quite different from those typically described in literature on innovation.

They [faculty] consciously sought to model learning for the students and include students as active participants in the construction of classroom
knowledge. Equally important, they sought to challenge student assumptions about how knowledge is constructed and have students take personal ownership over the learning process. (Tinto, 1997 [p. 611])

In this study, faculty modeled learning consciously and accidentally, and there was an inherent assumption that students were responsible for their own learning. Additionally, faculty did not control all aspects of the project, enabling ideas and skills to emerge that might not have otherwise. This transfer of some of the teaching control to students and more of the teaching control to the TAs enabled curricular problems to be addressed rapidly. Of interest would be additional information on which aspects of policies and procedures faculty or TAs typically control, and the degree to which student peer teaching occurs in introductory science classrooms during curricular innovation.

Performance Pressures

Performance pressures included both external pressures due to project requirements and job expectations, as well as internal pressures such as goals and interests. The debate placed public speaking pressures on students, as well as pressure to successfully work with group members. TAs, already dealing with classroom management issues such as students arriving late or missing class, had additional concerns with presenting ambiguous project requirements and correcting papers covering unfamiliar content. Faculty were pressured to respond to student and TA curricular concerns through rapid changes in lecture and searched for additional topic information. These pressures built as the debates encroached, with many students concerned about whether they would have adequate content knowledge so as not to be embarrassed during the debate. Some TAs worried that they would not be able to manage the debate, and other TAs were concerned that they would not comprehend the arguments. Faculty were increasingly tense over whether the other groups would be able to pull the whole show off.

Abrams and Wandersee (1995) noted that life science graduate students and faculty had different goals, with graduate students focused on finishing their degrees, and faculty focused on finding funding. Covington & Wiedenhaupt (1997) suggested that college psychology students were primarily motivated by the pursuit of high grades. Covington (1999) studied subject matter appreciation in college students taking psychology, and suggested that it could coincide with grade concern as long as the student’s grade goals were being achieved, what they were studying was of personal
interest, and the reasons for learning were task oriented (not failure avoidant or self-aggrandizing). This study suggested that appearing competent was a motivational factor for students, TAs, and F1, and that adequate public performance could overshadow grade-related evaluation concerns.

TAs felt pressure from their teaching commitments. Duba-Biedermann (1991) studied graduate student perceptions of their roles. Students with teaching assistantships reported higher role conflict and stress than students with research assistantships. TAs stated that they wanted additional supervision, feedback, and formal evaluation. TAs in this study received continual feedback from students and supervision by faculty during the project. This may have in part resulted in TAs playing a more active role in curricular changes.

As performance pressures were repeatedly cited in this study as a primary motivator for particular behaviors, additional information can be sought on the various aspects of performance pressures that impact faculty, TAs, and students in other courses. These pressures may increase during curricular innovation, and further study may reveal which types of innovation extend subjects beyond their “comfort range” of knowledge and abilities, and how these changes impact learning.

**Single Subject Voices Heard**

This category refers to shifting emphasis on students and TA contributing to the curriculum, as well as faculty increasing frequency of conversations with individual course participants. Typically students could keep a low profile in the studied course, listening to other group members, lecture, and missing classes without a great deal of notice. The group nature of the topic summary paper and the debate, as well as individual annotated references, notecards and critiques meant that students not only had to be present, they had to be heard. Students took this opportunity to communicate their views on the project topics as well as the course structure and other course participants.

TAs also could usually choose to listen during prep sessions and minimally prepare to teach, due to the student-centered nature of the activities. However, with the project, TAs were encouraged to actively participate in curriculum decisions as these decisions were directly impacting their own teaching. Faculty increased time spent discussing project-related topics with each other, as well as students and TAs, in part
because of the research, but also due to students and TAs seeking increased assistance.

Miller and Groccia (1997) compared lecture and cooperative learning formats in an introductory biology course. The researchers concluded that, based on emphasis on library research activities, students had increased ability to find information independently, and ability to work with others. The project incorporated aspects of both independent and group work, providing students with different platforms for learning. Further information can be sought on ways to balance individual and group contributions to the classroom.

Increased Reflection

Both the research process itself, and resulting aspects of subject reflection altered subject learning and the dynamics between subjects. Subjects reported spending additional time reflecting on their own teaching and/or learning. Additionally some of the interactions leading to curricular change during the project resulted from discussions between the researcher and other subjects.

Subjects sought assistance from other course participants. This behavior depends on identifying the need for assistance (meta-cognition), the magnitude of need, the source of assistance, and experiences seeking assistance (Karabenick & Sharma, 1994). Subjects may have increased question-answer oriented interactions due to project participation.

Flavell (1987) noted that developing awareness involved reflective thinking about the constraints and procedures to reach goals. Lin and Lehman (1999) studied college student reflection on learning and resulting transfer of knowledge in a computer-based biology class. The researchers suggested that different prompts could result in different outcomes. Similarly, in this study subjects were provided with a variety of different project-related and research-related opportunities to reflect on their teaching and learning. This may have led to increased awareness of course events and personal association with those events.

Classroom research may be a form of curricular innovation, in that it can engage participants in thinking about content and pedagogy through reflective practices. Further information on how university courses collect data on teaching and learning outcomes may reveal ways that reflection already occurs in the classroom. Action research can
potentially engage students, TAs, and faculty in strengthening conceptions of teaching and learning, which may be another route to preparing future K-16 teachers.

Resulting Learning Community

In the research literature, a learning community is generally defined as comprising of teachers representing a variety of disciplines. However, there are multiple definitions of a learning community (Calderwood 2000). In this study, TAs and faculty came from life and physical science backgrounds, and the students represented a wide variety of disciplines and ideas. Aspects of innovation led to students and TAs playing a more active role in shaping the curriculum.

Macfarlane, (1998) described a learning community as a metaphor for supported learning. Similarly in this study, the support for learning was altered through innovation, primarily through increased interactions, and this resulted in subjects reconstructing aspects of the learning environment. As characterized by Fitzgibbons (1981), learning was a process built on a series of decisions, impacted by a spectrum of beliefs.

Aspects of the learning community included complexity of individual student’s learning, similarity of subject learning, interactions impacting learning, fluidity of teaching and learning roles, developing pedagogical ideas through collaboration, defining excellence and science intellect, and the importance of Individual learning.

Complexity of Individual Subject’s Learning

As presented in the previous chapters, this study identified a large variety of learning tasks as well as diverse variables impacting learning (Tables 4.3A/4.3B and 4.9A/4.9B). Each subject exhibited a different group of learning variables (Tables 4.6 and 4.7) and factors impacting learning (Table 4.10 and 4.11). This category encompasses the learning that occurred in the context of the project. Individual learning was impacted by both pre-existing characteristics and the genetic technologies project. This learning in turn impacted subsequent learning.

The complexity of learning described in this study clearly demonstrates the difficulty in assessing learning outcomes within the studied course. The problem with assessing effectiveness of any particular instructional strategy, such as cooperative groups or lectures, may be that learning occurs sporadically in different students within a myriad of learning contexts. This does not necessarily negate the importance of a
strategy, but suggests that it would be only one of a suite of strategies targeting different students. Meaningful learning may vary widely from one individual to the next.

Similarity of Subject Learning

A repeated trend in the characteristics of learning was that there were similar examples of learning in all three subject groups. Differences emerged in the timing of learning, with some subject groups focused of particular tasks before others. There were not large differences in the "level" of learning, as many aspects of learning (such as project topics and computer use) were new for most participants.

Other characteristics of learning, in this category, included the overlap of most types of learning, as well as a high degree of similarity in categories or learning and the factors impacting that learning. Additionally, as many differences in learning appeared to exist between individuals within the same subject groups as between individuals in different subject groups.

Kindfield (1994) examined how individuals at different levels of science expertise, (professor, graduate student, undergraduate student) understood the process of meiosis. Even though all subjects revealed extensive meiosis models, the more experienced subjects demonstrated more scientifically correct conceptions and fewer misconceptions than less experienced subjects. Since all three subject groups in this study had been relatively unfamiliar with the genetic technology topics to begin with, as contrasted with a commonly taught concept such as meiosis, misconceptions developed in all three groups.

The project provided subjects with an opportunity to learn more about what other participants knew (and did not know). Donald (1993) had university physics teachers and researchers state what they believed students should learn about physics and compared that to the perceptions of the students enrolled in the physics courses. The professors assumed that students knew basic physics vocabulary, and primarily discussed the importance of instructional strategies and developing student learning skills. Students discussed their own limitations and stated that effective professors should not assume prior knowledge. During the course of the project, subjects became more aware of the strengths and weaknesses of other course participants, which enabled them to assist one another. This may be a potential avenue to developing
awareness of characteristics of learners, a component of professional development for future (and current) teachers.

Interactions Impacting Learning

Interactions between course participants varied due to the structure of the project, and the increasing degree of interactions impacted the curriculum itself. Additionally, interactions were part of the reason for the large breadth of types of learning between groups.

Having a debate as a central point of the project led subjects to confront views that opposed their own. Controversy theory states that when students encounter opposing points of view, they will reconceptualize, search for information, and refine conclusions (Johnson, Johnson, & Smith, 1998). That search for information led to increased interactions between subjects.

Vygotsky (1978) outlined the zone of proximal development as learners depending on others to model the knowledge that exists in the spot between the learner's previous knowledge and new knowledge. Many of the subjects mimicked behaviors of language adopted through interactions with other course participants. As described at the end of the previous chapter, aspects of learning could be traced traveling back and forth through subject groups (Figure 4.21). These learning patterns demonstrated how interactions over time could lead to information and skills passing repeatedly through subjects, changing form in the process.

Fluidity of Teaching and Learning Roles

As previously discussed, the nature of the project placed students as teachers, and TAs and faculty as learners. This fluidity of roles may not have occurred in a more stable situation where the faculty and TAs clearly had the “right” pedagogical and content answers, and limited flexibility. Subjects moved back and forth along a continuum of teaching or studenting (Figure 5.2).

![Figure 5.2: Teaching and Studenting Roles.](image)
Initially the process of TAs and faculty reaching limits in content knowledge appeared uncomfortable for all involved. However, students appeared to later understand that they were researching extremely current information and that the basic genetics presented in lecture, the text, and activities related to what they were researching on their own. Students continued to ask content questions even if it meant they would be searching the Internet for answers alongside their “teacher.” Although faculty were aware that they had content and pedagogical shortfalls, the TAs were reluctant to discuss their own understandings. This may reflect their positions within a campus culture that assumes that any professor should possess the content knowledge necessary to teach an introductory course in their discipline.

Students actively assumed the role of teaching fellow students, and many brought information to their TAs and faculty. They also offered a wide range of suggestions for curricular change, particularly related to the project. Students demonstrated more knowledge of specific topics than TAs or faculty. They shared and actively presented what they knew to other course participants. Van Driel, Verloop, & de Vos (1998) studied developing PCK in 12 chemistry teachers. In part they concluded that if teachers focused on content, the pedagogy followed. This may be similar to the phenomena of subjects learning content and then finding ways to share it with others.

Subject’s roles shifted as their goals shifted. Chinn & Hilgers (2000) examined the relationship between undergraduate science instructors’ course goals, their instructional activities, and students’ views of learning within the context of writing-intensive courses. Instructors had common stated goals, but highly varied instructional strategies. The researchers described results along a continuum from instructor as corrector to instructor as collaborator. In this study, T1 had mixed views of TA role (Figure 5.3).

![Figure 5.3: TA’s Perceived Roles. Based in part on Chinn & Hilgers (2000).](image-url)
McKeachie (1997) in summarizing the results of various studies on student ratings stated that "effective teachers come in all shapes and sizes" (p. 1218). This study suggested that teachers can be found in all groups of course participants.

Developing Pedagogical Ideas Through Collaboration

Subjects adopted new ideas about teaching and learning during the project. These ideas were largely attributed to their interactions with other course participants. Subjects discussed teaching and learning with members of their own peer groups. These conversations often revolved around analyzing the negative aspects of a particular course participant (student, TA, faculty). Through these conversations, subjects developed ways to interact with participants they perceived as difficult in some manner. TAs and faculty also discussed teaching techniques during the prep sessions, with increased emphasis on discussing pedagogy-related topics around the time of the debate.

As the project progressed, some students and TAs began discussing teaching during class, particularly in relationship to problems with the project directions. These conversations were also underway between the researcher and subjects, and widened to encompass the other faculty, TAs, and students in the hallways and offices. Conversation typically focused on resolving a particular instructional problem, and culminated in a joint construction of a solution. These interactions directly improved the course curriculum. Chism, Fraser, & Arnold, (1996) suggested that collaboration between course participants supplemented or strengthened individual academic effort. This appeared to occur to a degree in the studied course, in which students who were unlikely to attend other parts of the course, actively contributed ideas about ways to alter the curriculum.

In addition to talking about teaching, subjects mimicked aspects of teaching that they liked. This was especially apparent in how some of the TAs managed the final debate preparation session, and students chose to present their debate arguments.

Mahoney (1997) discussed that experienced faculty focused on learning content, not new teaching techniques, describing this as an aspect of career-long learning. However, this study suggests that innovation challenges participants to address both conceptual and pedagogical aspects of a curriculum.
Hammrich (2001) discussed the impact of a seminar on biology graduate TA understandings of instructional strategies. Teaching was seen primarily as "knowing your subject matter and having good organizational skills. Listening to the questions students ask and handling the lab as an inquiry were rarely mentioned" (Hammrich, 2001 [p. 75]). This study suggests that many aspects of pedagogy were discussed, and this may in part have to due with students joining the discussion on effective teaching.

Pollio and Humphreys (1996) interviewed ten faculty who had recently won teaching awards to generate a list of factors the subjects thought were critical components of good lectures. The factors generated by the faculty included connection and relevance of topics, degree of excitement and interest, continuity between topics, clarity, and degree of spontaneity. In this study, faculty, TAs, and students were constructing similar understandings of factors related to effective teaching of project topics, as well as other teaching methodologies used in the course. This may be another aspect of professional development that can occur in introductory science classrooms.

Defining Excellence and Science Intellect

Subjects came to forms of consensus of what should be classified as acceptable behaviors, beliefs, and understandings. As the project had never been previously implemented, it was unclear what student outcomes should be anticipated. In the initial project design, students were asked to evaluate the debates, TAs were to develop grading schemes for the various project assignments, and faculty were to write the exam questions that would reflect student understandings of the project topics. None of these tasks ended up being accomplished without feedback from the other subject groups. This process of designing the assessment coupled with the degree of reflection occurring due to research participation, led to group characterization of excellence related to project teaching and learning.

Gusky (1988) interviewed introductory level professors that they believed to be exemplary to determine which traits they had in common. These traits were consistent teaching strategies that included planning, positive regard for students, student participation, and consideration of feedback. These traits identified by Gusky closely matched student, TA, and faculty views of exemplary teaching brought to the project. Young and Shaw (1999) asked undergraduate students in a variety of disciplines to rate faculty teaching. The researchers concluded that the construct of teacher effectiveness
was multidimensional and could be defined in numerous ways, with factors impacting one another. Similarly, subjects discussed how different individuals could use a variety of techniques effectively, such as different student groups effectively presenting arguments through use of media, personal stories, or well-substantiated claims.

Typically learning outcome evaluation in the studied course would focus on mastery of project topics and other course topics. As this study makes clear, there were many other aspects of learning occurring in the course. Student and TA generated grading schemes for the debate focused on preparation, presentation, content coverage, and whether or not they felt they learned something from the arguments. The preparation, presentation, and content aspects matched the expectations of faculty, who incorporated perception of learning into the final general scheme. Subjects made decisions to not include other aspects of learning in the grading scheme.

This indicates that much of the learning in the course fell outside of the grading. Nordvall and Braxton (1996) discussed considering the importance of students learning course content while defining quality education. Much of current student evaluation focuses on general, content-independent, cognitive and affective outcomes. Subjects did use informal forms of assessment feedback (clapping, complements, laughing, frowning) to indicate response toward particular behaviors and statements. Assessing teaching and learning can be a process that relies on "communities of shared reflective judgment" (Schulman, 1993 [p.6]).

Subjects also represented science intellect in their writings, conversations, and presentations. This included adoption of scientific language and aspects of science culture. Students defined conceptual boundaries in their writings. In the context of the project, all subjects played a role in defining what it means to be scientifically literate. Nelson and Hammerman (1996) discussed the possible significance of sharing epistemological ideas within a learning community in mathematics courses changing to address reforms.

Further, working with teachers as they reinvent their practice provides the opportunity to develop "layered" communities of inquiry in which students investigate mathematics and what it means to understand it; teachers investigate students' mathematical thinking and the nature of teaching practice; and teacher educator/researchers investigate teachers' mathematical and pedagogical thinking, the process by which they change their practice, the contexts that support change, and their own practice. Such "layered" communities of inquiry imply that all parties
inhabit the same epistemological space and learn together. (Nelson & Hammerman, 1996 [p. 20])

As one of the primary role of the university is to foster developing intellect, co-construction of representations of intellect may be a critical component of science courses. As an introductory science course is the last science many non-majors may take, this is their opportunity to contribute views and values regarding scientific pursuits. In this study, students often retained ideas that scientists had surreal characteristics with extreme tendencies. There was little discussion of the activities of scientists. This echoed concerns in concurrent science editorials.

The idea that science is monolithic, incomprehensible, soulless and basically bad for us forms the core of a central paradox of our times: Science has become least popular and most feared at the height of its influence and intrinsic interweaving with our daily lives and activities – least pursued and cherished when most essential to the core of education for all thinking people. (Gould, 1998)

Additional research is needed on ways to support students developing views of science through their own research and inquiry.

Importance of Individual Learners and Discrete Learning

With the detailed examination of the subject interactions, particularly group dynamics, it is possible to ignore the degree of individual learning that occurred in the course. Much of the subjects’ activities occurred out of view of the researcher, such as students writing their papers in the computer center, TAs reading the textbook in their individual offices, or faculty preparing their lectures at home. A great deal of learning may have occurred as individuals worked on their own. This was evident at sequential formative interviews, in which subject ideas, beliefs, and abilities had changed outside of the observed course activities.

Additionally, even though subjects were working within a group in class, they were learning as individuals. This became apparent in studying the degree of dissimilarity in learning between students subjects in the same group. Considering an individual learner in a course of hundreds of students may seem impossible, or even irrelevant, but the data from this study suggests that there is no typical student or easily identifiable group of learning outcomes that can be applied to an entire subject group.
One student's learning may still be significant (at least to that student), even if it would often be blanketed by other student results.

Micro-macro perspective indicates observing details of the classroom while being able to also see a broader perspective (Frank, 1999). Using the analogy of a zoom camera lens, there are a wide range of perspectives for viewing what goes on in the classroom. This study utilized a wide angle view to capture a picture of general characteristics of subject learning, additional studies could provide focus into each of the variables. It should be noted that the laundry list of learning generated in this study applied to a subset of subjects (2 of the 3 faculty, 5 of the 7 TAs, 25 of the 519 students). This indicates the generated list of learning variables may not be complete, that even a greater number of variables may be elucidated through further studies. Additionally, a factor that appeared in one student subject may actually be present in dozens of students in the greater course (Figure 5.4).

Figure 5.4: Subset of students may not represent breadth of overall student learning in course.

Bianchi, Cavazos, & Helms (2000) studied aspects of science teachers and scientists' views of gender and ethnicity in science education. One of these aspects related to perceptions of student experiences. The data revealed a wide range of beliefs along a continuum from all students perceived as the same to students seen as individuals (Figure 5.5).
In this study, the word "subjects" can be substituted in Figure 5.5 for the word "students," in that subjects changed their own views of their roles over the course of the project, as well as the roles of other participants.

**Feedback and Changes over Duration of Innovation**

Arrows in the hypothesis of learning (Figure 5.1) represent change over time. Pre-existing conditions combined with characteristics of innovation led to development of a learning community over time. Additionally, aspects of the learning community impacted the pre-existing conditions and innovation over time. Time was a repeated theme in the data. This third dimension of learning is often missing in research accounts. Merely examining the "before" and "after" would have missed much of the interplay of factors impacting learning.

Timing was a critical context for learning. Even if subjects demonstrated similar learning, that learning often occurred at different times in different contexts (Tables 4.6, 4.7, 4.10, and 4.11). A great deal of variation of learning occurred over time within individuals, with most subjects learning more as the project progressed (Figure 5.6).
Different students in groups made different contributions at different times (for example, annotated references, organizing group summary, supergroup dynamics, debating). Many early interactions between subjects had negative impacts on learning, such as the early effects of TAs on learning more negative than positive. A shorter period of data collection may have missed the transition in impact of interactions on learning. Additionally, the longitudinal nature of the study identified aspects of the resilience of learning, whether particular aspects of learning were fleeting.

Results suggested the importance of defining the experience of learning itself. Finn (1997) stated that the concept of experience remains relatively unexamined in the research on cooperative education, including the aspects of time and repetition. Other researchers have also suggested the significance of viewing learning in a temporal context.

As we mentioned earlier, a key term for us is *temporality*. Partially we mean, of course, that an experience is temporal. But we also mean that experiences taken collectively are temporal. We are therefore not only concerned with life as it is experienced in the here and now but also with life as it is experienced on a continuum—people's lives, institutional lives, lives of things. Just as we found our own lives embedded within a larger narrative of social science inquiry, the people, schools, and educational landscapes we study undergo day-by-day experiences that are contextualized within a longer-term historical narrative. (Clandinin & Connelly, 2000, p. 19)

Weade (1992) discussed situating teaching and learning in time and space. Course participants were situated in the past, present, and future, home, school, community. Each participant brought a different set of points, and these points were woven together in classroom interactions. Time and situation were also critical components of this study, and further research is needed to determine their impact on other introductory science classrooms. Studying characteristics of context over time may reveal critical information about learning in the introductory science classroom, particularly in "long-term" innovations are implemented. As previously discussed, the context of learning needs to be considered, potentially negating the utility of "one-size-fits-all" teaching recommendations.
Characterizing the Learning Community in the Studied Course

The ability to establish a community of learners has been questioned in large-enrollment classrooms.

Common sense would indicate that large classes are an obstacle to the creation of an experience of intellectual community between faculty and students and among students. (Spitzberg & Thorndike, 1992 [p. 120])

Although the text continues by focusing on issues associated with large lectures, "large classes" are used as a blanket term that negates that large-enrollment courses can actually utilize a myriad of instructional strategies. This study challenges the idea that community can not be established in a large enrollment course. The curriculum can be developed along with the course community building, as occurred during the genetics technologies project.

...building the classroom community and learning the curriculum are the same thing: members of the classroom learn through building a community and at the same time build a community through learning. (Matusov, 1999 [p. 163])

Multiple individuals; students, TAs, and faculty; represent a variety of perspectives and disciplines.

...it is apparent that students are influenced by participating in a setting in which sources of learning come from a variety of perspectives beyond that of one faculty member. The sharing of a curriculum and the use of collaborative pedagogy that brought students and faculty together to teach added an intellectual richness to student experience that the traditional pedagogy did not. (Tinto, 1997 [p. 613])

Membership in a learning community does not indicate that all participants need to be learning the same thing in the same way, at the same time. Additionally, participants do not even have to share the same goals. In speaking of the role of community in education, Noddings (1996) notes "We ought to be cautious, also, in pushing for collective goals and demanding a collective identity." (p. 267)

Conflict and shared control were attributes of the project that facilitated development of the resulting learning community. The learning community was characterized by subjects with different backgrounds and temporally displaced learning, working in relationship to the project. For example, students found new ways to
approach a topic, such as locating a relevant Internet website, and shared the information with their TAs. The TAs altered teaching to make that information accessible to other students in the class. In some cases, the TAs also shared this information with the faculty, and the faculty incorporated the new information into curricular revisions. Instability or perturbations played a role in meaningful change.

Maybe conflict is the point, changing aspects of the course to the point that there is unpredictability. There may be risk associated with “playing it safe,” in that some aspects of the learning community may not occur. Traditional "textbook-based" biology courses attempt to eliminate content disturbances. However, these courses may undergo other types of disturbances such as changes in faculty. Additional research is needed to determine whether there is a relationship of conflict and learning outcomes in university courses undergoing innovation.

Summary of an Emerging Hypothesis of Learning

This study was designed to characterize learning in a course undergoing continual curricular innovation. The characteristics of innovation that provided the context for a diverse and fluid learning community can be summarized simply as change. The content covered was changing, the teaching was changing, and as a result, learning was impacted. The process of changing multiple aspects of the course, including both intentional and unintentional changes, led to a series of problems and opportunities. Resolution of the emerging conflicts enabled individual subjects to have an impact on the curriculum. Opportunities for interaction and a breadth of learning engaged subjects in the learning process. Further research is needed to determine whether these aspects of learning occur in other courses, and whether they are unique to the process of innovation.

Although this study is primarily descriptive in nature, it also may contribute to the development of theory. In order to understand the role this research may serve, this chapter continues with discussion of the role of the researcher as well as limitations of study methodologies.
The Role of the Researcher

Researcher as Participant

In participative action research, those involved are impacted by the research. As expected, there were numerous ramifications of the researcher doubling as participant in the studied course. Each role impacted the other continually, and discrete boundaries between roles were inextricable during data analysis.

Access to subjects and course events was both facilitated and limited by the researcher’s involvement as course coordinator. Participation as curriculum designer enabled the researcher to actively follow all aspect of the curriculum from beginning to end. As lecturer, the researcher was able to interact with other faculty, students and TAs through lecture, preparatory sessions, and office meetings. As a former TA, the researcher had familiarity with the activity settings and was able to interact closely with students and TAs in their laboratories and recitations. All of these factors led to an ethnographic advantage that enabled the researcher to observe and interact with subjects in many project-related settings.

The researcher's course-related roles also limited access in some aspects. Students were initially reluctant to express negative attitudes toward the course, and could have been impacted by “talking with the teacher” throughout the project. Additionally, TAs reported being self-conscious during early classroom observations, and may have altered behaviors in response to the “boss” being present throughout the term. Although subjects did not state that they altered their behaviors in response to researcher presence, it could have still been occurring in subtle manners. There may have been a type of “halo” effect in which subjects attempted to represent themselves in a positive manner to the researcher. The researcher also did not have access to student group activities outside of the classroom, learning center, or library. Group work at cafes, homes, or conducted via e-mail were only monitored through later reports from subjects.

Data collection and analysis was through the eyes of the researcher and this perspective was shaped by prior and concurrent experiences as participant in the courses. The researcher’s perspective of learning often differed from that of other subject’s, particularly when the researcher observed one thing and another subject recalled another. The researcher, lacking omniscience, was limited to weighing personal perspectives with that of other subjects.
Throughout data analysis it was apparent that at times individual subject’s perception of others could be more accurate than perception of self. This could also have been the case with the researcher’s own perceptions of self, as both course participant and researcher.

The researcher was not an impartial observer. As a participant, there was a goal to impact the studied course in order to improve it. That meant that the researcher assisted subjects as needed and that this participation was a factor impacting subject learning.

Additionally, personal characteristics of the researcher impacted aspects of teaching and research. Data collection was limited by the ethical boundaries of researcher. No data collection about subject involvement, such as a researcher speaking with students about a TA, or vice versa, occurred in a public setting. During interviews, the researcher did not encourage continued negative comments from one subject about other course participants.

**Evolving Teacher and Developing Researcher**

The researcher was undergoing dramatic changes in perspective and ability throughout the progression of this research, particularly as analysis of the data took a great deal of time. These changes impacted and were impacted by the research process.

Although the researcher had previously taught biology, many aspects of teaching were altered during the studied course. This included training for a new role as course coordinator, learning new biology content, and developing new teaching strategies. Former teaching strategies and ideas were altered due to researching the project, an evolutionary process of changing the frequency of actions and incorporating novel ideas.

The researcher benefited from both mentoring and independence in regards to research and teaching. Frequent discussions with F2 were important in formulating teaching strategies. Additionally, the research proposal and defense process were important in coalescing methodologies. Later, during the data analysis that followed the post-project interviews, autonomy enabled the researcher to explore several avenues of interpretations.

The genetic technology project also impacted the researcher’s interest in the content and teaching. This was a form of perspective transformation (Mezirow, 1981) that impacted further development of PCK. The research process itself also had a major
impact on building researcher interest and knowledge of educational theory and research.

Research results differed from the researcher's preconceptions. These differences were not immediately apparent and emerged after extensive data analysis. Difficulties in data analysis could in part be attributed to differences between the researcher's preconceptions about the results and the actual results. Over time, with an extensive review of the literature, categories emerged which has previously been unrecognized by the researcher.

Although the juxtaposition of the research and teaching led to serious time limitations, the process enabled the researcher to develop an equal affection and enthusiasm for the widely different thought processes involved in researching learning and teaching biology. Identifying parallels between teaching and research, such as the need to be open to new ideas, made it possible to maintain both a teaching and research agenda.

Reconciling the Narrative and the Interviews

Subject perspectives of events often differed from the perceptions of the researcher, and resolving these conflicts was one of the most critical components of data analysis. Additionally, the researcher and other subjects used distinctly different language, including examples, to describe particular experiences.

Goodson & Walker (1988) noted that there is continual tension between researcher's context and subject's speech. The researcher's views of the studied project were understandably distinct from those of other course participants. This was particularly the case in matters exposing subjects' own perceived vulnerabilities such as content and pedagogical weaknesses.

In order to give other subjects a voice during data analysis (beyond the post-project interviews), the researcher kept journal notations separate from subject artifacts and interview responses. Discrepancies between researcher and subject views were primarily addressed by adopting the variables generated by the balance of data from multiple sources.

Still, the researcher had a limited perspective on events, and with copious data related to subject learning, collected data were distilled down to variables that were assembled by the researcher into connected categories. The process of distilling down
the events into text meant defining a distinct narrative space that represented aspects of subject interactions and change over time.

With this sense of Dewey's foundational place in our thinking about narrative inquiry, our terms are **personal** and **social** (interaction); **past**, **present**, and **future** (continuity); combined with the notion of **place** (situation). This set of terms creates a metaphorical **three-dimensional narrative inquiry space**, with temporality along one dimension, the personal and social along a second dimension, and place along a third. Using this set of terms, any particular inquiry is defined by this three-dimensional space: studies have temporal dimensions and address temporal matters; they focus on the personal and the social in a balance appropriate to the inquiry; and they occur in specific places or sequences of places. (Clandinin & Connelly, 2000, p. 50)

The risk associated with defining this narrative space was evident in data analysis, when despite repeated comments from F2 that content was a significant factor impacting learning, the researcher did not initially pick up on this trend in the data.

> Remember, its not just how you teach, its what you teach, remember the content, the process of science is key. (F2)

Narrowed focus on how to teach rather than on what to teach, was indicative of how researcher background could change overall data interpretation. It was not until other subjects' voices were left intact in the data that many of the more general categories emerged.

An additional concern was researcher identification of trends in the data that had never been mentioned by other subjects. For example, the theme that conflict arising during innovation resulted in ambiguity, and for some, more learning opportunities, was never discussed by subjects (including the researcher) during data collection. Part of the role of the researcher was to utilize a wide angle lens to identify those themes that linked the data, irrespective of whether others had observed those themes.

Dewey (1929) discussed that in dealing with the unease of ambiguity, the researcher ultimately abandons the quest for certainty. An essential part of the research process was determining when no further information could be obtained from the available data.

**Research as Collaboration**

The nature of this study included subjects contributing to the data analysis portion of the research process. During data collection, the researcher continually
analyzed incoming data to search for variables and developed initial categories of learning. The researcher then asked directed questions during formative interviews to elaborate on categories. During the post-project interviews subjects were asked to respond to these categories, providing the researcher with additional information to resolve data conflicts and link categories. This meant that subject voices were heard during analysis as well as data collection, and the results of this study reflect the work and thoughts of all subjects, to varying degrees.

Drawbacks to this process of collaborative analysis included varying involvement by particular subjects. Some subjects were much more engaged in discussing research results at the end of the post-project interviews than others. Another concern was that there were particular topics subjects did not want to discuss, such as TA reluctance in expressing content knowledge. In these cases, discussing self in the third person, or developing hypothetical stories of data allowed subjects to share stories of mutual shortcomings. Another potential drawback was that subjects could be fabricating events outside of the observable classroom context, or misrepresenting knowledge in some manner. At times this was apparent through the exceptional nature of comments, but it was likely many cases of misrepresented knowledge were incorporated into the greater data set.

Another aspect of collaboration was the form of dialogue between the researcher and other subjects. This dialogue varied by subject and over the duration of the project. Since verbal reporting was such an essential component of data collection, developing a dialogue that could freely flow between question/answer and conversational was important. For most of the project, dialogue between researcher and student could be best characterized as question/answer, with a shift toward conversational occurring during the post-project interviews with many student subjects. By contrast, most interviews with TAs and faculty were more conversational in nature, and it was more difficult to maintain a question/answer dialogue.

Due to the degree of interactions between the researcher and other subjects, research progressed from cooperative interactions to collective self-reflection (Schartz, 1993) by the time of the post-project interviews. Collective self-reflection indicated that subjects reviewed events with the researcher to determine what messages could be gleaned from shared experiences.
Limitations of Study Methodologies

Concerns and Changes Related to Methodologies and Analysis

There were a number of logistical problems that were altering data collection and analysis as the study progressed. These changes were both expected and unexpected and ranged from minor inconveniences to time-consuming corrections.

During the first activity, designed to collect student background knowledge on genetic technologies, three of the TAs provided the answers to students. This reduced background information, which were partially filled in with the week one classroom observations and week two formative interviews. Most students indicated little to no background knowledge on either gene therapy and genetic engineering in general.

Although all TAs were fairly easily accessible, some of the students were difficult to collect data from, particularly three that had repeat absences, one of who missed the debate. These three students also had three of the lowest final grades out of the 25 student subjects, and the researcher searched for the impact of attendance on learning.

The researcher and other subjects altered the manner in which they communicated as the research progressed. Initially answers were brief and the researcher and subjects were formal in addressing one another. This changed as the week's progressed, and these changes in communication were yielding more data and potentially affecting substance of subject responses. This impact of research involvement on quantity and quality of data, as well as subject reflection was noted, and directly addressed in the post-project interviews.

Some of the subjects also appeared to be attempting to paint a particular picture to convince the researcher of a belief or action that may not have been an accurate or complete representation. The researcher had been searching for trends of bias in her own journal entries and attempted to search for suggestions of this type of diversion during the formative interviews (Weiss, 1994). The most obvious examples of this with student subjects were their early reluctance to disclose last-minute preparation of the annotated references, possibly not surprising considering the interviewer was also the teacher. However, as the project progressed, students did not appear reluctant to discuss working last-minute on assignments and approached new topics like altering lectures. Many students did, however, appeared to avoid talking about group members during formative interviews, which the researcher did not encourage due to the public nature of the setting.
TAs appeared to be reluctant to discuss the project topics and course content in general. Attempts to find out more about what they knew were frequently deflected with answers about teaching philosophies or techniques. This may have been in part due to the TA thinking the researcher was primarily interested in their teaching. However, two of the TAs also did not discuss classroom management concerns as important, although the researcher had classroom observation data indicating those TAs trying new strategies to control student behaviors. Questions regarding content knowledge and classroom management were raised in the post-project interviews.

The researcher was initially focusing on pedagogy during data collection, and efforts were made to "re-focus the lens" (Researcher Journal) to take in other aspects of learning. Prior to the debate, much of the focus was on the teaching-learning interactions. By week 2, the researcher was attempting to collect more detail about content. Following the debates, additional emphasis was placed on collecting information on subject beliefs. These shifts were not fully echoed in the hypothesis of learning later in the data analysis. The researcher was also being impacted by the research data, particularly in the affective domain of increased enthusiasm for the course. This was not controllable, but was noted as a factor impacting F1 learning.

Although there was not a noticeable increase in the time subject TAs and students spent in office hours, the research was limiting the time the researcher was available to non-subject students. This persisted until completion of the post-project interviews. Additionally, non-subjects were interacting with the study participants, and potentially impacting their learning. These interactions were noted as frequently as possible, although data was not collected on non-volunteers.

During the week six debates it became apparent that it would have been helpful to have data on entire supergroups. However, since recruiting students at the peak of data collection was not feasible, debate transcripts were somewhat fractured, particularly the questioning/answering.

An unanticipated change in the research design was the inability to videotape all of the debates. In order to videotape the debates, all students (subject and non-subject) had to agree. Some of the students stated that they would be nervous with a video camera, so the researcher relied on a combination of audiotape and selective verbatim. This made it a priority during debate data collection distinguish which comments were made by subjects while the debate progressed. Additionally, due to loud background noise between classes and concern over taping non-subjects, the researcher ended up
relying much more heavily on notes than audiotaping than previously planned. This led to a greater degree of analysis of data as it was converted to digital form frequently throughout the week.

The amount of time spent on collecting data, particularly re-writing field notes, left limited time to organize data and search for emerging categories. As a result, the researcher had a rapidly-expanding list of categories of learning and variables impacting learning, but limited idea of how these variables related to one another. The researcher compiled a list of specific topics to ask subjects about in the post-project interviews, often without being clear about whether those topics or variables were interrelated and whether they applied to other subjects. Similarities and differences in subject learning became more distinct during and after the post-project interviews.

**Unresolved Data Conflicts**

Due to the enormous scope of the research questions and the variety of data sources, data conflicts remained. The researcher addressed these persisting conflicts by trying to identify the reasons for data inconsistencies and devising a strategy to deal with vague data.

Subject perceptions of shared experiences varied, and were often irreconcilable with the researcher's interpretations. This did not indicate that one perception was more accurate than the others, the subject and researcher may have been viewing slightly different aspects of a complex phenomenon. It was difficult for subjects to retroactively point out where they learned something from or why they made a specific decision. As a result, confirmation of the factors impacting learning was cursory. Subjects generally confirmed the researcher's categories of factors impacting learning, but were not able to elaborate on many of the factors, suggesting that subject recall alone could be insufficient to flesh out categories.

In order to deal with persisting data conflicts, the researcher flagged specific points with comments indicating concerns, and incorporated this information into the discussion and hypothesis of learning. Data were not discarded and the conflicts appeared to be another piece describing the complexity of learning interactions.

Similar to the students, the TAs has some disagreements with the researcher's interpretations regarding the degree of impact a factor had on their learning. Most of the disagreement centered on the amount of content knowledge the TAs acquired in relationship to the project.
Scope of Research Questions

The scope of the research questions were very broad to characterize learning variables that could direct, or possibly re-direct, research on student, TA, and faculty learning. The open-ended nature of the questions of what was learned and what impacted that learning necessitated elaborate data collection and data analysis.

Even though data collection primarily centered on the six-week project, with a total sub-set of 32 subjects, the amount of data generated was enormous. This was in part due to the incorporation of a large variety of data collection techniques intended to identify as many variables of learning as possible. The degree of data generated meant that time to transcribe and analyze that data was extremely limited, leading to prioritization of some data (formative interview) over others (lecture video). Additionally, scheduling data collection was challenging. The researcher was unable to speak with every subject around each project activity due to conflicting schedules or subject attendance. Prioritizing data collection may have led to some data being missed or ignored. Even the post-project interviews were difficult to schedule, as many exceeded two hours in length due to conversations between the researcher and other subject.

Organization of data from different sources was also a major concern, with piles of notes, transcripts, and artifacts often accumulating in the researchers files prior to analysis. The original organizational plan of separating data into files by type of data had to be altered to filing by subject, which was later altered to chronological appearance in the research process.

Only a small percentage of total data was analyzed prior to the post-project interviews, leaving an extensive amount of data analysis to follow completion of the project. As this was the researcher's first study of this magnitude, data analysis went in many different directions before reaching the current conclusion. As previously mentioned, the resulting hypothesis reflects the researcher's construction of actual events.

The general nature of the research questions led to expansive data that encompassed broad aspects of educational theory from self-efficacy to collaboration to community. The researcher attempted to relate the results of this study to the various existing theory, cognizant that many aspects of theory related to this study may have been overlooked or generalized.

This study did not seek to compare the impact of innovation with that of "non-innovation". Instead this was an attempt to describe learning as it occurs within an
introductory course that periodically undergoes change. This was an attempt to represent the type of classroom that already exists, to see what practice and outcomes already exist in case educators are at risk of “throwing out the baby with the bathwater.”

This was a major study in scale, representing a great deal of subject effort and input. The study did not quantify learning or the degree to which particular factors impacted learning. Additionally, some aspects of learning were not evident in the data, such as the mechanism of learning (association, habituation, etc.) or provide detailed description.

**Design Limitations**

The study design was qualitative in nature to match the research questions, and research design decisions were made prior to and during the study which limited the data that would be collected, and the potential application of the results. A limited sample of subjects were studied, and as it was not clear which variables would be generated, no attempt was made to attempt to select a sample representative of the class or other classes. This indicates that results cannot, or should not, be extrapolated to other classroom settings. Instead, the generated hypothesis of learning can provide variables to search for in other courses.

Timing of data collection meant that subjects discussed learning after completion of the project. This was meant to engage subjects reflection on the process, but memory of particular experiences may have been limited at that point.

Extreme limitations in literature related to TA and faculty learning, as well as the characteristics of general undergraduate learning led to exploratory research questions and incorporation of a grounded theory design. Grounded theory meant identifying variables and moving from the specific to the general through continual changes in data collection and analysis. The researcher incorporated theoretical sampling, such as asking specific questions based on a previous observation, during the research process.

Theoretical sampling provides the flexibility of following clues in the data; but a flexibility that is channeled by being grounded in the data already collected and analyzed. (Taber, 2000 [p. 483])

This indicates that the research headed in specific directions based on the researcher's interests and interpretation of data. There was a temporality to the grounded theory design (Hutchinson, 1988), meaning that there were fleeting opportunities for a direction
of inquiry and that meaning and interpretation changed over time. Different directions may have been possible, but were not part of this study.

Despite the limitations of the grounded theory design, the variables generated may bridge the gap between anecdotal case studies and large-scale quantitative studies (Taber, 2000) or contribute to the generation of a unifying theory of university learning. The complexity of learning elucidated in this study may not have been apparent in a study organized around large sample size.

**Identifying Subject Learning**

Specific research concerns related to defining and identifying learning. To keep from missing particular aspects of learning, the researcher elicited assistance from subjects in characterizing their own learning, and sought additional aspects of learning described in educational research. Subjects commonly provided propositions, or connections between concepts, and the researcher had to determine whether these were learned in the context of the project, or already present.

Some aspects of learning were much easier to identify, such as learning vocabulary or how to summarize a scientific article. Other aspects, particularly developmental changes were initially difficult to detect. Subjects would indicate that they were changing their views in some manner, but did not themselves consider this to be a component of learning. This was particularly difficult in that although some beliefs were overt in nature, others were concealed and only revealed through action or indirect comment.

It was not within the scope of the methodologies of this study to determine to what degree learning was rote (surface) or meaningful (deep). However, it was evident that subjects engaged in cycles of learning and forgetting. This meant that some aspects of learning in the developed model may have been more transient than others, a factor that was not addressed in this study. It was also not possible to determine relative significance of factors impacting learning. Nonintellectual factors may or may not have a greater impact on student learning than intellectual factors.

Structured aspects of interview tasks included discussing instances, problems, and processes. Specific tasks, such as a card sort, were not utilized to construct causal explanations or the complexity of propositions (Southerland, Smith, & Cummins, 2000). Time limited interviewer preparation and some avenues of interview data collection may have been overlooked.
There were concerns with the development of phenomenographic categories of learning. A problem with analysis was that in constructing categories representing a portion of subjects' experiences, differences between individuals were often lost. Additionally, categories of learning were by necessarily broad to reduce inconsistent data assignment, and as a result, somewhat ambiguous (Meyer, 1995). To counter these concerns, an attempt was made during data collection and analysis to include subject, content, and skill case studies.

Identifying transfer of knowledge was particularly difficult as it was difficult to distinguish between subject thinking and doing. Subjects often expressed a disposition or tendency to do something, but it was unclear if they would actually do it at a later date. Frequency of mention or action was used to indicate the strength of the disposition (Fitzgibbons, 1981).

Ultimately, the primary concern with identifying student learning was that learning indicated change, but often the only evidence for that change was an observed performance. This meant that learning had to be extrapolated from a type of "before" and "after" snapshot, with many of the "befores" only available through subject self-reporting. Similar extrapolated instances of change were sought across subjects, and an attempt was made to be present for as much of the classroom learning events as possible.

Communication Issues

Subject communication styles had a significant impact on data collection. Subjects presented information differently in written, debate, or oral form. These forms of communication not only varied by subject, they also varied by context. For examples, students used more concise language in debates than in interviews.

Some of the subjects preferred to provide the researcher with written examples of their work and ideas over extensive conversation. Others, including TAs, expressed embarrassment over their spelling or grammar and preferred to speak directly with the researcher. This added further complexity to analyzing data across direct individual subjects.

Learning was often represented verbally by subjects ("I learned..."). By contrast, subjects spoke less frequently of factors impacting that learning. These factors were more generally ascertained through researcher observation and artifacts.
Subjects also were varying in terms of characteristics of responses to interview questions. Although most students were responsive, a few students typically spoke brief one sentence answers. This was particularly true of subjects S3B and S3C when expressing displeasure over the debate. The researcher noted that language may have been a factor contributing to short responses from a subject learning English as a third language (S3D).

Quotes were a major form of communicating thought in this study, and consideration of the nature of quotes was an essential component of data analysis.

A quotation is a polished prefabricated unit of thought or discourse which has many connotations and associations built in to it. It is thus like a text for a sermon, serving as a point of departure for many lines of thought. (Mackay, 1977; P. IX)

Quotes were extracted and organized as representations of particular ideas or occurrences, and as stated by Mackay, also directed lines of research inquiry. Risk of misinterpretation, including association of excessive meaning was always a risk. This risk was mediated through tracking quotes back to their original context prior to setting them in greater text.

Abbreviations such as GE (genetic engineering) and GT (gene therapy or genetic technology) were not used by the researcher as abbreviation and terms use varied in different stages of the project. When subjects became more comfortable with their topics, they began to use abbreviations. Also students used science abbreviations because it was a "science course." Alteration of language symbolized subject participation in a particular community of shared goals.

Subject comments and writings contributed to the developing hypothesis of learning within the studied course. Interviews provided an opportunity to meld subjects' personal theories of learning with those of the researcher.

**Triangulation of Data**

Recreating subject learning, the actual change and factors impacting that change relied on coordinating multiple data sources. Different data sources revealed different aspects of learning. For instance, student content knowledge was largely revealed in their debate participation. However, their acquired learning skills and teaching skills were disclosed in the formative and post-project interviews. Ideally multiple sources of data would reveal the same information, but in actuality different sources of data
generated different information. Those variables that were evident in multiple data sources were much easier to identify.

Reconstruction of learning meant balancing raw and heavily processed data. Raw results gave a feel for the drama and dynamics of course. Processed results allowed for organization of a large quantity of data into the hypothesis. This thesis presented both forms to more fully represent learning.

Attempting to locate learning, an elusive intrapersonal substance, through multiple forms of evidence was like being alive during the Jurassic age, but still needing to study skeletons to understand how the animals functioned. Evidence for learning included facts, details, and procedures that were within artifacts, actions, or dialog. As different individuals had vastly different structures for understanding and represented these structures in different ways, the types of predominant evidence varied by individual. This often led to "apples and oranges" diversity of variables that needed to be fleshed out through researcher observation.

In a study of this nature, consistency of data collection and analysis throughout the study is not a goal, instead changes are expected and identified wherever possible so it is clear that data collection and analysis occur within different contexts. However, validity, or representativeness of the analysis is important. In this study, mode validity was sought by utilizing multiple sources of data collection. Ultimately the model was constructed by the researcher, and an attempt was made to incorporate multiple sources of data in the model to accurately represent subject learning. A single type of information, such as a written response, may not accurately represent complex processes such as a teacher's conceptions of the nature of science (Lederman & O'Malley, 1990).

As stated, this study has limited generalizability of results to practice. Generalizability from this study primarily relates to the potential to transfer hypotheses to other situations. The research process was described at length so readers would have maximum accessibility to the phenomenon being studied, seeing it through the researcher's eyes (Donmoyer, 1990). The generated hypothesis of learning can be tested in other courses. Schofield (1990) suggested that it can be advantageous to study the typical classroom experience in order to be able to generalize results. This can include studying classrooms with typical attributes that are also on the leading edge of change. Additional assistance for generalizability of this study's results could be achieved through studying more classrooms as will be discussed.
Research Implications

This study’s questions and methodologies led to a list of variables describing learning in the studied course. Due to this design, implications are related to directing further research to identify variables impacting learning in other courses, determining relative significance of the variables, and ultimately determining how to improve teaching and learning practices. Specific recommendations for practice beyond the studied course would be premature, but this story of university learning suggests a great deal of avenues for future research. This section organizes and expands on implications discussed earlier in the chapter.

Impact of Research on Studied Course

This research had clear implications for the studied BI 102 course. There were specific procedural changes that were altered immediately for implementation during the subsequent BI 102 summer term (course schedule in Appendix Q). Plans were also made to apply results in other courses in the series (Appendix R), as well as incorporate findings into general curriculum goals (Appendix S). Later BI 102 courses reflected changes in scope and sequence based in part on findings from this study (Appendix T).

Concurrent with the research presented in this thesis, two other questions were researched: (1) What are the characteristics of interactions between subjects that impact approaches to learning and learning itself? and (2) How does each subject group’s learning influence subsequent learning and innovation. The results from these studies, as well as other research that followed in the course, built on the framework of the results discussed in this thesis, and will be published in future journals.

Instead of this study being an “epilogue” to a period of change, it indicated that the curriculum was a continual work in progress. This work will continue to be supported in part by ongoing processes of action research. The suggestion that sustainable innovation and diverse learning relied to an extent on continual conflict and resolution continues to be addressed in the BI 10X courses.

Implications for Research on Institutional Factors

There are numerous areas of research pertaining to higher education that await development to paint a more complete picture of teaching and learning. This includes research into the foundational assumptions of universities, including the goals inherent in
a university education. Young (1997) outlined some of the core values of higher education: service, truth, freedom, equality, individuation, justice, and community. Further research is needed to determine how the learning community in introductory science courses may relate to enhancement of university values.

**Challenging Unsupported Assumptions Regarding Higher Education**

A primary role of research is to challenge ideas not based in forms of community-accepted evidence. Arguably prescriptions for altering university teaching are based on a limited research base. Many of the assumptions currently appearing in higher education and science education publications are ripe areas for research. One common assumption is that smaller class size leads to better student learning outcomes.

If one takes these more basic outcomes of retention, problem solving, and attitude differentiation as criteria of learning, the weight of the evidence clearly favors small classes. (McKeachie, 1986 [p. 182])

This study presents how the complex settings and interactions within a large course can relate to diverse learning outcomes. Further research is warranted into whether attributes of large laboratory classes, such as the potential for more teachers, views, diversity of interactions, levels of discourse, community membership, avenues for learning, may actually augment learning in some situations.

Another common assumption is that TAs and faculty in the life sciences have adequate content knowledge to teach an introductory biology course.

At least one former colleague and some, if a minority, of those interviewed in a recent evaluative project would maintain that ‘There is no difference between faculty and students: All are learners.’ Well, we all hope that we will enable students to acquire the knowledge and intellectual skills that we should have. We may well learn from student’s life experiences. But do we not have a different starting point in our acquired knowledge and capacity to handle it and our obligations not quite different? This illustrates quite well the danger of cozy ascriptions of community that eschews differentiation and definition. (Kogan, 2000 [p. 210])

This may be the case within courses with a pre-set curriculum, but this study suggests that TAs and faculty may be challenged to learn content and pedagogy during implementation of the types of innovation that are recommended by many agencies
(changing what is taught as well as how it is taught). Further research on the degree of TA and faculty learning is needed.

Another assumption is that TAs primarily play the role of “babysitter” in university science courses as they are not necessarily designing the curriculum or making final grading decisions. This study suggests that TAs directly impact aspects of student learning and are a critical component of implementing curricular change. Research into TA impact on students learning a specific aspect of content may miss the role TAs play in constructing understandings with students, modeling science intellect, and their impact on other domains of learning. Due to the widespread reliance on TA teaching at universities, much more research is needed into the teachers who actually are on the “front lines” on undergraduate teaching.

This study suggests that some of the assumptions regarding undergraduate teaching and learning may need to be researched in further depth. Undergraduate classrooms and participants may be sufficiently different than K-12 settings to warrant more targeted higher education research.

Goals of Undergraduate Education

Steinhart (1969) suggested that the three major roles of the university are education, research, and discussion of problems. Discussions of problems often occur within peer groups (faculty-faculty, TA-TA, and student-student), and can be limited to seminars or forums. This study showed that within an introductory science course, individuals could discuss problems with peers as well as other course participants. With such a large proportion of a campus community teaching and learning in introductory courses, this may be the location where problems are discussed and resolutions are formulated.

One of the often cited goals of undergraduate educations is the development of student conversancy with a variety of core disciplines.

We do not expect undergraduates to attain expertise in a subject they study in college, if only because most disciplines are deeper and wider than can be fathomed in the time available. Conversancy with a number of areas, however, is a goal of undergraduate education, with the understanding that this notion is open to considerable variation in the firmness of grasp attained. But to be conversant with an area suggests being familiar with its basic information and with all the modes of thinking and investigating that enable one to move around in it. With all of its imprecision and range, conversancy implies an understanding that is a
sufficient basis for further learning and a perspective sufficiently broad so as to enable a student to see some of the field's relations to other worlds. (Weingartner, 1992)

An implication of conversancy is that the concepts of biology can not be taught separately from the way those concepts were developed. This was echoed to a degree in the study, where subjects did not fully understand the issues associated with gene therapy until they understood the underlying techniques and former attempts to improve the human race (eugenics). Students conversancy in the study was a combination of individual research and interactions with others. Further research could examine effective ways to present multiple aspects of a discipline through different teaching strategies.

Although literature supports a diversity of instructional strategies and processes of learning (Tang, 1998), there is a lack of emphasis on developing a diversity of learning outcomes. A wide diversity of learning outcomes was observed in the study, impacted by the existing course structure and subject characteristics, as well as qualities of the innovation. It was unclear whether learning would have been any less diverse without the innovation. Ultimately, if a goal of the academy is to develop thinkers for the future that can cope with a myriad of complex processes, diversity of learning may need to be acknowledged. A quality education may not involve radical changes in current university instruction, but elucidating the qualities of learning already present.

Current focus is on considering a diversity of instructional strategies, leading to a need for a diversity of assessment. What may be more basic, pervasive, and relevant is that the diversity of learning outcomes can occur within current instructional strategies, necessitating a diversity of assessment to portray the rich array of learning. Diversity of learning may encompass what the complexity of what participants bring to the classroom, the context for learning, and interactions between participants as the experience unfolds.

What we learn are contingencies of variation, constituting a space, representing the range of phenomena, situations, aspects, and appearances we are capable of dealing with. The larger, the richer, the more differentiated and integrated this space is, the better equipped we are to face the future. (Marton, 1998 [p. 196])

National calls for research discuss continued emphasis on understanding the process of learning, incorporating research on cognitive development (Bransford, Brown, &
Cocking, 1999). This study suggests that the outcomes as well as the process warrant examination. Broader considerations related to who is learning what within the university may need to be addressed prior to how that learning should occur.

The primary reason for a high school student not pursuing higher education in the 1950's was a lack of interest, or motivation (Hollinshead, 1952). Currently, not going on to higher education has become less of an option, but basic motivational issues may not be resolved within undergraduates.

**Supporting Curricular Innovation**

With repeated calls for change within undergraduate classrooms comes concerns about what factors are necessary for innovation to succeed. This study portrays the impact of a single innovation on course dynamics. Curricular innovation was a time-intensive process that challenged TAs and faculty to alter pedagogies and learn content. Close interactions between faculty as well as TAs linking students to faculty enabled quick implementation of needed changes. Campus facilities including the library, learning center, and computer centers became additional settings for learning. This indicates the need for a certain degree of institutional support for change.

This study suggested that the teachers in the course were an important component of successful implementation. With one faculty member possessing over twenty years of experience managing curricular innovations and supporting continual change, another faculty member eager to adopt new content and pedagogies, as well as an enthusiastic group of TAs, innovation was possible. This suggests that staffing courses may be an important area to study, including the balance between institutional memory and new ideas.

Funding, as evidenced through staffing, materials, and campus facilities was also a component impacting subject learning. Concerns over balancing access to higher education with rising costs and limited infrastructure have ebbed and flowed since the 1950s (Hollinshead, 1952). Studying techniques to alter curricula within the context of infrastructure, as was conducted in this study, would be a valuable area of study.

Changes to biology content in the “Biotech Century” (Isaacson, 1999), as well as changes in student groups represented in the university are drivers for reform within the university classroom. Boulter & Gilbert (2000) argue that identification of the complex and diverse models impacting classroom dynamics can potentially bridge the gap
between the sciences and humanities (education). It may be important to develop a myriad of models (science, teaching, learning) in developing new curricula.

**Identifying Exemplary Introductory Science Courses**

An exemplary course can be one in which there is a powerful, positive impact on learning (Angelo, 1996). The questions posed are: who judges that impact on learning; students, peers, or outsiders, and the nature of that learning; including persistence, depth, breadth, or application. There are no widely accepted standards associated with labeling a course as "exemplary." However, any recommendations for change should incorporate a vision of what the desired outcome is.

Generally university courses are judged not as an entire entity, but specifically on the quality of faculty teaching. Lowman (1996) characterizes exemplary college teachers (referring to both college and university) as proficient in (1) presenting information in a clearly organized or interesting way, and/or (2) relating to students in ways that communicate concern and motivate them to succeed. Qualities of exemplary teaching can be amassed from a variety of sources, including: systematic assessment of memories of exemplary teachers, observational study of exemplary instruction, descriptions in nominations for teaching awards, and comparisons of average and poor instructors (Lowman, 1996). Typically, assessment of whether a classroom is exemplary is limited to subjective evaluations of teaching, and not measures of actual student learning.

A further concern with focusing on teaching as the primary indicator of classroom success is that teaching may not be the most significant factor impacting university student learning. In a summary of twenty years of higher education research done by Pascarella and Terenzini (1991), the most consistent variable impacting the quantity and quality of learning was student academic effort. This was followed by interactions with other students, and then to a lesser degree, interactions with teachers. Focus on teaching may minimize the potential of judging classroom success based on student effort and student-student interactions. Additionally, an ability of a course to change over time, particularly to address the myriad of factors currently shifting in higher education, may indicate the need to judge courses based on long-term sustained outcomes.

With vague descriptors available to judge course success, researchers suggest additional studies of exemplary classes. Wright & Wright (1998) state
What is the best way to implement the standards? We must return to the basic questions that individuals involved in education must answer: Why should I change? How do I change? Can I change? Will the change bring success? These questions can be answered only by seeing exemplary models that individuals find credible and relevant to their own situations. (Wright & Wright, 1998 [p. 140])

Schön (1983 [p. 29]) also recommends that practitioners establish knowledge by determining which "kinds of knowing are already embedded in competent practice."

This study provides an example of a course with many of the attributes that may be ascribed to an exemplary course: high retention of students (academic effort), high student evaluations of course structure (academic effort and beliefs), large reliance on student peer teaching groups (student-student interactions), tracked students pursuing science teaching careers (long-term learning outcomes), and a twenty-year history of continual curricular change to address changing student needs, biology content, instructional technologies, and institutional resources. Additionally, the studied course was in the process of a series of curricular innovations, in part to address the impact of national science education standards on student learning. Attributes of this course can be compared to other university courses in order to establish possible profiles of exemplary classrooms.

Schilling and Schilling (1998) proposed an increased degree of faculty involvement in assessing overall program success. This assessment process could be tied to forms of evidence, reflective practice, innovative practice, significant questions of interest, language and metaphors, appropriate to context, and accommodating the nature of faculty life. Similarly, students and TAs could be recruited to evaluate course outcomes, as they assessed project success within the study.

Implications for Research on Professional Development

The call for professional development of faculty and future faculty has been ongoing (Diekhoff, 1956). This discussion will also consider professional development for undergraduate students. Since much of the motivation for change in university introductory science courses comes from examination of K-12 education, the preparation of undergraduates as future K-12 teachers will be considered first.

There is hope that some future generation of college teachers will have the benefit of training in their profession and therefore that their students will be better taught; but there is danger that the systematic training of the
future will be no better than the haphazard training which has produced college teachers in the past. (Diekhoff, 1956 [p. 45])

Preparation of Future K-12 Teachers

A common assumption is that undergraduate future K-12 science teachers taking introductory courses learn about teaching (or can learn about teaching) in their introductory science courses.

... many students either do not know or do not declare their intention to become teachers until later in their college careers. Thus, faculty in the life and physical sciences, mathematics, and engineering who teach lower-division courses in these subjects have a special obligation and responsibility to the education of future teachers. They must understand that any of their students may elect to become teachers and that this decision may not be made until after these students have completed introductory courses. (NRC, 2001 [p. 120-121])

This study supported that students developed ideas about teaching, although it was unclear whether they developed a transferable form of PCK. Student thoughts about teaching were impacted by interactions with other course participants, the variety of teaching contexts in the course, as well as reflection due to the research process. Research is needed to determine the relative importance of factors impacting student thoughts about teaching, how transient these thought are, and whether these thoughts relate to a form of PCK that can be transferred into practice.

Students considering becoming K-12 teachers are often as, if not more, interested in the process of teaching than content. This may mean that including discussions of pedagogy within introductory courses would be engaging for students as it appeared within this study. This may lead to concern that introductory courses be shifted toward a particular career, rather than development of a strong conceptual framework. Kennedy (1998) described the need to develop teacher knowledge in order to address science education reforms. This included developing four types of knowledge, including conceptual (major ideas in the discipline), pedagogical (representing concepts in a manner accessible to students), epistemological (how the discipline works), and attitudinal (respect for the science discipline). Any of these four types of knowledge may be valuable to all students in developing conversancy with he discipline of biology. Subject knowledge representing each of these categories was impacted by the studied project.
The Committee on Science and Mathematics Teacher Preparation (CSMTP) offered specific recommendations related to developing cohesion between higher education and K-12 education.

Science, mathematics, and engineering departments at two- and four-year colleges and universities should assume greater responsibility for offering college-level courses that provide teachers with strong exposure to appropriate content and that model the kinds of pedagogical approaches appropriate for teaching that content. Two- and four-year colleges should re-examine and redesign introductory college-level courses in science and mathematics to better accommodate the needs of practicing and future teachers.

Introductory courses should be structured in ways that help all students better understand the role and relationship of the sciences and mathematics to other disciplines, to students' lives, and to helping students make informed decisions about issues in which science and technology play integral roles. (NRC, 2001 [p. 12-13])

Arguably, many of these characteristics were present in the studied course, suggesting the need for closer examination of current practice in order to provide more specific and useful recommendations.

**Preparation of Future Faculty**

One of the goals of graduate education is to prepare future faculty. A teaching assistantship is often the only teaching preparation a graduate student has prior to becoming a teaching faculty member. As a university teacher, the former TA will be expected to select the content and processes to be covered in a course, select course materials, design activities, design assessment materials, and perform a host of other duties. Graduate students in TA positions have the opportunity to learn about many aspects of teaching. However, as previously stated, research on TA teaching and learning is very limited. Available studies focus on whether TAs impact specific student outcomes, rather than the question of whether a teaching assistantship prepares a graduate student to teach. Within this study, TA learning was extremely diverse, ranging from basic content through teaching and learning skills, to basic changes in beliefs about students.

Available research on TAs primarily relates to the impact of teaching programs on TA behaviors. A great deal of emphasis of professional development in higher education is on mimicking specific characteristics of a model teacher (Katz & Henry,
Modeling a process of learning about teaching (and learning) may be a more effective means to change. In the studied course, TAs were able to view and participate in the process of curricular innovation, including aspects of the corrective and assessment processes. Of interest would be determining how different TA positions, with differing responsibilities, impact TA learning, and ultimately which factors transfer to faculty teaching. This research could inform construction of TA training programs.

Some see the current culture of graduate education as in a state of crisis with lowering completion rates and extending duration (Damrosch, 1995). Graduate students are transitioning between students and faculty, and little is known about how relationships with students and faculty within a teaching assistantship mediate this transition. In this study, TAs mentioned feeling more prepared to teach due to their involvement in the project. Perhaps successes like these would impact graduate student retention, another concern associated with graduate education.

Faculty as Lifelong Learners

Reforming university science courses will require faculty change. Research on curricular innovation focuses on teacher beliefs, but does not address the degree of learning that will need to occur for faculty to design new curricula. This includes learning of new concepts and instructional strategies, often with minimal professional support.

The preservice education, continued inservice education, and "teacher lounge" interactions available to many K-12 teachers are non-existent for most university faculty. Within the studied course, close interactions between two faculty was a major factor impacting initial implementation of innovation. One teacher acted as a mentor for the other, with both sharing teaching and subject matter ideas. It is unclear how widespread this form of mentoring is within the university system, or to what degree it impacts student learning in other courses.

Current faculty development programs, when available, are generally not discipline-specific and focus on general pedagogical techniques. Information from this study revealed that faculty acquired a wide range of knowledge in order to develop and implement an innovation reflecting current science education reforms. This information suggests that professional development programs may need to address a broad range of factors, including aspects of content, in order to support faculty interested in changing their introductory science courses. This study also suggested that "small" (or initially imperceptible) variations in content can impact learning. Faculty may need to master
these subtleties. Faculty in this study were able to learn from instructional settings and through experiences (Driscoll, 1994). Research on professional development may need to expanded to incorporate aspects of learning that occurs within the classroom.

Faculty work is typically based on teaching, research, service, and citizenship. Learning content relative to teaching is not distinctly singled out in any of these endeavors. However, in this study, faculty spent a great deal of time learning about course content. This may have implications for promotion and tenure considerations for faculty committed to teaching biology courses.

Action Research as a Form of Professional Development

Kember and McKay (1996) discussed the potential role of action research as a form of professional development for faculty. Action research enables participants to investigate concerns with practice and is potentially a powerful tool for altering introductory science classrooms.

...there can be no adequate investigation of the classroom unless teachers spend considerable time learning about their own styles of thinking, their ways of interacting with their classes, the intricacies of the group process, the institutional surroundings, the physical nature of the classroom. (Katz & Henry, 1993 [p. 4])

Action research is a form of professional development in which teachers can formally reflect upon teaching and make observable changes in practice.

This study was a form of action research, in which results contributed directly to the course design. Additionally, students and TAs contributed to the research process. Increased reflection due to active participation in research on teaching and learning may be one way to generate pedagogical content knowledge. More formal incorporation of students and TAs as active researchers, formulating questions and methodologies, may be a way to extend the professional development characteristics of action research to groups of future teachers.

Implications for Research on Scientific Literacy

Hodson (1993) stated that there were three goals of science education: to learn science, to learn about science, and to learn to do science. In other words, a scientifically literate individual would know science concepts, how those concepts were developed, as well as how to contribute to the science literature. Another consideration
would be possessing the skills and beliefs which are necessary to learn about science. In this study, subjects learned about course and project topics, aspects of the process of science, and developed skills and beliefs related to learning science. The project led to development of aspects of science literacy in all three subject groups.


There are many ways to be scientifically literate... there is no right way to teach science, and within some fairly broad limits it probably doesn't matter much which path is taken. The important thing is that students learn something that they will find interesting so that they will continue to study science both formally and informally in the future. (Deboer, 2000 [p. 597])

In this study, subjects jointly constructed notions of what it meant to be literate related to understandings of genetic technologies. This negotiation of literacy may be an important component of courses undergoing change, a possible direction for research.

An aspect that is not always incorporated into research considerations of developing scientifically literate university students is whether the learning strengthens the potential for continued life-long learning. The various reforms suggest that student learning should shift from knowledge acquisition alone to the development of skills, values, and ideas that may utilize or expand on existing knowledge. As part of this attempt to broaden the description of student science literacy, educational reform measures have recommended a new focus on the relevance and application of scientific knowledge (NRC, 1996b). Bybee (1993) suggested that students should learn basic science concepts, problem-solving skills, and science-technology-society (STS) connections in order to be able to apply their knowledge to real-life experiences.

We all forget information that we learn, and the most important learning outcomes are those that influence the students' life 30 years after that student has experienced our course. It is not easy to achieve such long-term outcomes. (Druger, 1998 [p. 4])

Further research of which aspects of university learning sustain learning over the long-term could be important indicators of what should be taught in introductory science courses for non-majors which are often the last science courses many students take.
Implications for Research on Introductory Science Course Curricula

A common focus of recommendations for improving introductory science courses is on "improving" teaching by encouraging faculty to adopt new teaching strategies. This study suggests that many of the existing teaching strategies in the course (lecture, use of text) impacted student learning. Additionally, although the altered teaching strategies associated with the project altered learning, so did aspects of the content itself. Students moving through the American educational system may develop skills that enable them to focus on learning content within the context of varied teaching strategies. Content changes within university courses may be as significant as changes in teaching strategies.

"On the basis of available research, the effectiveness of a particular instructional material is more dependent on the nature and quality of the message than upon the characteristics of the channel of communication." (Encyclopedia of Educational Research, 1969)

With rapid advances in the life sciences, altering content may be as important, if not more so, than altering teaching strategies. Further research may take into the account the impact of existing teaching strategies on student learning as well as the impact of the content itself on learning.

Studying the impact of altering teaching on a small subset of variables may vastly oversimplify the learning process. In the study, factors impacting learning were tightly interwoven, and altering one factor often caused changed in several other factors. Conversely, changing one aspect of teaching may not impact learning, if subjects compensate through other factors.

Maximizing learning may rely on maximizing interactions among course participants. The attempt to manipulate a single variable to target a specific learning outcome, such as adding a computer program to a laboratory in order to increase student understandings of a particular concept may be only possible in a course where participants stick to very specific teaching and learning roles, independent of other teachers and learners. However, the attempt to target specific learning outcomes by tightly controlling course interactions may undermine the potential for a diversity of learning within all participants.

Another aspect of the studied course was that subjects learned different material from different parts of the course. Different content may be learned more effectively in different contents such as individual research, a lecture story, or interactions with peers.
Greater diversity of instructional strategies may lead to a greater range of learning outcomes, as in the studied course. Of particular interest would be to determine which characteristics of content match with particular instructional strategies (such as genetics issues through conversation vs. genetic techniques through an illustration).

Student and TA prior course experiences impacted how they approached the genetics technologies project. This may indicate that introductory science courses themselves, often among the first courses taken by students, may be important in setting behaviors for their remaining university experience. It would be interesting to attempt to quantify the impact of specific learned characteristics on subsequent course success.

In large-enrollment courses, particularly with forms of computer-graded exams, it may be easy to overlook the potential significance of the diverse learning outcomes demonstrated in this study. Even if only one student out of the 25 appeared to be learning a particular skill, or influenced by a particular factor, that number becomes potentially significant when extrapolated out to a class with hundreds of students.

Although it was apparent from this study that subjects engaged in learning as well as forgetting, it was beyond the scope of the study to determine how much subjects forgot. Some aspects of learning may have been more transient than others, and further inquiry into the area of the balance between learning and forgetting may assist in identifying aspects of teaching that relate to both of these processes in university participants.

Implications for Innovation

The design of this study was intended to characterize learning within a course undergoing continual curricular innovation. Additional research is needed to determine "cause and effect" relationships between aspects of curricular change and particular outcomes. This could include comparing courses teaching different content in different manners, or following a particular course as the curriculum is changed over time.

This study suggests that a fundamental feature impacting learning during innovation in the studied course were the resulting conflicts, and the group resolution of those conflicts. During design, faculty negotiated characteristics of the innovation, and this negotiation process continued to a degree with TAs and students as the innovation was implemented. Successful implementation in this case was due to the degree of interactions between participants, and the flexibility of teacher control. Further
elucidation of student, TA, and faculty characteristics that lead to successful implementation of innovation would be important.

Hord (1987) summarized concerns related to curricular innovation, which included: awareness, informational, personal (impact on implementer), management (time, resources), consequence (impact on students), collaboration, and refocusing. Similarly in this study, faculty (as well as students and TAs) can concerns related to the innovation. Concerns are generally seen in a negative light. By contrast, in this study the sharing of concerns was a means of subjects learning about teaching.

A question to be addressed is how faculty can maintain continual curricular change to match changes in content, student needs, and literature on pedagogy. Study of other courses with traditions of innovation would be critical in developing sustainable models of classroom practice.

Additional concerns related to assessment of novel content and teaching practices. Assessing an innovation can involve many components: impact on students, impact on teachers, dissemination, resource utilization, sustainability, synergy with institutional objectives, and the list goes on. Typically only one or a few of these aspects is selected (Hord, 1987). Similarly in this study, many aspects of learning that occurred during the project were not formally reflected in course grades.

**Broader Research Implications**

This research sounds a cautionary note that recommendations for altering university teaching practice may not be grounded in adequate research. This study sought to characterize learning in a single course. Descriptive empirical research from other courses may similarly support or refute assumptions associated with student, TA, and faculty learning.

Often educators seize upon a concept to organize or even revolutionize our profession and then fail either to reflect adequately on it or to share the products of our reflection with those we are educating. (Noddings, 1996 [p. 267])

Science faculty need to share their teaching and learning experiences through forms that can be tested and studied by others.

Research into other aspects of university culture, such as undergraduate retention acknowledge the complexity of students. Heaton & Weedon (1939) noted the enormous complexity of factors impacting student success and stated that a complex
diagnosis was needed to assist students in completing educational endeavors. Similarly complexity of factors impacting learning may need to be addressed through complex teaching and assessment. Research into this area is essential.

This study also suggests that research into student learning needs to address distinctions between statistical and practical significance. Many studies discuss teaching strategies as significantly impacting learning if a certain percentage of students demonstrate desired outcomes. This study suggests that with such an enormous variation in learning outcomes, it may be development of a breadth of learning that is as significant as depth. Additionally, even is only a small percentage of students learn in a particular way, that effect can be multiplied in a large classroom. Practical significance may include acknowledging uncommon learning events, such as a single student developing a computer tutorial for other students, in part because that discrepant learning can impact others, and in part because the university culture values unique efforts.

This study showed that many interactions occurred between the factors impacting learning. Studying just one aspect of learning, such as beliefs, may miss interactions with other types of learning. This has ramifications for research, as many educational researchers specialize in study of a particular aspect of learning. Similar to the sciences, educational researchers may need to work in teams to develop complex models of learning, similar to ecologists or geneticists.

A concern is the role of undergraduate students in research in higher education. After 12+ years in the educational system, these students, can be viewed as professionals of studenting, but are rarely partners in research on education. In a similar vein is the directed research focus on students as either minor players or the center of focus, with little consideration that students may be equally involved in the fray, occasionally bit actors, lead figures, and sometimes, something in between.

Much of the research on TAs and undergraduate classrooms is conducted by graduate students. This has an impact on the field, as graduate students have distinct access to university classrooms. Problems arise in that graduate students may need to conduct shorter studies, are generally relatively inexperienced researchers, and may not publish their work. Care needs to be taken to support graduate research and the unique perspectives of graduate students in the research process.

Much of the information in this study came from the interviews. Interviews enabled flexibility of discourse and revealed the "essence of a phenomenon" (Witz,
Many of the aspects of learning observed in this study, including fluctuations in learning, may have been missed without continual interviews with subjects. This has implications for similar research intended to study similar aspects of learning.

The scope of this study encompassed a "micro" scale of phenomena impacting subject learning. Not fully explored were the "macro" types of factors impacting learning, including institutional culture and baccalaureate priorities (Hammersley, 1993). Further studies exploring the scale of the phenomena impacting learning may paint a clearer picture of the complexity of learning within university communities.

Ultimately, the "bottom line" goal is improving student learning within introductory biology courses. Curricular changes that result in improved student learning may depend on faculty and TA learning. This study attempted to elucidate the faculty, TA, and student learning that occurred in the context of a specific curricular innovation and present identified learning variables within the framework of a hypothesis that can be tested in subsequent research. This study lays the groundwork for future studies on improving teaching and learning experiences within the university introductory science classroom. As universities begin to renew their commitment to undergraduate education, an understanding of the dynamics and complexities of the involved teaching and learning communities is necessary for meaningful change.

This study provides a window through which the complexity of learning within an introductory science course can be viewed. By illustrating this complexity it becomes clearer that simple solutions, such as adopting a new teaching strategy or evaluation policy, may be inadequate to accomplish the bottom line: sustaining a community of learners.
REFERENCES


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APPENDIX A: PILOT STUDY OBJECTIVES

National Science Education Standards (NRC, 1996)

The curriculum discussed in this pilot study was designed to address specific aspects of the Science Education Standards (NRC, 1996). Each of the standards below were incorporated into the lectures, activities, or assigned readings. Those standards that were the backbone of the new curriculum are indicated with an asterisk (*). For a more detailed example of how these standards related to curricular objectives, a more detailed description of the Cancer Sub-unit is provided.

Science Teaching Standards
*Teaching Standard A: Teachers of science plan an inquiry-based science program for their students.
*Teaching Standard B: Teachers of science guide and facilitate learning.
*Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and student learning.
*Teaching Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.
Teaching Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.
Teaching Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program.

Assessment in Science Education
*Assessment Standard A: Assessments must be consistent with the decisions they are designed to inform.
Assessment Standard B: Achievement and opportunity to learn science must be assessed.
*Assessment Standard C: The technical quality of the data collected is well matched to the decisions and actions taken on the basis of their interpretation.
*Assessment Standard D: Assessment practices must be fair.
Assessment Standard E: The inferences made from assessments about student achievement and opportunity to learn must be sound.

Science Content Standards (Grades 9-12)
*Content Standard A: All students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry.
(Content Standard B: Physical Science)
*Content Standard C: All students should develop understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms, matter, energy, and organization of living systems, and behavior of organisms.
(Content Standard D: Earth and Space Science)
*Content Standard E: All students should develop abilities of technological design and understandings about science and technology.
*Content Standard F: All students should develop an understanding of personal and community health, population growth, natural resources, environmental quality, natural and human-induced hazards, and science and technology in local, national, and global challenges.
*Content Standard G: All students should develop understanding of science as a human endeavor, nature of scientific knowledge, and historical perspectives.
### APPENDIX B: PILOT STUDY CANCER SUB-UNIT

#### Alignment with Content Standards

### Lecture

<table>
<thead>
<tr>
<th>Content Standard (NRC, 1996)</th>
<th>Learning Objective</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: The Cell (Extension of Standard)</td>
<td>Basic cancer concepts and terminology</td>
<td>Final Exam</td>
</tr>
<tr>
<td>F: Personal and Community Health</td>
<td>Behaviors link to cancer</td>
<td>Project</td>
</tr>
<tr>
<td>F: Science and Technology and Global Challenges</td>
<td>Societal impacts on cancer occurrence</td>
<td>Final Exam</td>
</tr>
</tbody>
</table>

### Laboratory/Recitation

<table>
<thead>
<tr>
<th>Content Standard (NRC, 1996)</th>
<th>Learning Objective</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>E: Understandings about Technology</td>
<td>Microscope technology and cancer study</td>
<td>Lab grade</td>
</tr>
<tr>
<td>B: The Cell (Extension of Standard)</td>
<td>Distinguishing “normal” from “cancerous”</td>
<td>Lab Grade, Final Exam</td>
</tr>
<tr>
<td>F: Personal and Community Health</td>
<td>Determining cancer risk factors</td>
<td>Lab Grade, Project, Final Exam</td>
</tr>
<tr>
<td>A: Use Mathematics to Improve Communications</td>
<td>Graphing cancer data</td>
<td>Recitation Grade</td>
</tr>
<tr>
<td>A: Communicate and Defend a Scientific Argument</td>
<td>Providing hypotheses for cancer occurrence</td>
<td>Recitation grade, Final Exam</td>
</tr>
</tbody>
</table>

### Textbook

<table>
<thead>
<tr>
<th>Content Standard (NRC, 1996)</th>
<th>Learning Objective</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: The Cell (Extension of Standard)</td>
<td>Basic biology and terminology associated with cancer</td>
<td>Final Exam</td>
</tr>
<tr>
<td>E: Understandings about Technology</td>
<td>Model of technological advances and cancer treatment</td>
<td>Final Exam</td>
</tr>
</tbody>
</table>
APPENDIX C: GENETIC TECHNOLOGIES PROJECT OBJECTIVES

National Science Education Standards (NRC, 1996)

The Genetics Technology Project discussed in this proposed study was designed to address specific aspects of the Science Education Standards (NRC, 1996). Each of the standards below were incorporated into the lectures, activities, or assigned readings. Those standards that were the backbone of the new curriculum are indicated with an asterisk (*). For a more detailed example of how these standards related to curricular objectives, a more detailed description of the Cancer Sub-unit is provided.

Science Teaching Standards
*Teaching Standard A: Teachers of science plan an inquiry-based science program for their students.
*Teaching Standard B: Teachers of science guide and facilitate learning.
*Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and student learning.
*Teaching Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.
Teaching Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.
Teaching Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program.

Assessment in Science Education
*Assessment Standard A: Assessments must be consistent with the decisions they are designed to inform.
Assessment Standard B: Achievement and opportunity to learn science must be assessed.
*Assessment Standard C: The technical quality of the data collected is well matched to the decisions and actions taken on the basis of their interpretation.
*Assessment Standard D: Assessment practices must be fair.
Assessment Standard E: The inferences made from assessments about student achievement and opportunity to learn must be sound.

Science Content Standards (Grades 9-12)
*Content Standard A: All students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry.
(Content Standard B: Physical Science)
*Content Standard C: All students should develop understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms, matter, energy, and organization of living systems, and behavior of organisms.
(Content Standard D: Earth and Space Science)
*Content Standard E: All students should develop abilities of technological design and understandings about science and technology.
*Content Standard F: All students should develop an understanding of personal and community health, population growth, natural resources, environmental quality, natural and human-induced hazards, and science and technology in local, national, and global challenges.
*Content Standard G: All students should develop understanding of science as a human endeavor, nature of scientific knowledge, and historical perspectives.
### APPENDIX D: GENETIC TECHNOLOGIES PROJECT

Alignment with Content Standards (Week 5)

#### Lecture

<table>
<thead>
<tr>
<th>Content Standard (NRC, 1996)</th>
<th>Learning Objective</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: The Cell (Extension of Standard)</td>
<td>Basic human genome concepts and terminology</td>
<td>Final Exam, Debate</td>
</tr>
<tr>
<td>F: Personal and Community Health</td>
<td>Social and economic aspects of genetics research</td>
<td>Project</td>
</tr>
<tr>
<td>F: Science and Technology and Global Challenges</td>
<td>Societal impacts on genetic diseases</td>
<td>Final Exam</td>
</tr>
</tbody>
</table>

#### Laboratory/Recitation

<table>
<thead>
<tr>
<th>Content Standard (NRC, 1996)</th>
<th>Learning Objective</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>E: Understandings about Technology</td>
<td>Analyze variety of genetic technologies</td>
<td>Lab grade</td>
</tr>
<tr>
<td>B: The Cell (Extension of Standard)</td>
<td>Understanding of the molecular basis of the human genome project</td>
<td>Lab Grade, Final Exam</td>
</tr>
<tr>
<td>F: Personal and Community Health</td>
<td>Impact of genetic diseases on society</td>
<td>Lab Grade, Project, Final Exam</td>
</tr>
<tr>
<td>A: Use Mathematics to Improve Communications</td>
<td>Graphing genetic disease data</td>
<td>Recitation Grade</td>
</tr>
<tr>
<td>A: Communicate and Defend a Scientific Argument</td>
<td>Prepare genetic technologies debate</td>
<td>Recitation Grade, Final Exam</td>
</tr>
</tbody>
</table>

#### Textbook

<table>
<thead>
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<td>B: The Cell (Extension of Standard)</td>
<td>Basic biology and terminology associated with the human genome project</td>
<td>Final Exam</td>
</tr>
<tr>
<td>E: Understandings about Technology</td>
<td>Model of technological advances and genetic disease detection and treatment</td>
<td>Final Exam</td>
</tr>
</tbody>
</table>
APPENDIX E: INTRODUCTION ACTIVITY

In Biology 102, we begin with six weeks of genetics, followed by two weeks of evolution, and two weeks of animal behavior. This week you will begin a six-week in-depth examination of a genetic technology (human gene therapy or genetically engineered organisms). This project will culminate in a debate over whether or not the government should prohibit (or severely limit) the specified genetic technology. There are several assignments that will help you find and organize materials for this debate. The primary objectives of this project are to provide the opportunity for in-depth research of a complex biology topic and an opportunity for application of that research to decision-making concerning a current and controversial topic.

Part I: Background on Genetic Technologies:

Advancements in science and technology have led to the development of a number of amazing genetic technologies. List several of these new technologies, including a brief description, and the ethical issues associated with each new technology.

<table>
<thead>
<tr>
<th>Genetic Technology</th>
<th>Description</th>
<th>Ethical Issues</th>
</tr>
</thead>
</table>

In this project we will focus on two topics: human gene therapy and genetically engineered organisms. Over the next six weeks we will cover a number of genetics concepts in lecture, laboratory, recitation, and the assigned textbook readings that will build a framework for understanding the complexity of genetic technology issues.

Part II: Your Group's Genetic Technology:

Part III: Genetic Technologies Project Requirements:

A. This is a group project.

B. The project includes the following requirements:

1. Find sources of information about your topic (using books, journals, Internet, etc.)

2. Write comments summarizing and critiquing your references (annotated references, at least three per group member, due: beginning of recitation, week 3)

3. Write a group summary of your topic that includes a detailed description of the technology and the "pros" and "cons" associated with using the technology (due beginning of laboratory, week 5).
4. After your TA randomly assigns you to the “pro” or “con” side of the issue (week 5), work with another group in the week 5 laboratory to develop your arguments for the debate (week 6).

5. Using previously gathered sources of information, every group member writes up notes to use in debate (due end of laboratory, week 6).

6. During the week six laboratory, debate your topic.

C. The Genetics Technology Project is a significant component of your BI 102 grade. The three annotated references (per group member) are worth 5 points, the group summary of the topic is worth 5 points, the individual preparation notes for the debate are worth 5 points, and debate participation is worth 5 points (possible 20 points per person). This is in addition to the points given in your week 1 recitation, week 5 laboratory, and week 6 laboratory (5 points each), and related exam questions.

D. Since this is a group project, you may want to consider assigning specific tasks. For example, each group member may be responsible for different components of the topic, with brief weekly meetings to coordinate information gathering and writing. If you would like to meet as a group outside of the scheduled laboratory and recitation times, the Biology Learning Center (131 Weniger) is available 8 a.m. – 5 p.m. weekdays.

Start as soon as possible! A schedule including course activities related to The Genetics Technology Project and recommended activities follows on the next page.
<table>
<thead>
<tr>
<th>Week</th>
<th>Course Activities Directly Related to the Genetic Technologies Project</th>
<th>Recommended Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Recitation</strong>: Introduction to the Genetics Technologies Project</td>
<td>Locate information about your group’s genetic technology topic (books, journals, Internet)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Continue locating information about your genetic technology topic. Write comments (annotations) on at least three of the references</td>
</tr>
<tr>
<td>3</td>
<td><strong>Recitation</strong>: Mendelian Inheritance in Humans and Project Update</td>
<td>Turn in at least three annotated references (each group member) at beginning of recitation, begin working on group summary of topic</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Work (as a group) on writing summary of topic.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Laboratory</strong>: Genetic Technologies Project</td>
<td>Turn in group summary of topic at beginning of the laboratory, begin working with partner group in preparing “pro” or “con” argument.</td>
</tr>
</tbody>
</table>
| 6    | **Lectures**: Biotechnologies, The Future of Genetics  
**Recitation**: Genetic Screening  
**Laboratory**: Project Debates | In lab, formal debate of topics and turn in individual notes used in preparing for debate. Start preparing for midterm 2! |
Part V: Questions:

These questions will help you get started on your topic:

1. List as much as you know about your topic, and share this information with your other group members.

2. The first part of this project involves finding information about your topic. Where can you go to find this information (list as many specific sources as possible). You may want to assign specific group members to examine these sources and compare notes the next time you meet.

3. Once you have found sources of information about your topic, you will be asked to comment on each source (brief summary and critical analysis of whether it is a reliable source of information). These “annotated references” are due at the beginning of recitation, week 3. How will you judge whether a source of information is reliable?

Example annotated reference (remember: the purpose of the comments is to remind you what the article is about):


Alton and Geddes provide a brief history of the development of gene therapy for cystic fibrosis. The article includes illustrations and information on the cystic fibrosis gene. The article was written prior to 1995, and does not contain more recent research related to cystic fibrosis gene therapy. However, the article includes interesting perspectives on the value of gene therapy from two researchers in the field.
APPENDIX F: WEEK 5 ACTIVITY
GENETIC TECHNOLOGY PROJECT

Today you will use your knowledge about your genetic technology (gene therapy or genetic engineering) to develop an argument for or against government regulation of the technology. First, your TA will randomly assign your group to argue for or against the topic. Your group will join with another group to prepare "pro" or "con" arguments. Next week your larger "supergroup" will debate the topic against another "supergroup" in the class. At the end of the debate, every group member will turn in the individual notes they prepared to participate in the debate.

Summary of Today's Activity:

1. Group summary of your genetic technology topic is due at the beginning of laboratory today.

2. TA assigns group as "for" or "against" regulation.

3. Each group combines with another group to form "supergroups" that will debate the pro or con sides of the argument. This will result in four supergroups, two that will debate gene therapy and two that will debate genetic engineering.

4. The supergroups will review the debate rules (distributed in class) and determine strategies for debating the other supergroup. Ideally every group member will be given the opportunity to contribute to the debate.

5. Each member of the supergroup will begin preparing individual notes to use in the debate. These notes will be turned in immediately following the debate. The notes can be on paper or notecards and should contain points, references, and ideas that can be used during the debate.
APPENDIX G: DEBATE RULES

1. *The tone of the debate will remain respectful.* One of the best parts of a debate is hearing sides of an issue you may have never considered. In order for everyone to benefit from the information gathered by his or her classmates, this debate will focus on sharing knowledge in a supportive atmosphere.

2. Your TA will be the debate moderator, which involves keeping time, asking occasional questions, and interjecting when he/she feels it is necessary.

3. The debate will begin with the first two supergroups seated at the front of the classroom, with the other two supergroups acting as the audience. After they debate, there will be a short break, and the supergroups will shift positions in the classroom.

4. The debate will have the following structure:
   A. **Introduction to the technology:** Each debating supergroup will have 5 minutes to educate the audience about their technology and state whether they will be arguing for or against the technology.
   B. **Arguments:** Each supergroup will have 10 minutes to present their arguments for or against the technology.
   C. **Rebuttals:** The supergroups will have 10 minutes to ask each other questions.
   D. **Audience questions:** The audience will have 15 minutes to ask either supergroup questions.

5. All members of a supergroup should be given the opportunity to contribute to at least one part of the debate structure outlined above. Active participation in the debate is worth five points.

6. The supergroups acting as the audience will be required to write down questions for the supergroups debating, and will turn in a brief assessment of debate. This will be the laboratory assignment worth five points.

7. If time permits, your TA will lead a brief summary discussion.
APPENDIX H: WEEK 6 ACTIVITY
GENETIC TECHNOLOGY DEBATE

Today the genetic technology project will culminate in a debate between the “supergroups” arguing for or against having the government prohibit (or severely limit) gene therapy and genetic engineering. You will be using your prepared notes to contribute to the debate, and will also assess the other groups participating in the debate.

Summary of Today’s Activity:

1. TA will review debate rules (distributed in previous laboratory).

2. The supergroups will debate their topics. Half of the class will act as an audience for the other half of the class. Following each debate, the audience will be given an opportunity to ask questions. Additionally, all participants will fill out forms to assess the quality of the debate.

3. Individual notes will be collected from everybody in the class.

4. Basic ideas related to gene therapy and genetic engineering will be on the exams, so it is important to listen to the other debating groups!
APPENDIX I: GENETIC TECHNOLOGIES ACTIVITY AND LECTURE TOPICS

Week One Recitation: Introduction to the Genetics Technology Project
Overview of project requirements
Listing of background knowledge of genetic technologies
Assignment of debate topics
Initial defining of topics
Discussion of sources of information
Group planning for library research

Week Three Recitation: Project Update
Individual annotated references turned in
Discussion of project progress
Groups divide up work on group summary papers
Examination of traits following patterns of Mendelian inheritance in humans
Dominant traits not necessarily more frequent

Week Five Lecture: Human Inheritance
Human karyotypes
Mendelian and Non-Mendelian human traits
Variable expression due to environmental effects
Eugenics movement
Interactions between science, technology, and society

Week Five Lecture: Human Diseases
Cystic Fibrosis and mutations
Huntington’s Disease and human pedigrees
Hemophilia and sex-linked traits
Use of animals in genetics research
Normal is a relative, subjective term

Week Five Laboratory: Genetic Technologies Project
Group summary paper turned in
Groups merged into supergroups
Pro and con sides assigned
Supergroups prepare strategies for debate

Week Six Lecture: Biotechnologies
Gene Cloning
Restriction enzymes, bacteria, and plasmids
Transgenic Organisms
Uses of genetically engineered organisms
Animal Cloning

Week Six Lecture: Human Genome Project/The Future of Genetics
Introduction to human genome project
Genetic screening: techniques and policing the human gene pool
Future trends in genetics research
Links between genes, evolution, and behavior
Week Six Laboratory: Genetic Technologies Debates
Supergroups debate topics
Individuals turn in note cards

Textbook Readings
Selective breeding
Fundamental DNA technologies
Recombinant DNA
Transgenic organisms
Agricultural implications
Government regulatory agencies
Germ-line gene vs. somatic cell gene therapy
APPENDIX J: SCRIPT FOR SOLICITING VOLUNTEERS

1. Hi! My name is Lesley Blair a doctoral student in the Department of Science and Mathematics Education, and as you know, a lecturer in this course.

2. Various organizations are advocating reform of university introductory science course curricula to promote scientific literacy. Over the next several weeks you will be participating in new labs and recitations designed to link biology topics to students' (your) daily lives.

3. I will be researching the effectiveness of the new activities and the project, introduced this week. In order to do so, I am looking for individuals who will volunteer to participate in this study.

4a. (for instructors, TAs) If you volunteer, you would agree to let me see your notes, overheads, and other materials related to implementing the curriculum. During this unit, you would also agree to let me observe your classes (lecture or laboratories), during which I will take notes related to various aspects of the curriculum. Additionally, I will ask for volunteers to participate in interviews near the end of the project. These interviews will be audiotaped to facilitate later analysis.

4b. (for students) If you volunteer, you would agree to let me see your course work, including laboratory and recitation activities, projects, and exam scores. Also, I will ask a small group of students to participate in interviews about the curriculum near the end of the course. These interviews will be audiotaped to facilitate later analysis.

5a. (for instructors, TAs) Before you volunteer, I would like you to know that you are not obligated to participate in this study. Also, to insure confidentiality, anyone who volunteers will be assigned a code number so individual students can not be identified. If the results from this study are published, individual data will not be identifiable. You can also withdraw from this study at any time without any penalty.

5b. (for students) Before you volunteer, I would like you to know that you are not obligated to participate in this study. Volunteering will not influence your grade and I will not be involved in assigning any grades this term. Also, to insure confidentiality, anyone who volunteers will be assigned a code number so individual students can not be identified. If the results from this study are published, individual data will not be identifiable. You can also withdraw from this study at any time.

6. The primary advantage of participating in this study is an opportunity to provide feedback on this course, and the research results may have implications for other undergraduate courses.

7. If you are interested in participating in this research study, please read and sign the forms I am passing around the room. I will collect the forms. If you volunteer, I may be contacting you later in the term to schedule a half-hour interview. Thank-you for your time!
Various organizations are advocating reform of university introductory science course curricula to promote scientific literacy. Over the next several weeks you will be teaching new activities designed to make biology more relevant by linking topics to your daily lives. This research study is intended to determine the effectiveness of the new curriculum.

Participation will include the researchers having access to your classroom materials, including notes and overheads. The researcher will also observe classroom activities, including lecture, laboratory, and recitation. Additionally, you may be asked to participate in a half-hour audiotaped interview at the end of the term. The tapes and other data will be stored in a locked file cabinet, and destroyed at the end of the study. Names will be replaced with codes on all documentation to protect anonymity. If results from this study are published, individual data will not be identifiable to ensure confidentiality.

You are in no way obligated to participate in the study. You are also able to withdraw from this study at any time.

If you agree to participate in this research study, please sign below.

________________________________________
(signed name)

________________________________________
(printed name) (date)

________________________________________
(local phone number)

________________________________________
(e-mail address, if available)

If you have any additional questions, please contact Lesley Blair at:

[campus address]
[campus phone number]
[researcher's e-mail]

or Dr. Norman Lederman at

[campus address]
[campus phone number]
[major professor's e-mail]
Various organizations are advocating reform of university introductory science course curricula to promote scientific literacy. Over the next several weeks you will be participating in new labs and recitations designed to make biology more relevant by linking topics to your daily lives. This research study is intended to determine the effectiveness of the new curriculum.

Participation will include the researchers having access to your coursework, including the course project and exam scores. Additionally, you may be asked to participate in a half-hour audiotaped interview at the end of the term. The tapes and other data will be stored in a locked file cabinet, and destroyed at the end of the study. Names will be replaced with codes on all documentation to protect anonymity. If results from this study are published, individual data will not be identifiable to ensure confidentiality.

You are in no way obligated to participate in the study and participation will not influence your grade. You are also able to withdraw from this study at any time.

If you agree to participate in this research study, please sign below.

________________________
(signed name)

________________________   ____________
(printed name)               (date)

________________________
(local phone number)

________________________
(e-mail address, if available)

If you have any additional questions, please contact Lesley Blair at:
[campus address]
[campus phone number]
[researcher's e-mail]

or Dr. Norman Lederman at:
[campus address]
[campus phone number]
[major professor's e-mail]
APPENDIX M: WEEK 5 PREPARATION NOTES

HUMAN INHERITANCE
BI 102 - Winter 1999 - Week 5

Textbook

1. Chapter 19: This chapter provides an overview of the human genome. At this point, students need a clear understanding of the relationship between chromosomes, DNA, and genes (addressed in the chapter). This chapter is linked to lectures #1 and #2.

2. Chapter 20: This chapter provides detail into various human genetic disorders. Students with additional questions and concerns about genetic disorders may be directed to the Student Health Center or their physician. Review questions at the end of the chapter focus on the assigned chapter excerpts. This chapter links closely with lecture #2 and the human pedigrees recitation.

Lecture #1 (Human Inheritance)

This lecture provides an overview of the human genome. The first part focuses on human karyotypes and reviews aspects of human chromosomes introduced in previous lectures. This is followed by a link between protein synthesis and observable traits, such as those discussed in the Mendelian Inheritance recitation (week 3). Finally, students are introduced to the eugenics movement that took place earlier this century (also a box essay in chapter), and asked to contemplate if we are moving toward eugenics with our current genetic technologies.

Recitation (Human Pedigrees)

Students will construct and analyze human pedigrees to reinforce understandings of a variety of topics, including: dominant/recessive traits, sex-linked traits, and monohybrid crosses. It will take almost the entire 50 minutes for students to work through the problems. A brief introduction can show students how to read pedigrees (the key on page 67 is pretty self-explanatory) and suggest that students use letters (such as "A", "a") to fill out all the pedigrees (especially in #1). In #3, students construct a real pedigree and realize why it is not always easy to determine whether a trait is "dominant, recessive, or sex-linked." We will not be using the computer model on page 70, but interested students may want to visit the websites written on the side chalkboard (recitation room).

Lecture #2 (Human Genetic Disorders)

The lecture provides students with examples of genetic disorders, while reviewing several concepts covered in previous weeks. The focus is on Huntington's Disease, Cystic Fibrosis, Hemophilia, Sickle-Cell Anemia, and genetic aspects of cancer. Human pedigrees and chromosome maps are used to explain these disorders. Students are also asked to reflect on the heroic contributions of those involved in genetic research.

Laboratory (Genetic Technologies Project)

Students will be turning in their group summaries at the beginning of the class and placed into their supergroups. Each "supergroup" will be assigned as "pro" or "con." The supergroups can negotiate what they are debating (if the TA wishes to narrow the debate topics). The laboratory time is intended for students to (1) negotiate the debate question (optional - TA may decide in advance), (2) review debate rules, (3) assign specific roles within the supergroup, and (4) use the computers to locate additional information. Students may decide to leave early. To earn their five laboratory points, they should be able to explain (verbally or on paper) how they are planning to organize the debate and allow all supergroup member to contribute (all students will be turning in their individual notes at the end of the debate laboratory). Possible debate rule follow (those marked with "**" are required in some form). TAs have flexibility to define their own debate rules.

1. In any discussion of complex issues by educated citizens, it is essential to listen to and respect everyones opinions. Do not interrupt other students. Concepts should be debated, there should be no attempt to minimize anyone's personal point of view.

2. Everybody in each supergroup should be prepared to participate in the debate. This includes being prepared with notes (due at the end of the debate).

3. The TA is the moderator and "supreme arbitrator" of the debate.

4. The "audience supergroups" will participate by
   A. Listening attentively,
   B. Asking questions at the appropriate time, and
   C. Critiquing the quality of all debating supergroups (including their own).

5. Each debate has a maximum of one hour. One possible format is:
   A. Each supergroup begins with a 5 minute introduction to the technology (may have multiple students from each supergroup speak) ending with their position on the debate question (pro or con). The pro group goes first, followed by the con group. Groups may use "props" (pictures, quotes, etc.) to explain the technologies to the audience.
   B. Following the introductions, the pro group (multiple students) make points supporting their claim for 10 minutes using examples from their research. This is followed by the con group for 10 minutes. Non-speaking students in both groups should be taking notes to ask questions in the next part of the debate.
   C. One student from each group (recognized by the moderator) asks the other supergroup a question. These questions continue for 10 minutes.
   D. The audience (recognized by the moderator) are allowed to ask questions.
   E. All students and the moderator use their notes to briefly evaluate the debate.
APPENDIX N: WEEK 6 PREPARATION NOTES

*Midterm #2 is next Monday, Feb. 15, 6 p.m.
*No prep for this week, but prep (all groups) for next week’s lab (“Dot Lab”)

Textbook

1. Chapter 21 (Biotechnology): Assigned excerpts from this chapter (p. 394-404, 408-413) cover a wide range of topics. First, there is a general overview of human uses of organisms (biotechnologies) and the development of genetic technologies. This is followed by a detailed discussion of gene cloning, the basis of most of our genetic technologies (genetic engineering, gene therapy, etc.). Gene cloning will also be discussed in lecture #1. The readings continue with an overview of genetic engineering, focusing on bacteria, public policy, and transgenic animals. This part of the chapter links closely with the debate and lecture #1.

2. Chapter 22 (Humans and Genetic Technologies): The assigned excerpts from this chapter (p. 416-420, 427-433) focus on human applications. The chapter begins by discussing the ethical questions related to diagnosing genetic disorders and focuses on the genetic screening available for Huntington Disease (introduced in last week’s readings and lectures). This is followed by an overview of germ line and somatic cell gene therapy. The chapter ends with a description of the human genome project and more detailed information on cystic fibrosis (introduced last week). This chapter relates to this week’s debate, recitation, and lecture #2.

Lecture #1 (Introduction to Genetic Technologies)

After a brief description of biotechnologies, the lecture will focus on genetic technologies, particularly gene cloning, transgenic organisms, and animal cloning. Since students will be discussing genetic engineering during the debates, the lecture will focus on concepts that are fundamental to most genetic technologies (gene cloning) and a few recent examples of genetic engineering (transgenic organisms and cloning applications). This lecture is intended to complement the assigned genetic engineering readings (chapter 21) and the related debate presentations. About half of the lecture material (particularly animal cloning) is not in the textbook or elsewhere in the course.

Recitation (Genetic Technologies and Society)

During both activities this week, students will be given the opportunity to learn about different genetic technologies and formulate decisions in a verbal debate and discussion format. In recitation, the discussion will focus on aspects of genetic screening related to the genetic disorder Tay-Sachs. Since this discussion may quickly involve moral, ethical, and political points, it is recommended that all students read and agree to the ground rules on the bottom of page 73. In the past, TAs have assigned a question to each group (1-4, with two groups doing each question) and have given students time to read about Tay-Sachs, discuss the disease with one another, and attempt to answer the assigned question. After approximately 15-20 minutes, the class is given an opportunity to discuss each question, with the TA acting as moderator. Question #5 can be omitted if the discussion runs too long. Students can turn in their discussion notes (written on the manual pages 74-75). Generally, grading focuses on whether the students completely answered the questions and participated in the activity because there are no right or wrong answers. NOTE: students may be asked questions about Tay-Sachs on the exam, and will need the activity manual pages for studying. It may be necessary to simply give points in class, so they can take the activity with them, or return the graded pages prior to the weekend.

Lecture #2 (The Future of Genetics)

This lecture covers three areas: the human genome project, genetic screening, and the future of genetics (related to chapter 22). Embedded in genetic screening will also be a brief discussion on gene therapy so students can see the relationship between their debates and other material in the course. The future of genetics topics will include: aging, cancer, behavior, and organ replacement. About half of this material is only presented in lecture.

Laboratory (Genetic Technologies Debate)

This is it! If possible, the debates should remain focused on the “biology” of genetic engineering and gene therapy, but students may also benefit from examining the strong interplay between science-technology-society. It may help to begin by re-stating the debate rules. Also, if the first debate ends early, there may be a brief time for a “break” for nervous students to use the facilities or burn off some steam!

**We may be ending the formal genetics unit, but genetics will continue to be an important thread woven throughout the evolution and behavior units!
How to Avoid Plagiarism

*Plagiarism*: To steal and use the ideas or writings of another as one's own

The university has "zero tolerance" for plagiarism, indicating that students can receive zeros on assignments, an F for a course grade, or even, after a committee hearing, expulsion from the university.

**EXAMPLES OF PLAGIARISM**

**Example #1**: Direct copying of words or an image without crediting the original source.

**Example #2**: Using someone else's words and thoughts without crediting the original source.

(Original) Previously, agencies conducted business independently. Salmon, whose life cycles crosses the jurisdictional boundaries of all agencies, suffered.

(Student) Each agency conducted business independently, and ultimately this hurt the salmon because they cross jurisdictional lines.

**How to avoid Plagiarism:**

1. Synthesize what you find and try to put it into your own words.
2. If using someone else's work, provide a citation:


Or [http://www.pbs.org](http://www.pbs.org), author unknown.
APPENDIX P: WRITTEN EVALUATION FORM

*Thank-you for taking the time to complete the evaluations!

1. Do you have any comments about specific lectures?

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting the Stage</td>
<td></td>
</tr>
<tr>
<td>The Discovery of DNA</td>
<td></td>
</tr>
<tr>
<td>Protein Synthesis</td>
<td></td>
</tr>
<tr>
<td>Human Inheritance and Eugenics</td>
<td></td>
</tr>
<tr>
<td>Human Genetic Disorders</td>
<td></td>
</tr>
<tr>
<td>Genetic Technologies</td>
<td></td>
</tr>
<tr>
<td>The Future of Genetics</td>
<td></td>
</tr>
<tr>
<td>Instinct and Learning</td>
<td></td>
</tr>
<tr>
<td>Social Behaviors</td>
<td></td>
</tr>
</tbody>
</table>

2. How can Lesley's teaching be improved?

3. How can BI 102 be improved (labs, recitations, lecture, project, text, etc.)?
## APPENDIX Q: BI 102 SUMMER TERM 1999 COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/19</td>
<td>7/20 Heredity - Inheritance in Corn and Mendel's Peas (activity)</td>
<td>7/21 Structure and Replication of DNA (activity)</td>
<td>7/22 Genetic Technologies Debate (activity)</td>
</tr>
<tr>
<td>Introduction</td>
<td>Inheritance in Humans (activity)</td>
<td>Protein Synthesis Puzzle (activity)</td>
<td>Protein Synthesis Poster (activity)</td>
</tr>
<tr>
<td>Levels of Certainty in Biology (activity)</td>
<td>Pop-bead Chromosomes (activity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Read:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 14, 294-298, 307-312, 314-317, 327-330, 338-343</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/26</td>
<td>7/27 Human Genome Project (activity)</td>
<td>7/28 Genetic Technologies Debate (activity)</td>
<td>7/29 Field Trip Willamette Valley Diversity</td>
</tr>
<tr>
<td>Quiz #1</td>
<td>Genetic Technologies and Genetic Screening (activity)</td>
<td>DNA Fingerprinting (activity)</td>
<td>leave 8:00 a.m. from parking lot East of Weniger, return 5 p.m. Bring lunch, water, and sunscreen</td>
</tr>
<tr>
<td>Human Pedigrees and Inheritance (activity)</td>
<td>Work on Debate notes</td>
<td>Prepare for Field Trip</td>
<td></td>
</tr>
<tr>
<td><strong>Read:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>354-364, 368-370, 376-385, 388-391, Chapter 21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/2</td>
<td>8/3 Predator-Prey Interactions (activity)</td>
<td>8/4 Fish Behavior (activity)</td>
<td>8/5 Field Trip Oregon Coast Behavior/Evolution</td>
</tr>
<tr>
<td>Quiz #2</td>
<td>Fossil Record (activity)</td>
<td>Social Behaviors (activity)</td>
<td>leave 8:00 a.m. from parking lot East of Weniger, return 5 p.m. Bring lunch, water, and sunscreen</td>
</tr>
<tr>
<td>Darwin's Finches &amp; Speciation (activity)</td>
<td>Work on Diversity Field Trip Project</td>
<td>Prepare for Field Trip</td>
<td></td>
</tr>
<tr>
<td><strong>Read:</strong></td>
<td></td>
<td>Diversity Field Trip Project Due 3 p.m.</td>
<td></td>
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<tr>
<td>Chapter 23, 476 - 484, Chapter 24, 495-502</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/9</td>
<td>8/10 Species Diversity II (lecture)</td>
<td>8/11 Current Research in Genetics, Evolution, and Behavior (lecture)</td>
<td>8/12 Comprehensive Final Exam</td>
</tr>
<tr>
<td>Quiz #3</td>
<td>Hawaii Species (activity)</td>
<td>Coast Field Trip Poster Presentations (activity)</td>
<td></td>
</tr>
<tr>
<td>Species Diversity I (lecture)</td>
<td>Work on Coast Field Trip Project</td>
<td>Coast Field Trip Project Due 3 p.m.</td>
<td></td>
</tr>
<tr>
<td><strong>Read:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapters 28 &amp; 29</td>
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<td></td>
<td></td>
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</tbody>
</table>
APPENDIX R: PLAN FOR GENERAL BIOLOGY COURSES

OVERVIEW

The general biology courses for non-majors (BI 10X) at Oregon State University have long histories of curricular and instructional innovation. Lectures have focused on current breakthroughs and historical perspectives using a variety of media and teaching strategies. The laboratory activities have utilized hands-on activities, computer technologies, and cooperative learning groups to explore biology topics in-depth. Numerous faculty and graduate teaching assistants (GTAs) have contributed to the process of curriculum design and have provided exemplary service to the undergraduate student body. The BI 10X courses have introduced thousands of students to the complexity and dynamic nature of living systems, and the relevance of those systems to students' daily lives.

These courses will continue to meet the ever-changing needs of undergraduate students and will incorporate new instructional technologies, aspects of national and state science education standards, professional development for faculty and GTAs, new teaching opportunities for graduate teaching interns (GTIs) and undergraduate teaching interns (UTIs), collaborative interactions with other departments, outreach to state K-12 classrooms, and dissemination of program outcomes to other institutions.

This document contains a few of the ideas that will direct the BI 10X courses over the next several years. These ideas depend to a degree on continued pursuit of grant funding and maximization of current resources. Curricular changes will be researched, documented and disseminated in science education journals and at regional and national conferences, further establishing the BI 10X courses at Oregon State University as a model for innovation in higher education.

BI 10X CURRICULUM GOALS

In order to address changing student needs, state and national science education standards, and emerging technologies, the BI 10X courses will continue to change and adapt all aspects of the curriculum. Following are ten of the focus areas for curricular changes within BI 10X.

Extension of National and State Science Education Standards

There is currently a renewed focus on K-12 science education reform with guidelines for science literacy in the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993), and the National Science Education Standards (National Research Council [NRC], 1996). These reforms have clear implications for higher education, the training ground for future K-12 teachers, and recipient of students taught in reform-based K-12 classrooms. Additionally, Oregon has adopted a number of new science teaching and assessment standards that may have a significant effect on students enrolling in introductory courses in the years to come.

In order to address these new reforms and the potential problems and opportunities they present, several steps can be taken in the BI 10X courses. The first and most basic would be an assessment of the needs, abilities, and concerns of students now entering the courses. This would be followed by a re-examination of the course goals, including instructional strategies and assessment in the context of student needs and reform recommendations. For example, many Oregon K-12 students are now developing projects and portfolios as a component of their science courses, a
technique of performance-based assessment that may be adopted in the BI 10X courses. Finally, in order to assist with this shift toward incorporating science education reform standards into the BI 10X courses, collaborative grants will be written with the Department of Science and Mathematics Education and the Academy for Excellence in Science Teaching, which will provide needed feedback and support.

Varied Instructional Strategies

Today's undergraduate students are a diverse multi-ability group that can potentially benefit from varied instruction. Aspects of the BI 10X lectures and activities can be further altered to address student abilities. In the BI 10X lectures, multi-media computer presentations incorporating audio, video, and still images can be used to present content in multiple representations in order to engage students with different learning styles. Additionally, small-group discussions, student-directed question and answer sessions, and interactive demonstrations/skits can be used as lecture strategies to engage student interest and maximize learning opportunities.

In the laboratory and recitation activities, cooperative group work can be expanded to include assigned task roles within the groups, and more open-ended investigative activities. Additionally, assignments can allow individual students to push their personal limits, and reflect on their contributions to their cooperative groups. Activities can address a diverse range of cognitive, affective, and psychomotor goals with the use of "mini campus field trips," hand-on manipulations, science equipment, and computer models. Students will be presented with a large range of representations of biology content and processes.

Alternative Assessments

In addition to varying instructional strategies, assessment within the courses may also shift to reflect student needs and science education reforms. Currently 75% of the student grades are determined by performance on multiple choice examinations. Increased emphasis on long-term projects and activities and varied, authentic assessment may shift the overall assessment to include a more even spread of points between the activities, projects, and exams.

Additionally, there is currently limited emphasis on formative assessment, or assessment that can lead to instructional response while the course is proceeding. This type of assessment may include mid-term "mini" faculty and GTA evaluations, more formalized student feedback through e-mail (via, the BI 10X web pages), lecture and activity observations by experienced graduate teaching interns (GTIs), additional communication between the GTAs and faculty in the weekly preparation sessions, and the consistent communication between all participants in the course, facilitated by the laboratory coordinator.

Multiple Learning Environments

One of the goals that permeates the BI 10X courses is the intention of having students extend their knowledge beyond the confines of the classroom, to develop skills that will carry into other aspects of their lives. In order to reach this goal, students will be increasingly asked to participate in course activities that extend beyond the traditional lecture hall and laboratory. The first move was to incorporate a recitation environment, or a context that facilitated discussion of biology-related issues. The next move was to develop a multimedia classroom that allowed students to access the incredible variety of resources available on CD-ROM and the Internet. Most recently, a Learning Center was
added to provided students with a meeting place to discuss biology, interact with the GTAs, and work on biology projects.

These learning environments will continue to expand as we ask students to further investigate biology topics. Collaboration with Valley Library staff has led to design of a pilot program that will train BI 10X GTAs and UTIs to assist students with locating resources using the wide range of materials available within the library system. This collaboration will continue to include course activities that require students to learn to use the Valley Library facilities as they develop course projects. In order to expand ability to engage students in these long-term, investigative projects, another space will be developed, a biology research and projects facility, which will allow students to monitor water chemistry, grow plants, maintain cultures, and participate in the "fun" and inspirational aspects of biological inquiry.

**New Technologies**

The world is increasing reliance on digital information, and this trend may have an enormous impact on education, including introductory biology courses. Students may have increasing familiarity with computer technologies, but often have few, if any experiences analyzing and critiquing computer sources of information. Future consumer and citizenry decisions on biology-related topics may depend on an individual's ability to access and analyze digital information. Additionally, computer technologies allow information to be presented and interacted with in a classroom setting, in ways previously not possible.

In the BI 10X courses, long-term projects will incorporate the utilization of computer resources, particularly Web sites on the Internet. Students will learn to access information using a variety of search engines, determine the validity of the information, and apply that information to their own investigations. Students will also be asked to make decisions on controversial topics utilizing Internet resources. Computer technologies will also be used to present lecture material in a more interactive "hyper-stacked" manner, display student work and question on the BI 10X course Web page, and provide digital output from laboratory equipment that can be statistically manipulated and analyzed. Consideration will also be given to the development of distance learning opportunities utilizing developing computer technologies.

**Professional Development**

An important and often missing component of undergraduate education is professional development activities for faculty and other teaching staff. Within the BI 10X courses, professional development activities for faculty have centered on informal curriculum development meetings and joint lecture attendance. GTAs have been supported through faculty-led orientation and weekly preparation sessions. Recently this professional development has been extended to include weekly preparation sessions for the undergraduate teaching interns (UTIs). These professional development activities are an essential component of sustained curricular innovation.

Professional development activities within the BI 10X courses will be extended to augment teaching in all aspects of the courses. A faculty development facility is being designed to provide lecturers with technical support in order to adopt new instructional strategies and assist one another with curriculum development. The laboratory coordinator will maintain this facility and assist faculty with adopting new computer technologies. Additionally, faculty from other departments will be invited to participate in
professional development activities, particularly those associated with the use of instructional technologies.

"Veteran" GTAs within the BI 10X courses who have an interest in undergraduate teaching may become graduate teaching interns (GTIs). These graduate students will expand on their GTA experiences by participating in curriculum development and supervision of faculty and GTA teaching. These GTIs will also collect data for grant-supported research projects. Preparation of the UTIs, many of whom are interested in teaching, will be extended to include discussion of curriculum goals, pedagogical alternatives, and assessment strategies.

Collaboration with other Science Units
Currently BI 10X benefits from the expertise of guest faculty lecturers from several departments in the college of science. Collaborations can be extended to include course research and curriculum development with members of other science units. This will take full advantage of the vast resources available within the university.

Recently the biology program has embarked on developing a collaborative program, Project SCOPE, with the Department of Science and Mathematics Education and the Academy for Excellence in Science Teaching. Project SCOPE centers on improving undergraduate education and centers on curriculum design and professional development within the BI 10X courses. Proposals for funding will be submitted to the Department of Education and the National Science Foundation. Project SCOPE would also include members of the BI 10X teaching team in developing biology teaching methods courses for graduate students and research experiences for MAT (masters of the art of teaching) students from the department of Science and Mathematics Education. This will maximize use of the biology facilities and draw on the expertise of the BI 10X staff.

Outreach to K-12 Schools
Many universities are increasing their involvement with K-12 schools to improve student learning, promote recruitment, and maximize available resources. Currently members of the BI 10X teaching team have a peripheral involvement in K-12 education, including teaching weekend courses and summer courses through "Saturday Academy," providing resources to preservice and inservice science teachers, incorporating high school students in undergraduate courses (BI 271), and researching high school student learning within university science programs (ASE - Apprenticeships in Science and Engineering). These interactions also benefit the BI 10X courses as new ideas and enthusiasm penetrates the curriculum.

Outreach activities will increase in the BI 10X courses, partly funded by a grant from ABLE, the Association for Biology Laboratory Education. Data collected by the BI 10X students will be digitally recorded and made available to high school students through the BI 10X Web site. Resulting high school student and BI 10X projects and papers will be presented on the same Web site.

Research and Funding
Funds from a variety of sources have been used to support the BI 10X courses. Most recently, funds from the Howard Hughes Foundation assisted in purchase of computers for the biology courses and development of the Biology Learning Center.
Additional funding will be sought to support sustainable curriculum development and research into effective undergraduate biology teaching. The previously discussed Department of Education and National Science Foundation grants exemplify the magnitude of these funding efforts. Additional smaller grants, such as the grant from ABLE, will be used to develop and implement a variety of curricular innovations.

Program Dissemination

The BI 10X courses exemplify many of the characteristics suggested by the various science education reforms, including cooperative group learning, increased emphasis on decision-making, and hands-on activities. These characteristics will be expanded to include professional development activities, long-term student projects, multiple instructional strategies, and alternative assessments.

Professional development activities will be shared with other science units at OSU. This may be extended to include seminars and short courses on curriculum development in the context of the science education standards, and the use of computer technologies in the classroom. Information on the BI 10X courses will also be disseminated through journal articles, and research presentations at regional and national meetings.
APPENDIX S: PLANNED BI 10X COURSE GOALS

What do we want the students to get out of this course that they can use five or ten years from now?

Two major BI 10X course goals:
1. Be able to research a topic for citizenry, consumer decisions.
   a. Understanding of very basic concepts and processes, keywords to investigate topics (need to list these; genes, alleles, inheritance, etc.)
   b. Accessing and critiquing information.
   c. Making decisions about biology issues.
   d. Discussing and presenting information

2. Understand how science works
   a. Scientific inquiry, process of exploration and experimentation
   b. Changes in understanding over time, historical development, timelines
   c. Nature of science, tentativeness, creativity
   d. Link between science, technology, society

Outcomes related to course goals:
1. Two types of projects can specifically and effectively address these goals each term: A library research project (already in place each term) and a long-term experiment. The current projects have been the most successful components (in terms of student learning) of the courses.
2. The focus should shift to the projects, with the lectures and readings providing necessary support. Currently the sequence of material coverage does not match student project activities
3. Currently the textbook and accompanying lectures form the core of the classes, with laboratory and recitation activities shuffled to avoid need to change the lectures.
4. Shifting to focus on the projects will require faculty to redo most if not all lectures and review supporting readings.
5. This change will be time-intensive, but will require minimal materials (most are already acquired).

Projects for BI 10X:
1. BI 101: Salmon Study Poster Presentation and Aquarium Water Quality Experiment
2. BI 102: Genetic Technologies Debate and Earthworm Behavioral Experiment
3. BI 103: Disease PowerPoint Presentation and Seedling Growth Experiment

Proposed Curricular Changes:
Curricular changes to address these goals will be extensive. The current and potential revised curricula are attached.
# BI 102 2000 COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
<th>Chapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NO TUESDAY LECTURE</td>
<td>Early and Mendelian Genetics</td>
<td>Introduction to the Genetic Technologies Project</td>
<td>1, 14</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Meiosis</td>
<td>The Chromosome Theory</td>
<td>Inheritance in Corn</td>
<td><em>Meiosis and Life Cycles</em></td>
<td>15, 16</td>
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<tr>
<td>3</td>
<td>Non-Mendelian Genetics</td>
<td>Changes in Chromosomes</td>
<td>Mendelian Inheritance in Humans Project Update</td>
<td>Fruit Fly Genetics*</td>
<td>16</td>
</tr>
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</table>

**MIDTERM EXAM 1 (40 questions)** – Monday, January 24, 6:00 p.m.- 6:50 p.m.

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Recitation</th>
<th>Chapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 The Discovery of DNA</td>
<td>Protein structure and function</td>
<td><em>DNA Structure and Protein Synthesis</em></td>
</tr>
<tr>
<td>5 Human Inheritance and Genetic Disorders</td>
<td>Genetic Technologies</td>
<td>Human Pedigrees</td>
</tr>
<tr>
<td>6 Designing Treatments for Genetic Diseases</td>
<td>The Future of Genetics</td>
<td>NO RECITATION (Release time for Midterm#1)</td>
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</tbody>
</table>

**MIDTERM EXAM 2 (40 questions)** – Monday, February 14, 6:00 p.m. - 6:50 p.m.

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Recitation</th>
<th>Chapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Darwinian Evolution</td>
<td>The Modern Synthesis</td>
<td>Speciation</td>
</tr>
<tr>
<td>8 The Origin of Species</td>
<td>The Unfinished Synthesis</td>
<td>The Pace of Evolutionary Change</td>
</tr>
<tr>
<td>9 Human Evolution</td>
<td>Instinct and Learning</td>
<td>Human Evolution</td>
</tr>
<tr>
<td>10 Social Behaviors</td>
<td>Current Research on Behavior</td>
<td>NO RECITATION (Release time for Midterm#2)</td>
</tr>
</tbody>
</table>

**FINAL EXAM (70 questions)**, Tuesday, March 14, 4:00 p.m. - 5:50 p.m.

1 Laboratory Exercises Booklet (Available at bookstore).
## BI 102 2001 COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
<th>Textbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Course Concepts and Themes</td>
<td>Early and Mendelian Inheritance)</td>
<td>Intro to Genetic Technologies Project</td>
<td>Life Cycles; Mitosis; Meiosis</td>
<td>TD: ch. 8, 9 JW: p. 3-36</td>
</tr>
<tr>
<td>3</td>
<td>Changes in Chromosomes</td>
<td>DNA: Blueprint for Life</td>
<td>DNA Model</td>
<td>Fruit Fly Genetics</td>
<td>TD: ch. 9, 10 JW: p. 37-69</td>
</tr>
<tr>
<td>4</td>
<td>Protein Synthesis, Genes, and Alleles</td>
<td>Genetic Engineering Techniques</td>
<td>Genetic Technologies Debate Prep</td>
<td>Protein Synthesis Puzzle and Poster</td>
<td>TD: ch. 11, 13 JW: p. 70-98</td>
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**MIDTERM EXAM 1** (40 questions) – Monday 1/29, 6:00 - 6:50 pm (location to be announced)

<table>
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<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
<th>Textbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>The Origin of Species</td>
<td>The Unfinished Synthesis</td>
<td>Speciation</td>
<td>Predator - Prey Interactions</td>
<td>TD: ch. 17 JW: p. 157-189</td>
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<td>8</td>
<td>Human Evolution</td>
<td>Threats to Genetic Diversity</td>
<td>Pace of Evolution</td>
<td>Natural Selection</td>
<td>TD: ch. 17 JW: p. 190-235</td>
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<tr>
<td>9</td>
<td>Linking Genetics, Evolution, and Behavior</td>
<td>Instincts and Learning</td>
<td>NO RECITATION (release time for midterm)</td>
<td>Fish Behavior</td>
<td>TD: ch. 29 JW: p. 236-266</td>
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<tr>
<td>10</td>
<td>Social Behaviors and Fitness</td>
<td>Current Research on Behavior</td>
<td>NO RECITATION (release time for midterm)</td>
<td>Connecting Genetics, Evolution, and Behavior</td>
<td>TD: ch. 29 JW: 267-303</td>
</tr>
</tbody>
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**FINAL EXAM** (70 questions), Tuesday, 3/20, 4:00 - 5:50 pm. (location to be announced)

Laboratory and Recitation Activity Manual (Available at bookstore).

TD: Chapters in text: *Asking About Life; Tobin & Dusheck* (review questions are available at the end of each chapter)

JW: Pages in text: *The Beak of the Finch; Jonathan Weiner* (reading questions are provided in this manual)
# BI 102 2002 COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
<th>Textbook Readings</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Course Concepts and Themes</td>
<td>Genetic Discoveries</td>
<td>Intro to Genetic Technologies Project</td>
<td>Inheritance in Plants</td>
<td>1, 2</td>
</tr>
<tr>
<td>2</td>
<td>Structure of DNA</td>
<td>Genes and Genomes</td>
<td>Inheritance in Humans</td>
<td>DNA Model</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>DNA Mutations and Repair</td>
<td>Cellular Functions</td>
<td>DNA Fingerprinting</td>
<td>Cellular Structure and Function</td>
<td>4</td>
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MIDTERM EXAM 1 (40 questions) – Monday Week 4, 6:00 - 6:50 pm (location to be announced)

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<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
<th>Laboratory</th>
<th>Textbook Readings</th>
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<tbody>
<tr>
<td>4</td>
<td>Protein Structure and Function</td>
<td>Protein Synthesis</td>
<td>Cystic Fibrosis</td>
<td>Protein Synthesis Puzzle and Poster</td>
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<tr>
<td>5</td>
<td>Control of Genes</td>
<td>From Genes to Organism</td>
<td>Genetic Technologies Debate Prep</td>
<td>Fruit Fly and Human Genetics</td>
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<td>6</td>
<td>Genetic Engineering</td>
<td>Human Genome Project</td>
<td>Human Pedigrees</td>
<td>Genetic Technologies Debate</td>
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MIDTERM EXAM 2 (40 questions) – Monday Week 7, 6:00 - 6:50 pm (location to be announced)

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<th>Lecture 1</th>
<th>Lecture 2</th>
<th>Recitation</th>
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<th>Textbook Readings</th>
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<tr>
<td>7</td>
<td>Evolutionary Ideas</td>
<td>Changes Over Time</td>
<td>Predator - Prey Interactions</td>
<td>Evidence for Evolution</td>
<td>8</td>
</tr>
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<td>8</td>
<td>Variation and Selection</td>
<td>SPECIATION</td>
<td>Speciation</td>
<td>Natural Selection</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Human Impacts on Genetic Diversity</td>
<td>Instincts and Learning</td>
<td>NO RECITATION (release time for midterm #1)</td>
<td>Fish Behavior</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Social Behaviors and Fitness</td>
<td>Intelligence</td>
<td>NO RECITATION (release time for midterm #2)</td>
<td>Connecting Genetics, Evolution, and Behavior</td>
<td>3</td>
</tr>
</tbody>
</table>

FINAL EXAM (70 questions), Tuesday, Finals Week, 4:00 - 5:50 pm. (location to be announced)

Laboratory and Recitation Activity Manual (Available at bookstore).
Readings from: *Exploring the Way Life Works*, Hoagland, Dodson, & Hauck, 2001