Title: Biology Teachers’ Perceptions of Subject Matter Structure and its Relationship to Classroom Practice

Abstract Approved: ____________________________
Norman G. Lederman

Current reforms in science education advocate instruction which capitalizes on broad, integrative understandings of a few underlying concepts. Such recommendations imply that science teachers already hold integrated conceptualizations and will use such understandings to guide practice. However, little research exists which delineates the global content understandings of biology teachers (herein called subject matter structure - SMS) or assesses if these understandings translate into classroom practice. The purpose of this investigation was to determine the nature of biology teachers’ SMSs and the relationship of these structures to classroom practice.

Case studies of five experienced biology teachers were constructed through interviews, classroom observations, and analysis of instructional materials. Teachers were observed 15 times during their first semester of biology teaching. The data were qualitatively analyzed to determine the exhibited SMS of the teacher as elucidated from the classroom context. This SMS was compared to SMSs provided by the teachers in post-observation interviews and to a SMS generated from the text. The nature of the SMSs, the sources and formation of SMSs, and the variables which differentially affected teachers’ abilities to translate SMSs into classroom practice were identified.

The teachers’ SMSs for biology were based on discrete content topics rather than conceptually integrated themes. Though most teachers recognized the integrated nature of biology content, few explicitly stated such relationships or used such conceptions to purposefully guide practice. The initial formation of SMSs were typically credited to college content courses and modified by the act of teaching. Opportunities for reflection and reinforcement seemed critical for the formation of coherent SMSs.

The relationship of SMSs to classroom practice was complex and varied. The most direct form of translation occurred in the scope of course content. Content integration typically occurred only in those areas for which there was the greatest expertise. Variables which differentially affected SMS translation (typically through mitigation) included teacher
intentions, content knowledge, pedagogical knowledge, students, teacher autonomy and
time.

These results exist in contrast to those found using other methodologies. Implications
for both preservice and inservice teacher education and the potential feasibility of current
science reforms exist.
Biology Teachers' Perceptions of Subject Matter Structure
and its Relationship to Classroom Practice

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# TABLE OF CONTENTS

## CHAPTER I: THE PROBLEM
- Introduction ........................................... 1
- Statement of the Problem ............................ 2
- Significance of the Study ......................... 3

## CHAPTER II: REVIEW OF THE LITERATURE
- Introduction ........................................... 5
- Subject Matter Knowledge .......................... 7
- Relationship of Subject Matter Knowledge to Classroom Practice .................. 10
  - Pedagogical Content Knowledge ................. 10
  - The Nature of Science .......................... 16
- Effectiveness of Inservice on Pedagogical Content Knowledge .................. 20
- Discussion and Conclusions ....................... 23
- Recommendations ................................ 27

## CHAPTER III: DESIGN AND METHOD
- Introduction ........................................... 29
- Subjects ............................................... 29
- Method ............................................... 30
  - Phase I: Pre-observation Interviews ............... 30
  - Phase II: Classroom Observations ................. 33
    - Observations ..................................... 34
    - Documents ....................................... 37
    - Anecdotal Data .................................. 39
  - Phase III: Post-Observation Interviews ............ 40
  - Triangulation of Data Sets ..................... 44

## CHAPTER IV: ANALYSIS OF DATA
- Introduction ........................................... 47
- Textbook Subject Matter Structure ............... 49
  - Methods of Analysis and Construction of a Subject Matter Structure .......... 50
    - Description of Textbook Subject Matter Structure .................. 55
- Alex: Content IS Process .......................... 58
  - Academic and Professional Profile ............. 58
  - Course Specific Perceptions and Concerns ....... 64
  - Classroom Profile ................................ 77
  - Classroom Subject Matter Structure ............. 83
  - Self-Described Subject Matter Structure ........ 90
  - Summary of Alex .................................. 97

- Ben: Growing to Appreciate Biology .............. 101
  - Academic and Professional Profile ............. 101
  - Course Specific Perceptions and Concerns ....... 106
  - Classroom Profile ................................ 118
  - Classroom Subject Matter Structure ............. 122
  - Self-Described Subject Matter Structure ........ 132
  - Summary of Ben .................................. 138
Carl: If Only I Had Better Students ........................................ 144
Academic and Professional Profile ........................................ 144
Course Specific Perceptions and Concerns .............................. 151
Classroom Profile .............................................................. 158
Classroom Subject Matter Structure ...................................... 163
Self-Described Subject Matter Structure ............................... 170
Summary of Carl ................................................................. 174

Don: Staying With the Text ................................................... 178
Academic and Professional Profile ........................................ 178
Course Specific Perceptions and Concerns .............................. 181
Classroom Profile .............................................................. 188
Classroom Subject Matter Structure ...................................... 194
Self-Described Subject Matter Structure ............................... 200
Summary of Don ................................................................. 205

Ed: Following the Logical Sequence of Biology ........................ 209
Academic and Professional Profile ........................................ 209
Course Specific Perceptions and Concerns .............................. 212
Classroom Profile .............................................................. 219
Classroom Subject Matter Structure ...................................... 225
Self-described Subject Matter Structure ............................... 230
Summary of Ed ................................................................. 234

CHAPTER V: DISCUSSION AND CONCLUSIONS ......................... 239
Introduction ........................................................................... 239
The Nature of Biology Teachers' Subject Matter Structures ........ 239
Content ................................................................................. 239
Themes ................................................................................. 241
Format ................................................................................. 242
Source and Formation of Subject Matter Structures ................. 243
Sources of Subject Matter Structures .................................... 243
Opportunities for Subject Matter Structure Formation .......... 244
Summary ............................................................................. 246
Subject Matter Structures and their Relationship to Classroom Practice ........................................ 247
Uses and Translation of Subject Matter Structures into Classroom Practice ....................................... 247
Variables Which Influence the Translation of Subject Matter Structure into Classroom Practice ........... 249
Teacher intentions ............................................................... 250
Content knowledge ............................................................ 251
Pedagogical knowledge ....................................................... 252
Students .............................................................................. 253
Teacher autonomy ............................................................. 255
Time .................................................................................... 256
Testing Effects in the Assessment of Subject Matter Structures ......................................................... 258
Limitations of the Study ....................................................... 259
Implications and Recommendations for Science Teacher Education .................................................. 261

REFERENCES ........................................................................ 267
# APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Letter of Introduction</td>
<td>271</td>
</tr>
<tr>
<td>B</td>
<td>Letter of Confirmation of Participation</td>
<td>273</td>
</tr>
<tr>
<td>C</td>
<td>List of Content and Education Coursework</td>
<td>274</td>
</tr>
<tr>
<td>D</td>
<td>Subject Matter Structure Questionnaire</td>
<td>275</td>
</tr>
<tr>
<td>E</td>
<td>Textbook Subject Matter Structure</td>
<td>276</td>
</tr>
<tr>
<td>F</td>
<td>District Scope and Sequence</td>
<td>283</td>
</tr>
<tr>
<td>G</td>
<td>Derivation of Alex's Subject Matter Structure</td>
<td>285</td>
</tr>
<tr>
<td>H</td>
<td>Derivation of Ben's Subject Matter Structure</td>
<td>293</td>
</tr>
<tr>
<td>I</td>
<td>Derivation of Carl's Subject Matter Structure</td>
<td>298</td>
</tr>
<tr>
<td>J</td>
<td>Derivation of Don's Subject Matter Structure</td>
<td>303</td>
</tr>
<tr>
<td>K</td>
<td>Derivation of Ed's Subject Matter Structure</td>
<td>308</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Textbook Subject Matter Structure</td>
<td>54</td>
</tr>
<tr>
<td>2</td>
<td>Alex's Volunteered Subject Matter Structure</td>
<td>66</td>
</tr>
<tr>
<td>3</td>
<td>Alex's Classroom Subject Matter Structure</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>Alex's Self-Described Subject Matter Structure</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>Ben's Classroom Subject Matter Structure</td>
<td>124</td>
</tr>
<tr>
<td>6</td>
<td>Ben's Self-Described Subject Matter Structure (Pretest)</td>
<td>134</td>
</tr>
<tr>
<td>7</td>
<td>Ben's Self-Described Subject Matter Structure (Posttest)</td>
<td>136</td>
</tr>
<tr>
<td>8</td>
<td>Carl's Classroom Subject Matter Structure</td>
<td>165</td>
</tr>
<tr>
<td>9</td>
<td>Carl's Self-Described Subject Matter Structure</td>
<td>171</td>
</tr>
<tr>
<td>10</td>
<td>Don's Classroom Subject Matter Structure</td>
<td>196</td>
</tr>
<tr>
<td>11</td>
<td>Don's Self-Described Subject Matter Structure (Pretest)</td>
<td>202</td>
</tr>
<tr>
<td>12</td>
<td>Don's Self-Described Subject Matter Structure (Posttest)</td>
<td>204</td>
</tr>
<tr>
<td>13</td>
<td>Ed's Classroom Subject Matter Structure</td>
<td>227</td>
</tr>
<tr>
<td>14</td>
<td>Ed's Self-Described Subject Matter Structure</td>
<td>231</td>
</tr>
<tr>
<td>15</td>
<td>Derivation of the Textbook's Subject Matter Structure</td>
<td>278</td>
</tr>
<tr>
<td>16</td>
<td>Derivation of Alex's Subject Matter Structure</td>
<td>287</td>
</tr>
<tr>
<td>17</td>
<td>Derivation of Ben's Subject Matter Structure</td>
<td>295</td>
</tr>
<tr>
<td>18</td>
<td>Derivation of Carl's Subject Matter Structure</td>
<td>300</td>
</tr>
<tr>
<td>19</td>
<td>Derivation of Don's Subject Matter Structure</td>
<td>305</td>
</tr>
<tr>
<td>20</td>
<td>Derivation of Ed's Subject Matter Structure</td>
<td>310</td>
</tr>
</tbody>
</table>
BIOLOGY TEACHERS' PERCEPTIONS OF SUBJECT MATTER STRUCTURE AND ITS RELATIONSHIP TO CLASSROOM PRACTICE

CHAPTER I

THE PROBLEM

Introduction

Current interest in teacher accountability has stimulated research efforts designed to identify what teachers know about their subject matter. Earlier research efforts have reported only low correlations between traditional measures of teachers' knowledge (e.g., GPA, numbers of courses taken) and student achievement (Medley, 1979). These findings suggest that research efforts must go beyond the simple documentation of certification requirements and explore alternative procedures to elucidate and evaluate the subject matter knowledge held by teachers.

Consequently, recent research efforts have refocused the assessment of subject matter knowledge by looking at both the facts teachers know as well as the way teachers structure their subject matter. Much of this research has been initiated under the direction of Lee Shulman in an effort to explore "pedagogical content knowledge" (Shulman, 1986a, 1986b). This line of research, often referred to as the "missing paradigm" in educational research (Shulman, 1986a), seeks to identify the distinctive body of knowledge held by the content teacher - a knowledge which blends an understanding of subject matter with a knowledge of pedagogy. Within this context, subject matter knowledge has been studied as an independent domain of knowledge as well as a component of pedagogical content knowledge. Research in a wide range of fields (Berliner, 1987) has revealed that teachers with "expert" knowledge have well developed schema or structures on which to build knowledge, making knowledge acquisition more efficient. Furthermore, there is some indication (Carter & Doyle, 1987) that teachers who have well developed subject matter structures will be more efficient at learning and presenting subject matter to students. For the purpose of this study, 'subject matter structure' (SMS) will refer to any conceptual framework or schema which teachers have for their knowledge of the content they teach.

In many of the studies which serve as the foundation for understanding the subject matter knowledge of biology teachers (Baxter, Richert, & Saylor, 1985; Carlsen, 1989; Hashweh, 1986; Hauslein & Good, 1989), subject matter knowledge was visualized as the structure given to the content and often resembled a cognitive map. The richness of a
teacher’s subject matter knowledge was, thus, determined through the relationshipsexpressed among various content topics/concepts. Translation of this knowledge intoactivities designed to simulate classroom interactions and/or planning activities were oftenconducted, establishing the potential influence of subject matter knowledge and structureon the act of teaching.

Though the current approach to studying subject matter knowledge has offered newinsights, many of the past methods employed may contain serious flaws. First, all of thestudies which have sought to determine a teacher’s subject matter structure assumed thatequally coherent structure exist at all levels of expertise. It is intuitively accepted thatexpert teachers develop coherent cognitive structures in their areas of expertise, however,there is much less agreement for the belief that all teachers at all levels of experiencepossess such coherent and well defined structures. Despite some indication that novicesalso have subject matter structures (Baxter, et al., 1985), it is necessary to determine iftheses structures were formed as a consequence of learning subject matter, or as an artifactof the research method which required subjects to reflect on the structure of their specificsubject matter.

Second, nearly all studies of subject matter knowledge (with the exception of Gess-Newsome & Lederman, 1991; Lederman, Gess-Newsome & Latz, 1992) have providedteachers with a set of items which were to be included in content maps, or SMSs, whichthey were asked to create. Such restrictions may dramatically influence the outcome of aninvestigation. For example, teachers may be presented with terms or ideas which theywould not have generated if asked to identify the key themes, ideas, or topics of theirsubject matter. Providing such terms may actually "create" knowledge by acting as astimulus for the formation of relationships among topics which had not been previouslyconsidered, or, this approach may simply lead to a misrepresentation of one’s knowledgestructure.

Statement of the Problem

If teachers have SMSs which they use to guide instruction, the elucidation of thesestructures may clearly have significant implications for the preparation and evaluation ofteachers. Unfortunately, direct ties between possible SMSs and classroom practice have rarely been investigated.

Research which has attempted to explore the relationship of teachers' subject matterknowledge with teaching practice have often been limited to laboratory based activities
which simulated the classroom situation (e.g., Clermont & Krajcik, 1989; Hashweh, 1986; Krajcik & Layman, 1989; Marks, 1989). Although these activities control for many variables, they provide limited understanding about the ramifications of SMS on teacher performance in an actual classroom.

The exploration of the translation of subject matter knowledge within the context of an actual classroom situation is critical when one considers the conflicting information which currently exists. Some researchers (Carlsen, 1969; Dobey & Schafer, 1984; Leinhardt & Smith, 1985; Wineburg & Wilson, in press) contend that they have found direct influences of subject matter structure and knowledge on classroom practice. Other researchers feel that this interaction is much more complex than initially envisioned.

In addition, factors exist which appear to interfere with the direct translation of teachers' views to students. These factors include the teaching context (Brickhouse, 1989b; Duschl & Wright, 1989), the curriculum (Lantz & Kass, 1987), and the students themselves (Beyerbach, Smith, & Swift, 1989; Brown, 1989; Housner & Griffey, 1985; Lederman & Gess-Newsome, 1991). More importantly, attempts to relate teachers' views of the nature of science to classroom practice (Duschl & Wright, 1989; Lederman & Zeidler, 1987) have found no evidence to support a transfer of beliefs to the classroom situation.

The literature which deals with the SMS of teachers has many limitations in methodology and has left many questions unanswered. The purposes of this investigation were to determine the nature of biology teachers' structures, the source and formation of the current SMS, the relationship of a teachers' SMSs to classroom practice, and to assess the possible testing effects which may result from investigations of this nature.

Significance of the Study

Both theoretical and practical implications for the findings of this investigation exist. The theoretical realm raises an issue concerning knowledge structures. Past research has assumed that SMSs exist within a teacher's knowledge base at all levels of experience. Perhaps more importantly, it has also assumed that expert teachers have more coherent and well defined SMSs than less effective teachers. Much of this research has utilized methodologies of assessing SMSs which may introduce bias. The focus of this study is to clarify the nature of the SMSs held by biology teachers in a manner which avoids many of the flaws of earlier methodologies. Based on the results of this study, previous findings on teachers' SMSs may need to be reassessed in order to determine if the SMSs reported were simply artifacts of the data collection process.
On a more practical note, understanding the impact of teachers' SMSs on classroom practice is critical to teacher education. If classroom impacts of these structures cannot be found, the identification of teachers' SMSs may be an interesting, but an unproductive avenue of research. If impacts can be identified, implications for preservice and inservice teacher education exist. For instance, the formation or enhancement of a teacher's SMS may significantly affect the ability of the novice teacher to learn and present his/her subject matter. If this is the case, the components of the SMS and the factors which influence its formation must be identified. This may also lead to the investigation of the relative effectiveness of different SMSs. Such findings should stimulate research to identify the best means of facilitating the development of SMSs in both preservice and inservice teachers, thereby fostering the transition from novice to expert teacher. In short, it is anticipated that the results of this investigation will have implications for both the subject matter education and professional teacher education of science teachers.
CHAPTER II
REVIEW OF THE LITERATURE

Introduction

The study of teachers and the characteristics which identify the most effective teachers have been pursued for nearly three decades (Medley, 1979). During this time, numerous research programs with various definitions of effective teaching and models of mediating variables in the teaching process have existed. The most vigorous of these research programs have been process-product and presage-product. These research agendas attempted to correlate teachers' observable behaviors in the classroom (such as number of questions asked or the use of review) and personal characteristics (such as GPA and gender) with student outcomes, primarily academic achievement (Brophy & Good, 1986; Clark & Peterson, 1986). The goal of this research was to characterize effective teaching in a manner which transcended both individual teachers and specific situations (Medley, 1979). Though few individual behaviors were found to consistently contribute to student achievement, some general patterns of behavior which seemed to characterize effective teachers did emerge. For example, it has been consistently shown that effective teachers ask frequent questions, present organized lessons, provide concrete examples, possess clarity of expression, and effectively use class time (Brophy & Good, 1986).

Despite the popularity and success of process-product research, critics such as Lee Shulman (1986a) and Margret Buchmann (1982) have noted the general tendency to ignore the "substance of classroom life, the specific curriculum content, and the subject matter studied" (Shulman, 1986a, p.22) as important variables in the study of teaching and learning. Shulman (1986a) explains his criticism as follows:

Since the events we are coming to understand occur in classrooms and schools, they invariably occur in the service of teaching something. That something is usually capable of characterization as the content of a subject, ...a particular set of skills, strategies, processes or understandings relative to the subject matter, or a set of socialization outcomes. The content ought not to be viewed as only a "context variable," comparable to class size or classroom climate. The content and the purposes for which it is taught are the very heart of the teaching-learning process. (p. 8)

Shulman (1986b) formulated a theoretical framework of teacher understanding for the transmission of knowledge by making a distinction between three kinds of content.
knowledge: subject matter knowledge, pedagogical content knowledge, and curricular knowledge. The literature base which directly pertains to the present study concerns the elucidation of a teacher's subject matter knowledge and the transmission of this knowledge in the classroom. For this reason, studies pertaining to two parts of Shulman's model, subject matter knowledge and pedagogical content knowledge, as they apply to science classrooms, will be reviewed. Studies from other content areas will be used to support or contradict findings which exist in the teaching of science.

A central assumption in education is that knowledge of subject matter is a prerequisite for effective teaching (Buchmann, 1982; Shulman, 1987). Thus, this review will not concern itself with comparisons of teachers who know their subject matter with those who do not. Specifically, studies which relate either grade point average or courses taken to teaching effectiveness will not be discussed. The focus upon subject matter knowledge addressed here will be related to variations which exist among those who already possess certifiable subject matter competency as well as the interaction of this knowledge with pedagogical skills.

For the purposes of this paper, subject matter knowledge will be defined as an individual teacher's understanding of the specific discipline and inclusive topics he/she has been assigned to teach. The most comprehensive description of any discipline contains three commonly accepted components: 1) the body of knowledge - including the foundational principles, facts, laws, etc., of the discipline 2) the processes - the methods by which knowledge is generated and validated, and 3) the "way of knowing" (or nature of the discipline) - the inherent values and assumptions of a particular discipline. There is an obvious overlap among these three components, but each, in itself, distinguishes a form of subject matter understanding. This classification allows for the study of individuals and the varying degrees of depth and breadth of understanding which they may possess in each of the three areas. This review focuses on studies which clarify the subject matter knowledge base possessed by science teachers.

Pedagogical content knowledge (PCK) is a term coined by Lee Shulman (1987) to identify the distinctive body of knowledge of the content teacher. This knowledge transcends content knowledge and pedagogical knowledge to form a completely new domain of knowledge which is different in nature from a mere combination of the original two domains (Wilson, Shulman & Richert, 1987). According to Shulman, pedagogical content knowledge includes:

for the most regularly taught topics in one's subject area, ...the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others. (Shulman, 1986b, p.9)
For this review, studies which specifically attempted to address science pedagogical content knowledge, or those which examined how a teacher's knowledge of science content and pedagogy interact to affect classroom practice, will be reviewed.

Subject Matter Knowledge

As previously defined, studies which evaluate subject matter knowledge include those reports which deal with a teacher's understanding of the products and/or processes of a given subject matter, or in the way that subject matter is viewed as "a way of knowing." Two studies which specifically address science teachers' subject matter knowledge will be discussed. Studies dealing with teachers' subject matter knowledge as it relates to instructional practice will be discussed in the next section of this paper.

In a qualitative study of five novice biology teachers, Baxter, Richert and Saylor (1985) looked at the similarities and differences of teachers' knowledge of biology concepts and their conceptions of biology teaching. All five novices were enrolled in a fifth-year teacher certification program, had no previous teaching experience, and had completed a minimum of a BA in a field of biology. Data were collected through a series of five structured interviews and a thematic card sort task during the first semester of the teacher training program.

The interviews focused on information related to the novices' educational background, understanding of biology, knowledge of general pedagogy, and plans to teach biology. To derive the organization of biology concepts, a thematic card sort was conducted. This technique required each teacher to sort ten cards into groups. On each card, one of ten "unifying" themes of biology was written. The teachers were then asked to explain the reasons for their groupings. These themes included: science as inquiry; relationship between biology, technology and society; biological roots of behavior; diversity of type and unity of pattern; complementarity of structure and function; complementarity of organism and environment; regulation and homeostasis; preservation of life in the face of change; genetic continuity of life; change of living things through time: evolution; and history of biological conception.

Four primary findings were discussed by the authors. The subjects' overall responses concerning the role of inquiry in science, the organization of content, and the plans to teach biology were placed on a continuum derived for each theme. The five novices all claimed that inquiry was important to science. However, upon further questioning, it was discovered that the meaning of this term, and how inquiry would be used in the classroom, varied from a conception of inquiry as being omnipresent and fundamental to the
understanding of science to a view that inquiry involved the learning and application of a specific set of techniques. The organization of the content themes also varied. While some novices constructed elaborate and complex relationships among the themes provided, others saw the themes as discrete, and grouped them in a linear or hierarchical fashion containing few relationships. Finally, teachers varied on the overall organization of their teaching approach. While some favored an approach which moved from the general themes of biology to specific content, others preferred a more inductive approach, while still others only discussed the teaching of biology in terms of addressing specific content.

The researchers noted that the level of biology education and the presence of independent research experiences seemed to influence the relative position which these subjects maintained in relation to each other on the aforementioned continua. The group which seemed to have the "preferred" views of biology, as determined by the researchers (i.e., inquiry as omnipresent, deductive teaching orientation, and complex interactions of subject matter), had backgrounds in laboratory sciences, additional graduate training, and an independent science research endeavor, whereas the group with the "less favorable" views did not have such backgrounds.

A study by Hauslein and Good (1989) attempted to elucidate the structure of biology content knowledge in five groups of subjects. Thirty-nine volunteers were asked to participate based on their science and/or teaching background. These subjects represented five populations: 1) Preservice biology teachers who were seeking certification and had not yet taken a secondary science methods course (n=7), 2) Novice inservice biology teachers with one to three years of teaching experience (n=7), 3) Experienced inservice biology teachers with five or more years of teaching experience (n=10), 4) PhD biologists (n=7), and 5) Undergraduate biology majors in their junior or senior year (n=8).

Each subject was asked to participate in a modified version of the Instrument for Free Sorting of Concepts. This instrument/procedure consisted of 37 biology concepts written on separate cards. Through printed directions, the subjects were asked to sort the topics into categories "based upon their understanding of the relationships among the concepts" (p.5). Once satisfied with their results, the subjects were asked to place the cards in columns, one for each group, and then label each column with a term which reflected the relationship of the concepts. Subjects were also requested to "think aloud" during this procedure, especially concerning the decisions they were making. All verbal transactions were audiotaped.

The data generated from the Free-sort were quantitatively analyzed using Latent Partition Analysis and Alpha Factor Analysis which forced the items into eight categories. Individual concepts were then analyzed to determine their degree of membership in a
category, reflecting the level of agreement of placement by the subjects within and between each group. Finally, multidimensional scaling was used to explain the differences between the populations and categories by locating them in two-dimensional space relative to each other. The qualitative data generated by the "think-aloud" procedure was used to validate the findings of the quantitative analysis.

According to the researchers, the eight categories of concepts generated by this method were very similar to one another for the five populations studied. These categories, named from the labels generated by the participants, included: Evolution, Reproduction, Cell Transport, Cell Growth, Physiological Systems, Ecology, Energy, and Plants. Though the specific concepts placed in these categories were not identical for each group, there was overlap. Multidimensional scaling placed the categories and their items in a grid described as having a community-to-organism characteristic versus a biochemical-to-cellular characteristic. Novice and experienced teachers often discussed sequencing concepts to match the order in which they were last taught. Further analysis of these comments revealed that this order was not the one necessarily recommended by the "textbook." Biology majors and preservice teachers often mentioned the sequence of items as presented to them in a recent college biology class.

Multidimensional scaling was also used to represent the cognitive distances among the five groups. The two dimensions were labeled deep versus surface structure and fluid versus fixed structure. The grid indicated that scientists and experienced teachers have hierarchical, well organized cognitive structures as compared to the rather unstructured, loosely organized cognitive structures of the preservice teachers. The differences found between the experienced teachers and the scientists versus the other three groups in terms of the depth of the structure seems to be typical of the results from other expert/novice studies (Berliner, 1986; Chi, Feltovich & Glaser, 1981). The differences between the teachers and scientists in the fluid-fixed dimension may reflect a greater procedural rather than conceptual knowledge by the experienced teachers.

The most interesting finding may be the indication that teachers restructured their thinking about content as they became more experienced in the teaching of that content. The authors suggested that the knowledge of subject matter and knowledge of pedagogy...are not two structures intimately linked, but only one. The data of this study suggested that the experienced teachers cannot think about the concepts of biology apart from how they are taught, the content is literally fixed upon the pedagogic cognitive structure. (Hauslein & Good, 1989, p.30)
Hauslein and Good continued by suggesting that the preservice teacher may "fix" content understanding on the more clearly defined pedagogical structure when the need for such a framework in the content arises.

**Relationship of Subject Matter Knowledge to Classroom Practice**

The importance of a knowledge base in both subject matter and pedagogy has been demonstrated in a meta-analysis of studies (Druva & Anderson, 1983) which correlated teacher characteristics with teacher behaviors and student outcomes. Though correlations were typically quite low, teacher knowledge of content and educational training have been shown to be positively correlated to students' science achievement, attainment of process skills, attitudes toward science, and with science teaching behaviors. These findings contrast with those of more recent researchers (Guyton & Farokhi, 1987) who claimed that test scores which indicate a teacher's content knowledge do not translate into practice, but that indicators of educational training, such as grades in education courses, have significant impacts on teacher performance.

Studies which examine how a science teacher's knowledge of pedagogy and content interact to affect classroom practice, or their pedagogical content knowledge, have been selected for examination in this section. Three primary interactions have been addressed in this review. The first deals with general knowledge of content and its effects on instructional practices. Four studies explored this topic. Second, four studies explored the relationship between a teacher's understanding of the nature of science and classroom behaviors. Third, attempts to inservice science teachers in specific aspects of science understanding and promote translation into classroom practice were explored in three studies.

**Pedagogical Content Knowledge**

Hashweh (1986) conducted a study to describe science teachers' subject matter knowledge and to relate this knowledge to planning and simulated teaching. Three teachers with experience teaching physics and three with experience teaching biology were assessed with respect to their understanding of levers and photosynthesis in a series of three interviews over a period of two to three weeks. The purpose was to determine differences in the knowledge of topics both within and outside the normal content areas of the teachers.
Teacher knowledge of each topic was assessed by summary comments on each topic, related topics, and teaching experiences in these content areas. The teachers were also given a list of 20 physics terms and 17 biology terms and were asked to draw a map connecting the concepts and label the connecting lines. The final task involved the sorting of 11 mechanics problems and 9 biology "exam" questions into groups based on the ideas or concepts needed to answer them.

The second session was used to determine how teachers' knowledge of these concepts affected their preactive decisions and simulated teaching of the topics. Each teacher was asked to think aloud while planning to teach levers and photosynthesis lessons. A textbook chapter dealing with each topic was provided as was information concerning grade level, abilities of students, and the material which the students already knew. At the end of this session, the teachers were asked eight questions concerning evaluation plans, modifications based on student abilities, representations used, use of student prior knowledge, student misconceptions, and long range plans.

In the last interview, teachers were presented with a set of critical incidents which might occur in the interactive teaching of this unit. Twelve incidents were selected for use in the physics portion, nine in the biology portion. These reflected situations in which students might present misconceptions, insightful answers, difficulty in understanding a point, or an unplanned opportunity to discuss a related topic. Teachers' responses to such incidents were recorded.

The data generated in these three sessions were inductively and qualitatively analyzed in terms of teachers' subject matter knowledge, preactive and interactive teaching decisions, and the relationships between the two. Not surprisingly, teachers were found to have a superior knowledge base and structure within their own field of teaching which was characterized by a more detailed knowledge of the topic, more knowledge of related topics, connections of the main topic to these related areas, and more knowledge concerning the particular topic in relation to the conceptual scheme of the discipline.

In an examination of planning tasks using a textbook chapter, the knowledgeable physics teachers were often found to reject the chapter organization in favor of an organization reflecting the conceptual schemes evidenced as part of their subject matter knowledge (work/energy), added concepts to the chapter to enhance this organization, and deleted concepts which did not match their conceptual schemes. Unknowledgeable teachers followed the text structure closely. Where knowledgeable biology teachers detected the vague theme in the chapter related to photosynthesis and used it or an alternative structure as a basis for their planning, unknowledgeable teachers could detect no structure and often could not understand the importance or interrelationships of the
topics included in the chapter. Knowledgeable teachers were found to make more modifications of the chapter and could generate more activities not described in the text to teach the concepts.

The preconceptions held by the teachers, both knowledgeable and unknowledgeable, were found to influence their final plans in such a way that these inaccuracies would be passed on to students. In all cases, the teachers' prior subject matter knowledge was felt to have an effect on the preactive planning of the unit and extended to the planning of evaluation materials. Unknowledgeable teachers tended to ask more fact/recall questions which could be answered from the text, whereas knowledgeable teachers asked questions which required synthesis of text-based topics, or asked for information which was not specifically covered in the text.

Analysis of the critical incidents revealed that knowledgeable teachers were more likely to detect student misconceptions and correct them, whereas unknowledgeable teachers not only failed to detect these misconceptions, but also, in some cases, reinforced them. Knowledgeable teachers were found to capitalize on opportunities to elaborate on their subject matter and on insightful comments made by students. Unknowledgeable teachers often did not use these opportunities. Knowledgeable teachers were also found to deal more directly with student difficulties in the understanding the topic and used more analogies and examples. Again, these differences were attributed, and often traced back to, teachers' prior knowledge on these two subjects.

Carlsen (1989) sought to study lesson planning as a function of subject matter knowledge. Four novice biology teachers, as part of a first year internship program in which teacher training was concurrent with student teaching, were interviewed in this year long study. All of the subjects had a master's degree in a field of biology. Each teacher's subject matter knowledge was measured by self-report as stimulated by a 15 item card sort task of biology topics and analysis of undergraduate and graduate transcripts prior to the start of the school year.

To determine how teacher knowledge may affect classroom behavior, 12-16 lessons were audiotaped over the course of the school year. These lessons and the teachers' lesson plan books were examined and coded as to the number of days spent on each topic and the types of instructional activities which were used. Teachers were asked to check the coding of their lesson plans for accuracy and to fill in any missing information. Activity types were transformed into rates or frequencies of usage for the year.

The topic of interest was how teachers' classroom behaviors varied with their content background. To this end, the lessons from each teacher's three highest-knowledge topics
and three lowest-knowledge topics were examined. Emphasis was placed on within teacher differences and patterns in the data rather than the magnitudes of differences.

Initial examination of the results indicated problems with the use of the researcher designated topics and units. These often differed from terms used by the teachers and resulted in units of unequal curricular hierarchy (e.g. "chordates" and "human systems" were listed as equivalent topics in terms of content coverage). After removing the data generated from the topic "human systems," which created the greatest problem, it was reported that the number of days which teachers spent on high and low knowledge topics did not systematically differ.

In low knowledge topics, students were found to spend more time working in small groups, used more class time to prepare for oral reports, were more often involved in laboratory exercises and spent more time in student presentation of materials. Differences in lab use did not appear to have a consistent relationship with a teacher's subject matter knowledge. In high-knowledge topics, teachers spent more time in lecture/recitation activities, giving quizzes and tests, and reviewing homework assignments and tests. Movies were used equally with both high and low knowledge topics, indicating that movie use may be largely opportunistic.

The author concluded that teachers use instructional strategies which reflect their level of subject matter understanding. In teaching low-knowledge topics, teachers shy away from whole class instruction and review where their content knowledge may be threatened, and structure their activities so that classroom work is more student-centered.

Dobey and Schafer (1984) chose to look at the relationship between elementary teachers' science backgrounds and their use of inquiry in the classroom. Twenty-two prospective teachers who were completing a course in elementary science methods constituted the sample for this study. Each teacher was pretested using a ten item test on pendulums to determine their initial knowledge level on this topic. In addition to the multiple choice questions, teachers were asked to explain why they selected the answers they did. These tests were compared to pre-established criteria to rank the teachers into groups representing no knowledge (NK), intermediate knowledge (IK), or full knowledge (K) of pendulums. Nineteen of the teachers were initially placed in the NK group, one in the IK group, and two in the K group.

The teachers in the NK group were randomly assigned to one of the three groups so that membership was approximately equal. Each group received instruction through an independent source sufficient to assure knowledge at the level of the group to which they were assigned. Prior to the teaching of the lesson, each teacher was posttested as to knowledge level. The final groupings resulted in seven teachers in the NK group, five in
the IK group, and ten in the K group. Each teacher was then asked to teach an inquiry lesson on pendulums to two randomly assigned fifth grade students. The lesson was videotaped for use in a stimulated recall session in which the teachers were asked to clarify how they used their science knowledge to make decisions while teaching.

The lessons were quantified into 32 categories of classroom behavior using the Instrument for the Analysis of Science Teaching, Version Two. Scores on seven of these categories were selected as indicators of a teacher effectively using inquiry to teach the lesson. An ANOVA was used to study the extent to which the three levels of knowledge influenced the teaching behaviors associated with inquiry. Interviews were qualitatively analyzed as to the rationale behind decisions made during the teaching process.

The authors felt that limitations imposed by the selection of indicators which reflect inquiry oriented teaching may have influenced initial findings of no significant differences in teaching behaviors among the three knowledge groups. Following a reanalysis of the data addressing these concerns, significant differences between the groups in terms of teacher directed activities were found. Post hoc analysis showed no significant differences between the NK and K groups, but a significant difference between these groups and the IK group.

Qualitative analysis of the interviews revealed that the NK group lacked confidence in their ability to teach an inquiry lesson on pendulums and were less likely to allow students to pursue new or unfamiliar avenues. These teachers also controlled the lesson activities in order to keep student activities within the scope of their knowledge, thus limiting student inquiry. The Knowledgeable group expressed more confidence in their abilities and were found to directly lecture at some point in the lesson, with the goal of directly teaching the concepts. These teachers often interrupted students when they felt they were doing something "wrong," to check for student understanding, or to explain the current observation or concept to the student. This often resulted in the teacher setting the pace and moving to the next concept when they felt the student had mastered the current task. In general, the teachers which exhibited behaviors most in line with those advocated by an inquiry approach were those with an intermediate knowledge base. The authors concluded that there was little justification for the idea that superior content knowledge alone would facilitate inquiry teaching, but indicated that at least an intermediate level of knowledge seemed essential. They further stated that:

Knowledge is not enough. Teachers must use their knowledge to gain insight into the structure and content of children's scientific thinking and must use that insight and knowledge to contrive questions, challenges, and experiences which sustain inquiry and extend children's understanding.

(p.49)
In the final study of how subject matter knowledge affects general classroom practice, Lantz and Kass (1987) studied why teachers and classrooms function as they do. The purpose of this study was to determine the nature of a teacher's functional paradigm, and how this and other factors contributed to the interpretation of curriculum materials. The authors hoped to use this information to develop a model of teachers' interpretations of curriculum materials, with the ultimate goal of determining how the interpretation of curriculum materials by teachers affects its translation into classroom practice.

Two data sources were used. The first was a 90 item researcher developed survey concerning teachers' perspectives on the newly approved ALCHEM curriculum program. The second data source involved interviews of three chemistry teachers with a range of experience (2, 15, and 19 years). The information derived from the interviews was used to clarify and elaborate the data collected from the surveys.

In general, teachers viewed high school chemistry as a list of specific topics to be taught as mandated by the curriculum guide. Teachers had varying perceptions of what adequate levels of treatment involved and were influenced by personal beliefs as to the emphasis given to lab work and the overall curriculum (e.g. the value of applied chemistry, nature of science, etc.). The adoption of curricular materials was influenced by several variables. A high emphasis on pedagogical efficiency was reinforced by a feeling of being rushed for time. This perception often led to new sequencing and elimination of topics which did not contribute significantly to the understanding of basic chemistry concepts. Other views included the stressing of academic rigor, the motivation of students through lab work and entertaining, novel teaching approaches. Additional student impacts were described in terms of student ability and interest.

Other factors which were found to influence the interpretation and use of curriculum materials included the teacher's background and the teaching situation. Teachers often used successful teaching ideas from the past. This replication accounts for the development of sometimes idiosyncratic classroom routines and curricula. Training in chemistry and experience teaching chemistry seemed to have the most influence on the use of curriculum materials. As summarized by the authors, "it seems that as a teacher gains more training and experience, they become more self-sufficient and rely less on officially approved curriculum materials" (p.125).

Interviews were conducted with three chemistry teachers to validate the results of this survey and to gain further insights into the results generated. The experienced teachers (those with 15 and 19 years of experience) viewed chemistry as a well established, complex body of concepts, principles and theories. These topics may or may not correspond with the curriculum program in current use. Because these teachers often
supplemented the curriculum with units which were successful in the past, they often had difficulty finding the time to teach all of the content. The novice teacher in this sample saw chemistry as an established body of knowledge which was expanding. This teacher was greatly influenced by science courses which he had taken at the university, but limited his content coverage to the core topics covered in the curriculum guide. In general, curriculum materials were accepted as they were, with little or no modification. Due to these teaching practices, the novice had little trouble finding the time to teach all of the concepts recommended in the established curriculum.

The authors concluded that the use of curricular materials depended on the beliefs and values of the teacher. Differences in these beliefs accounted for differences in classroom implementation. This result was particularly evident for differences in academic training and experience.

The Nature of Science

Brickhouse (1989a) examined how a teacher's content knowledge about the nature of science was expressed in the classroom. Seven secondary science teachers were interviewed concerning their knowledge about the nature of science. From this group, three teachers were selected who represented a diversity of views for further investigation. Each teacher was interviewed in a minimum of four one-hour audiotaped sessions about their knowledge of the nature of science, their roles as teachers, and their students' roles as learners, and were observed and audiotaped in a minimum of 35 hours of classroom teaching. In addition, data in the form of textbooks, discipline documentation, tests, quizzes, worksheets, and lab activity sheets were collected. A case study of each teacher was generated and each will be briefly summarized.

Cathcart was a middle school science teacher of 26 years. He described the scientific method as the use of a rational, stepwise procedure. His classes were activity based and he used the textbook extensively. His emphasis was on procedural rather than conceptual knowledge and he discouraged deviations from stated procedures in activities because they might lead to wrong answers. Science was described as an accumulation of facts based on observations which are limited by current technology. Theories were believed to be truths which need to be memorized but, as an avid creationist, Cathcart refused to teach the theory of evolution. In general, he felt that students were incapable of applying the scientific concepts which they had learned, so this was not a goal stressed in his classroom.
Lawson was a high school physics teacher of 15 years with a master's degree in physics. She stressed the interplay between observation and theory, believed that science changes on the basis of the new interpretation of data, and stressed the utility of theories in explaining observations and solving problems. Though she presented the "scientific method," it was not stressed because it was covered extensively in prerequisite courses. She taught science as an accumulation of facts but believed that these facts existed in a hierarchical order which facilitated student understanding. Class material was taught deductively with extensive student participation fostered through questioning.

The final subject, McGee, was discussed both in this study and an additional case study written by Brickhouse (1989b). McGee was described as a second year teacher, trained in earth science and math, who was teaching the full range of middle school science topics. He was characterized as seeing the scientific method as a stepwise process which he used to provide students with the structure they needed for learning. Though he believed that data collection in science is subjective and correctly distinguished between science and technology, he saw science as an accumulation of knowledge. He closely followed the text when teaching and used the text as a curriculum guide since he was given no other. Since McGee felt pressure to teach all of the material in the book he emphasized the memorization of vocabulary terms which he felt would ensure students' later success in science. McGee's major complaints about teaching focused on the constraints which forced his actual classroom teaching to differ from his picture of the ideal. These constraints were categorized as interactive and institutional. Interactive constraints centered around students' grade consciousness and competitiveness, and his admitted recognition of his own poor content preparation in many of the subjects he was being asked to teach. Institutional concerns included McGee's perceptions of other teachers in the building, the materials and text he inherited, his heavy teaching load, and the pressure to cover more content than he felt possible or practical.

The author drew no conclusions and offered no summaries, but suggested that the data illustrated how teachers' views of science may be expressed in classroom instruction. Brickhouse concluded with the observation that a teacher's understanding of the nature of science may be influenced by the number of years spent teaching "textbook" science.

Duschl and Wright (1989) investigated the manner and degree to which science teachers considered the nature of their subject matter in the process of selecting, implementing, and developing instructional tasks. The nature of the subject matter was defined as teacher considerations for the nature and structure of scientific theories, which represents one aspect of the nature of science.
Sixteen weeks of observations were conducted in the science department of a large high school in Atlanta. An ethnographic research methodology was employed and the data was analyzed at three different levels of observation. All 13 science teachers in this department, with the average teaching experience being 12 years with the range of experience varying from 2-21 years, were observed and interviewed. Data sources included field notes from classroom observations and informal interviews, audiotapes from formal interviews, reviews of instructional materials, and the results from the Nature of Science Scale (NOSS).

Instructional strategies which were emphasized were placed in one of three lesson-type categories: organizational/process skill lessons (academic and behavioral routines), cognitive and scientific process skill lessons, and objective lessons (curriculum and personal goals). The use of these lesson types varied with the time of year, the course taught, and the ability level of the student.

To study the role of scientific theories in teacher decision making, four teachers, one from each of the science disciplines, was selected for intensive observation. This consisted of daily classroom observations in one class period for one month. Data analysis indicated that the nature of scientific theories are, at best, only superficially considered or taught by teachers. If these topics were discussed, their importance was often diminished through the exclusion of these topics on exams and the limited continuity of coverage across instructional tasks.

To determine if this lack of consideration of the nature of scientific theories was a result of teacher beliefs, the 11 teachers in the study were administered the NOSS which was followed by a structured interview concerning the role that theories play in science and the teaching of science. A mean score of 15.5 was achieved on the 29 item survey, with a range of scores from 8-22. These results indicated that the teachers did not hold contemporary views of the nature of science but had views based on hypothetico-deductive philosophy, which stresses a commitment to a step-by-step scientific method. The audiotaped structured interviews illustrated that the teachers were more at ease in talking about the role of theories in science than they were about the role of theories in the teaching of science. In fact, many teachers were unable to name the major theories which constituted the content area they taught.

In summary, Duschl and Wright concluded that the nature and role of scientific theories were not integral components in the constellation of influences affecting teachers' educational decisions. This indicated that the essence of the subject matter is not being considered or taught to students.
In a third study examining the effects of a teacher's understanding of the nature of science, Lederman and Zeidler (1987) tested the validity of the commonly held assumption that a teacher's conceptions of the nature of science would have a significant relationship to their classroom behaviors. Eighteen biology teachers from nine secondary schools were selected as the sample for this study. Each teacher had a minimum of five years teaching experience, with a mean of 15.8 years, and was following the New York State Regents Biology syllabus in which one of the specified objectives was to develop an understanding of the nature of science.

The Nature of Scientific Knowledge Scale (NSKS) was administered to each of the teachers as a pretest during the first week of school, and as a posttest the last week of the fall semester. Teacher scores (i.e. their views) were found to remain stable over the course of the study period.

One randomly chosen tenth-grade biology class was selected from each teacher as a source of classroom observations. Three observations were conducted in each of the teacher's classrooms during the fall semester. Field notes concerning teacher and student verbalizations, chalkboard notes, handouts, assignments, teacher mannerisms, nonverbal cues, and classroom physical plan were collected resulting in 18 data sets, one for each teacher.

The results of the NSKS were used to rank teachers on their conceptions of the nature of science. The four teachers with the highest scores (teachers whose scores ranked in the top six on at least four of the seven NSKS scales) and the four teachers with the lowest scores (teachers whose scores ranked in the bottom six on at least four of the seven NSKS scales) were chosen for further analysis. Teachers at the extremes were analyzed so that comparisons would be made only between teachers who clearly differed in their understanding of the nature of science.

Prior to knowledge of the results of the NSKS, systematic pairwise qualitative comparisons were performed among the original 18 data sets to determine differentiating classroom characteristics. Forty-four classroom variables were derived through this process and were operationally defined. These variables were used by the second investigator, who was unaware of the teachers' rankings, to systematically compare each "high" scoring teacher's data set with the data set of each "low" scoring teacher. The purpose of this comparison was to differentiate the teachers as to having "more" or "less" of a particular variable. These comparisons were repeated by the primary author. The resulting data were subjected to a binomial test of significance which was used to establish differences in classroom behavior by teachers with differing conceptions of the nature of science.
With the exception of Down Time, none of the 44 classroom variables were significantly related to a teacher's conception of the nature of science. These findings contradict the assumption that teachers' knowledge and beliefs are translated into classroom practice. Down Time was more prevalent in the "low" group, but the authors felt that this variable may be more logically related to other factors, such as poor planning and classroom management than to a teacher's conception of the nature of science.

Lederman and Zeidler cautioned against the use of these results to trivialize the importance of a teacher's understanding of either their subject matter or the nature of their subject matter, but emphasized the fact that knowledge alone is not enough to ensure adequate classroom coverage which will lead to gains in student achievement and understanding. These findings suggested that other factors besides a teacher's understanding of subject matter may be more influential in determining classroom practices.

Effectiveness of Inservice on PCK

In the first of three studies which looked at the effectiveness of inservicing teachers in pedagogical content knowledge, Krajcik and Layman (1989) examined 22 middle school teachers' content knowledge of temperature and heat energy as well as their knowledge of how to teach these concepts to students. Data was collected in the form of semi-structured interviews prior to the beginning of a three week workshop focusing on the use of microcomputer-based laboratories to teach heat energy and temperature concepts and again at the beginning of the following school year. Interview data on 11 randomly chosen participants centered on five tasks regarding each teacher's understandings of heat and temperature concepts and three tasks probing how they would use these understandings to teach these concepts. Interviews were audiotaped and transcribed and a flowchart of the interview sequence was provided.

Data concerning an individual's understanding of a concept was analyzed through concept propositional analysis which allowed for the evaluation of a comment as representing a comprehensive scientific concept, a sufficiently scientific concept, an incomplete concept, or an alternative concept (or misconception). Content analysis was used to code teacher statements regarding tasks related to the teaching of heat and temperature. These inductively derived categories included complete descriptions of activities, variations, extraneous activities, incomplete descriptions, complete descriptions but faulty explanations, hands-on activities, and other teaching strategies.
An analysis of the results indicated that prior to the workshop few teachers held sufficient scientific views of temperature, heat energy, the relationship between heat energy and temperature, and views regarding the heat loss between two beakers of equal temperature but unequal volume. Following the workshop, gains were made by a majority of teachers in achieving a "sufficient" understanding of these areas. None of the teachers, during either interview, were judged as having "comprehensive" conceptions of any of the topics.

In analyzing classroom strategies used to teach these concepts it was discovered that, prior to the workshop, only one teacher could give specific examples of activities which could be used to help students understand the distinction between heat energy and temperature or the loss of heat from the two beakers. These abilities were improved with exposure to the workshop material.

The authors concluded that while modest gains were made in teachers' understandings of some of the concepts stressed, this increased knowledge was not consistently reflected in teachers' responses concerning how to teach the concepts to students. These findings suggest that the development of appropriate scientific concepts and deep conceptual understandings of how to teach science concepts takes careful work over extended periods of time and may only be gained from teaching experience.

Clermont and Krajcik (1989) sought to examine the growth in pedagogical content knowledge resulting from an intensive workshop designed to help science teachers develop their chemical demonstration teaching skills in the concepts of density and air pressure. Eight inservice teachers working in elementary (n=1), middle school (n=5), and high school classrooms (n=2) composed the sample for this study. These teachers were selected because they were responsible for teaching physical science or beginning chemistry and they reported relatively low levels of confidence in conducting chemical demonstrations. The mean teaching experience for this group was seven years, and the teachers averaged three semester hours of college level chemistry.

The goal of the workshop was to increase the use of effective chemical demonstrations. This was attempted through instruction on the purposes and characteristics of effective chemical demonstrations, modeling good demonstration techniques, preparation, practice and feedback on workshop performed demonstrations, and feedback on a chemistry demonstration presented to a group of middle school students.

Data were collected through both clinical and semi-structured interviews. The clinical interview sessions, conducted before and after the workshop, asked the subjects to view a videotaped model of a chemical demonstration conducted in a classroom setting and to
stop the tape at critical points during the demonstration. Two demonstrations, one representing a favorable performance and the second an unfavorable performance, on the concepts of density and air pressure were selected. The semi-structured interview, which immediately followed the critical-stop task consisted of questions concerning the presentation and possible alternative demonstrations which might be used to teach the same concepts.

Data were analyzed for quantitative differences and were used qualitatively to define differences in pre and post-workshop interviews. Interviews were coded into eight categories of comments related to knowledge growth in concept specific chemical demonstrations, demonstration variations, changes in extraneous examples, understanding of the complexity of some chemical demonstration systems, the ability to analyze critical incidents in the videotaped chemical demonstrations, discourses on inquiry approaches to chemical demonstrations, the quality of explanations, and suggestions for improving observed chemical demonstrations.

Significant differences were found in the number of chemical demonstrations which could be discussed following the workshop and the number of variations mentioned. Increased confidence was mentioned as part of the qualitative data in both these categories. Qualitative data in this area seemed to indicate a decrease in pedagogically unsound demonstrations and a decrease in the mention of seatwork and use of discussions.

Qualitative analysis revealed more statements that related to the complexity of specific chemical demonstrations and how these complexities may foster misconceptions in students following the workshop. These concerns were often accompanied by suggestions about how to simplify or alter a demonstration in ways which reflected these concerns.

No statistical changes were observed in the total number of critical incidents discussed before or after the workshop. A slight shift in focus was noted from generic teaching concerns to more subject matter oriented concerns. The authors also noted an increased direct use of the term "inquiry" after the workshop and an increase in teacher awareness of the quality of explanations. Participants also became more cognizant of the uses of physical drawings when explaining complex demonstrations and with strategies for increasing demonstration visibility.

The final study on the inservicing of science teachers in pedagogical content knowledge was conducted by Yeany and Hale (1989). The focus of the study was to train middle school teachers through an inservice program in the use of skills to teach logical reasoning, process skills, and science content, and to determine the impact of this inservice training on student performance.
In this study, middle school teachers were provided with training in the use of manipulatives and activities through the modeling and viewing of lessons which were later discussed in terms of the activities used specific to the teaching of science content. Classroom observations were conducted to provide the teachers with feedback on the use of "science content pedagogy." Narrative descriptions and critiques were composed for all the trained teachers and were provided to the group six times over the course of a year.

Pupils in these classrooms were compared to a stratified random sample of students from four other middle schools in the area. Data collected included 1987 and 1988 Iowa Test of Basic Skills (ITBS) science and math subscales, the Group Analysis of Logical Thinking, and the Middle School Integrated Process Test. The 1987 ITBS scores were used as a covariate for the other dependent measures which were collected following the study. In addition to these quantitative measures, interviews were conducted with a random sample of 35 students, stratified on race and gender, from the two groups. Interviews were performance oriented and dealt with logical reasoning skills, process skills, and some content knowledge.

The researchers reported that the training of teachers in science content pedagogy had significant impact on pupil logical reasoning skills and pupil process skills as measured by both paper and pencil tests and performance interviews. It should be noted that the student was incorrectly used as the unit of analysis and mean differences were less than four points on each measure. Changes in student achievement were directly attributed to changes in teacher behavior caused by the inservice. Finally, it was reported that there did not seem to be a consistent pattern in the effects of teacher training on the science content achievement of the pupils.

Discussion and Conclusions

The studies reviewed suggest some obvious relationships between a teacher's knowledge of subject matter and classroom practice. Teachers with a strong degree of subject matter expertise have been documented as being more confident in the teaching of that topic (Brickhouse, 1989a, 1989b; Dobey & Schafer, 1984; Lantz & Kass, 1987), tended to allow students to digress or explore the topic (Dobey & Schafer, 1984), relied on the text less often for underlying themes or ways to teach (Hashweh, 1986; Lantz & Kass, 1987), were more often involved in direct teaching strategies (Carslen, 1989; Dobey & Schafer, 1984), and required students to have understandings which were deeper than those measured by fact/recall questions (Hashweh, 1986). Teachers who expressed discomfort with their subject matter knowledge relied heavily on materials provided in curriculum
guides and the text (Brickhouse, 1989a, 1989b; Lantz & Kass, 1987), controlled student participation so that discussions did not extend beyond the teacher's realm of knowledge (Carlsen, 1989; Dobey & Schafer, 1984), often did not recognize (and sometimes actually reinforced) student misconceptions (Hashweh, 1986), and used measures of student understanding which were often based on memorization skills rather than conceptual understandings (Hashweh, 1986). Despite this seemingly simple picture, there seems to be some disagreement about the effect of weak content understanding. Carlsen (1989) suggested that teachers in this situation avoid public discourse which may threaten their knowledge and opt to involve their students in group activities. Dobey and Schafer (1984) suggested that low knowledge teachers feel uncomfortable giving students free reign in an activity situation. Of less disagreement is the fact that teachers cannot teach what they do not know and that inadequate knowledge can result in teachers presenting inaccurate content or not being able to identify and correct student misconceptions.

Many of the studies used to glean this information were conducted in laboratory settings (Baxter, et al., 1985; Clermont & Krajcik, 1989; Dobey & Schafer, 1984; Hashweh, 1986; Hauslein & Good, 1989; Krajcik & Layman, 1989) or did not include extensive classroom observations (Brickhouse, 1989a, 1989b; Carlsen, 1989; Lantz & Kass, 1987; Yeany & Hale, 1989). Unfortunately, the influence of subject matter knowledge is quickly complicated when similar data gathering techniques are moved to classroom settings. Of the major influences which seem to shape the translation of subject matter knowledge into classroom practice, students seems to be the most influential. Teachers have been described as changing their classroom structures based on student interests and abilities, maintaining curriculum materials which have been popular with students in the past (Lantz & Kass, 1987), and reducing attention to curriculum goals in a effort to keep students happy and involved (Housner & Griffey, 1985). These observations are supported by other reviews of this literature base (Clark & Peterson, 1986; Shavelson & Stern, 1981). On this basis, it seems apparent that a true picture of a teacher's subject matter knowledge can only be derived in the context of a naturally occurring classroom situation.

It is also obvious, from the studies reviewed, that teachers do not consider the structure/nature of science when planning instructional tasks, although some disagreement exists among the studies as to the reasons for this lack of consideration. All studies suggest that factors other than the teacher's understanding of the nature of science, such as constraints imposed by students and the adopted curriculum, are a primary influence on classroom activities. It is interesting to speculate whether these findings will generalize to teachers of other subjects, or if there is something inherent in the nature of science which prohibits its simple transmission to the classroom setting.
Despite the wealth of findings which have been generated thus far, methodological concerns prevent the generalizability of results. Six specific areas of concerns will be addressed: problems related to card sort tasks, potential researcher bias in observations, the possibility of a testing effect from subject matter knowledge assessment procedures, collection and use of data, teacher intentions, and the role that the researcher's subject matter expertise may play in the analysis of data.

As can be noted from the previous research, the card sort task was the preferred method of assessing SMS. Unfortunately, several problems are inherent in this method which were not addressed in these studies. First, it seems naive to assume that the topics which a subject would independently select to describe the structure of a subject matter would be the same as those terms supplied by a researcher. Problems associated with this were noted by Carlsen (1989) when he used researcher selected card sort topics as the basis of his data analysis. Hence, the validity of providing items to subjects must be questioned. The study by Hauslein and Good (1989) improved on this methodology by increasing the number of items in the card sort, providing topics as opposed to themes, and recognizing that the list produced was merely representative of the topics which potentially could have been selected. This provided the subjects with greater flexibility in terms of categorization, though the final results are still weighted in favor of the topics selected. A comprehensive list of topics, such as that used in the card sort procedure by Wilson (1989), may improve on the validity of this technique, as would a more open-ended questionnaire.

More importantly, users of the card sort procedure assumed that they were objectively assessing a structure of content which already coherently existed for the subject. None of the studies have tested this assumption by asking the subjects if they had thought of their content as having a structure prior to the card sort task. Without this precaution, it is difficult to determine if what is being reported is a true "picture" of the cognitive structure of the subject, or an artifact of the card sort procedure. It can be argued that participation in the card sort has created knowledge which did not previously exist, rather than providing a representation of the teacher's SMS.

Though some flaws exist in the card sort method as it has been used, it does provide a vehicle for the elucidation of subject matter knowledge. However, it should be noted that asking a teacher what he or she knows, and then looking for evidence of this knowledge in their teaching behaviors, can bias results. For example, if a teacher claims to be heavily influenced by the inquiry approach, this comment may unintentionally sensitize the researcher to record classroom incidences which use an inquiry approach. Only in the cases of Dobey and Schafer (1984) and Lederman and Zeidler (1987) were specific
measures taken to remove this potential source of researcher bias. In each of these cases
the results of the pretests of teachers' knowledge were not known to the individuals
responsible for making classroom observations or categorizing data. In a majority of the
other studies, teacher knowledge or attitudes were known to the researchers prior to
additional data collection.

A final concern relating to instrumentation involves a potential testing effect. If a
teacher is asked to make connections between several content topics which are related,
the teacher may actually "see" connections which had not been considered prior to that
time. The effects of repeated administration of an assessment technique may be to
artificially "inflate" or create teacher knowledge. Though this problem may never be totally
removed if one seeks to understand teacher knowledge, it may be minimized by asking for
SMSs only once to obtain baseline data or by asking for SMSs only at the end of a study.
Additionally, once a teacher is asked to reflect upon the structure of his/her subject matter
it is possible that this individual may alter subsequent instructional practice to match this
newly recognized/created conception. The result might mistakenly be perceived (by the
researcher) as a clear relationship between SMS and classroom practice, while in reality all
that has occurred is a testing effect created by the assessment technique.

In several cases, data were collected from many sources: interviews, teacher tasks,
lesson books, worksheets, etc. Of these, heavy reliance on teachers' lesson plans as a
source of data presents a concern. Though it may be properly assumed that lesson plans
will act as a guide to a teacher's classroom instruction, rarely do these plans represent the
total picture of what goes on in the classroom (Weisz, 1989). Unless extensive classroom
observations are made in addition to viewing these plans, little validity may be attributed to
this source of data. These problems would be especially acute in studies such as
Carlsen's (1989), which used plans as a primary source of data, or those studies which
only ask teachers to plan their lessons without actually giving them an opportunity to teach
these lessons, such as in Hashweh's study (1986). Additionally, the richness of multiple
data sources were sometimes used in an effort to "triangulate" findings. Unfortunately, the
specific use of these additional data sources were rarely addressed, causing one to
wonder how or if they were actually used in the study.

A source of data which is often ignored involves teachers' intentions as they apply to
classroom performance. Some studies assume that teacher knowledge will automatically
be evidenced in classroom teaching behavior. It is possible that teachers purposely do not
teach some content (such as the nature of science). It is also possible, as demonstrated
by several of the studies, that teacher thoughts may not be effectively translated into
classroom practice due to other constraints, such as curriculum or beliefs about students.
Once again, this criticism warrants specific classroom observations as well as interviews to assess teachers' intentions.

Finally, given the nature of subject matter research, the investigators' knowledge of subject matter is critical to the accurate interpretation of card sort and interview data. When viewing subject matter knowledge and the manner in which it is structured, a researcher with minimal subject matter knowledge may unwittingly concentrate on the superficial features of the knowledge portrayed, without the skills necessary to judge depth of subject matter knowledge. For example, in Baxter, et al. (1985), one individual who placed evolution as a subordinate theme in biology was considered to have an exemplary understanding of biology. Most biologists would agree that evolution is the central unifying theme in the biological sciences. Unfortunately, the backgrounds of the individual researchers are not known, forcing the reader to be the judge of the validity and accuracy of their assessments of teachers' subject matter knowledge.

The subject matter knowledge which a teacher holds seems to have complicated interactions with teaching behaviors. Many researchers stress that expert content knowledge alone is not enough to ensure excellent teaching, but does have an effect on classroom practice. In general, it seems that the structure of subject matter knowledge is affected by the source of the content information (university or self-learned) as well as the way in which it is used. Teachers seem to be highly influenced by the act of teaching in both what they know and how they organize this information. It seems that this understanding, which may become "deeper" with classroom experience, may affect subsequent learning of subject matter and classroom use.

Recommendations

As can be seen from the literature reviewed, the relationship between a teacher's subject matter knowledge and subsequent classroom practice can be complicated. Given the limitations of prior research in this area (assessment of subject matter structure, laboratory versus classroom observation, teachers' intentions, etc.), the need for a more careful and thorough examination of the transfer of subject matter knowledge to classroom practice is evident. Several specific changes in methodology are apparent.

First, changes in the assessment of teachers' SMSs are needed. There are three major areas of concern related to this topic. First, the topics which are included in a teacher's SMS must be left open to the teacher. This should help eliminate the potential researcher bias which is evident in other studies of this type. Second, the assumption that all teachers have a coherent SMS in place must be tested. This can only be done through
direct questioning on such matters and through the comparison of classroom practice to
teacher stated structures. As part of this comparison, it will be imperative that the
researcher conducting the classroom observations not be sensitized by prior knowledge of
the teacher's SMS. Finally, the potential testing effect of asking teachers to state their
subject matter structure prior to observation must be examined. The congruence among
the stated SMSs and classroom practices of teachers who have been asked about their
SMS prior to classroom observation should be compared with such congruence among
teachers who have not been asked to delineate their SMS prior to observation. Such a
comparison should help assess the existence and/or magnitude of any testing effects.

Second, the relationship of SMS to classroom practice must be investigated. This can
only be accomplished through extensive classroom observations as opposed to simulated
situations in the laboratory. In addition, teachers' intentions will need to be assessed to
determine if what occurs in the classroom is a true reflection of their subject matter
knowledge or a function of other confounding variables.

Finally, if SMSs are found to significantly translate to classroom practice it will be
necessary to assess the relative effectiveness of the variety of structures which might be
found. In addition, situations which cause the formation, restructuring, or reinforcement of
SMSs will need to be identified for further experimental testing and potential addition to
preservice and inservice teacher preparation.
CHAPTER III
DESIGN AND METHOD

Introduction

The purpose of this investigation was to determine the nature of the conceptual framework, or subject matter structure (SMS), which biology teachers possess for their knowledge of biology, the sources and formation of the current SMS, the relationship of the SMS to classroom practice, and to assess the potential testing effect which may be inherent in studies of this nature. Biology teachers and biology content knowledge were the focus of this investigation since biology is the content background of the researcher and, by definition, one can not adequately study the structure of a subject matter outside one’s area of expertise.

The exploratory nature of this study necessitated a multiple case study design. This design involved the utilization of qualitative data collection and analysis procedures. Specific selection of subjects and the general methods of data collection and analysis will be described early in this chapter. This discussion will be followed by sections on each of the three distinct phases of data collection and analysis, explaining each in detail. The phases will be discussed in the sequence in which they occurred in the investigation.

Subjects

Since research suggests that a teacher’s understanding of the classroom situation and the content that he/she teaches changes with experience (Berliner, 1986; Grossman, Wilson, & Shulman, 1989), teachers with a range of experience teaching biology were sought. In the Spring of 1990, contacts were made with certified high school biology teachers in four school districts (six high schools) who would be teaching biology in the Fall of 1990. A sample of convenience within a geographical region in a rural western state which was easily accessible by the researcher was used.

Initial inquiries to attract teachers willing to participate in the study were directed to biology teachers in the schools suggested by local teachers, or were directed to the science department chair. Early contacts, made by phone and/or letter (Appendix A), were used to assess the district’s and teacher’s overall willingness to participate in the investigation. The general intent of the research project was explained in addition to the types of data to be collected and the time commitments of the teacher involved. To avoid
sensitizing the subjects to the focus of the investigation, each teacher was told that he/she would be observed as part of a study to determine the various techniques used to teach high school biology. Since many acceptable variations in the teaching of biology exist, it was hoped that such an explanation would help reduce teachers' concerns about critical evaluation and minimize the impact of the observations on classroom structure.

Once the names of specific teachers who expressed an interest were obtained, a second letter (Appendix B) was mailed out to confirm willingness to participate. It was hoped that this format would allow teachers a "safe" manner in which to disengage from further participation if they so desired.

In the Fall of 1990, all teachers who expressed an interest in the project were contacted by phone to reconfirm their interest. Building administrators were also contacted so that the intent of the study could be explained and to gain permission for the participation of the teacher. This resulted in the final selection of five biology teachers from three school districts and five high schools.

**Method**

Since this investigation was exploratory in nature, an inductive, qualitative method of data collection and analysis, as described by Bogdan and Biklen (1982), was used. Generally speaking, this means that the data generated in each phase of the study was looked at holistically in order to derive any evident patterns or categories of information. These patterns and categories were then "tested" against data from subsequent phases with patterns and categories being added or deleted. It was hoped that this method of data analysis would remove potential bias which may be introduced by use of a priori patterns or categories.

Each phase of data collection and each type of data was analyzed separately through a constant comparative format. The details of this method will be described within each phase of the data collection and analysis which follows. Triangulation among data types and phases was sought in order to confirm or question the patterns of evidence found among the various phases and types of data collected. The specifics of this methodology will be discussed as appropriate.

**Phase I: Pre-Observation Interviews**

The initial data collection phase of this investigation focused on the development of a profile for each teacher. A semi-structured interview of approximately one hour was
requested and conducted prior to the start of the school year in each teacher's classroom. This scheduling format was selected to provide maximum time flexibility, to put the teacher at ease in familiar surroundings, and to allow the researcher an opportunity to locate the classroom. Actual interviews lasted from 45 to 90 minutes.

Prior to the start of the interview, each teacher was reminded of the general 'purpose' of the investigation, the types of data which would be collected, and the time frame for the investigation. In accordance with Human Subjects Committee regulations, each teacher was also reminded that the information collected as part of the study would remain anonymous and would not be used for evaluative purposes. Finally, each teacher was asked for permission to audiotape the interview session and was shown the audio equipment which would be used to record classroom interactions.

The first part of the interview focused on the general academic and professional background of the teacher. The following questions were used to guide the interview:

When and why did you decide to become a biology teacher?
What schools did you attend?
What were your areas of content specialization?
How would you describe your overall academic preparation?
How many years have you been teaching?
What types of courses have you taught?
How many years have you been teaching biology?
How many biology classes do you anticipate teaching next year?
What other job responsibilities will you have?
Have you ever worked on curriculum projects? If so, when?

The second part of the interview consisted of questions targeting the specific climate for teaching biology in the school and the intentions of the teacher in terms of teaching biology. The following interview questions were used to guide the discussion:

What is your basic philosophy of education?
What are your specific goals for the teaching of biology?
What textbooks and/or supplementary materials do you use?
Do you have a curriculum which you follow?
How would you describe the other members of your department?
What level of cooperation exists among your biology staff? Your science staff?

How would you describe the level of support for science teaching in your school?

What are your biology students like?

Are there one or multiple levels of biology taught in your school?

How does biology fit into the overall science sequence?

What is the basic organization of your biology course?

How do you feel your students learn biology best?

The interview was followed by a request for a written list of subject matter and education courses taken as part of preservice or inservice teacher preparation (Appendix C). It was hoped that asking for a list of courses as opposed to transcripts would decrease any feelings of being evaluated. Since the creation of such a list was facilitated by access to personal records, the researcher asked the teacher to return the list at the time of the first classroom observation. Though many of the teachers forgot to fill out this form within the stated time frame, lists of subject matter and education courses were received from each teacher within the first four weeks of the classroom observations.

In addition to the above information, two of the five teachers were randomly selected and asked to complete the following questionnaire prior to the first classroom observation (Appendix D).

What topics make up biology?

If you were to make a diagram of these topics, what would it look like?

Have you ever thought about biology in this manner before? Please explain.

Each teacher was informed that this questionnaire was intentionally vague and that there were no wrong or right answers. The results of this questionnaire were requested in writing and remained unknown to the researcher until the conclusion of data analysis in Phase II. This process avoided potentially biasing the researcher's subsequent classroom observations and derivation of apparent subject matter structures as they appeared in classroom instruction.

The methodology described was considered superior to those used in previous investigations for three reasons. First, the topics which could be included in the schematic of biology remained open-ended, removing possible sources of bias imposed by the researcher. Second, only half (approximately) of the subjects were asked to complete the questionnaire at the time of the first interview. It was hoped that this approach would help
determine the potential testing effect of the questionnaire. Testing effects could occur through the "creation" of a subject matter structure where one did not previously exist or through the sensitization of a teacher to a SMS, potentially increasing the possibly of translation of the SMS into classroom practice. Third, by not allowing the researcher to see this information, the classroom observations had the potential to act as objective measures of the impact of a teacher's subject matter structure on classroom practice, as opposed to verification of a belief already held by the researcher.

Before the initial interview was concluded, the researcher requested a copy of the textbook which was to be used and a copy of curriculum guidelines (if they existed), and drew a basic map of the room. Arrangements concerning the best time and place to make weekly teacher contacts concerning teaching schedule and the collection of classroom materials were established, as well as decisions concerning the biology class to be observed.

All pre-observation interviews were audiotaped and transcribed. Additional information which could not be gleaned from the audiotape (discussions which occurred before and after taping, facial expressions, etc.) were noted following the interview and then added to the interview transcripts.

The information collected from the initial interview and the list of education and subject matter courses provided by the teacher was used to construct an Academic and Professional Profile of each teacher. This preliminary profile included personal characteristics, professional preparation, philosophy of education and biology, perceptions of students, and perceptions of the professional and social climate in the school. Additional information, offered by the teachers throughout the investigation and during the final interview, was used to enhance or modify this profile. Specific information which may have changed during the course of the investigation (i.e., the number and type of school related responsibilities outside the classroom) was sought in the final interview and used to correct teacher profiles when necessary. The teachers' Academic and Professional Profiles comprise the first portion of each case study reported in Chapter IV.

Phase II: Classroom Observations

The second phase of the investigation consisted of extensive classroom observations and the collection of classroom documents and anecdotal data. The primary purpose of this phase was to attempt to inductively generate the SMS of each teacher as evidenced by patterns in classroom teaching. This methodology was considered superior to previously used techniques because it removed researcher bias introduced by prior
information concerning teachers' knowledge structures and acted to closely link evidence of potential SMSs to classroom practice.

Three types of data were collected and analyzed: classroom observations, classroom documents, and anecdotal data. Specifics of the data collection and analysis will be discussed in the following sections. Each data type was analyzed separately and then across data types to assess congruence and to generate a comprehensive profile of the classroom situation. Informal analysis, or data analysis which occurred weekly during the classroom observations, was used to ascertain patterns, develop working hypotheses, and direct future data collection. Hypotheses formed each week for individual teachers were tested through subsequent analysis of additional data. Patterns supported through a number of sources were recognized as more consistent. Patterns supported through single and multiple data sources acted as foci for questioning during the final interviews.

Formal data analysis occurred following the collection of all classroom data. This analysis consisted of reading the classroom data in totality, testing working hypotheses, and searching for additional patterns that may be derived from the data. In addition, the formal data analysis stage was used to verify the SMSs as evidenced in classroom practice and to select quotes and other forms of evidence which could be used to support the derived conclusions.

Observations. Classroom observations were prearranged with the teachers for each of the 18 weeks of the Fall semester. All observations occurred within a single Biology class of the teacher's choosing. Teachers' intended schedules were discussed each weekend and potential days for classroom observations were agreed upon. Generally, the researcher had the opportunity to select an observation day of choice from the intended schedule. Attempts were made to observe as wide a range of classroom situations as possible. In particular, observations were scheduled for days when the teachers were actively involved in the teaching of content or were interacting with students in lab or activity-oriented situations. Movies and tests were typically not observed since the amount of information concerning a teacher's SMS would probably be limited on such days.

To facilitate data collection, the researcher asked to be introduced to the class early in the school year. The introduction was conducted in a manner recommended by the teacher (teacher conducted or a self introduction) and was used as an opportunity to discuss the general "purpose" of the classroom observations with the students. The introduction appeared to quickly desensitize the students to the researcher's presence and allowed the class to proceed as normally as possible. All observations lasted for the entire
class period with the researcher arriving prior to the start of class and leaving after the final bell.

Classroom observations focused on the general presentation of biology content. All verbal transactions between the teacher and the students were audiotaped using a remote wireless microphone worn by the teacher and a tape recorder controlled by the researcher. Extensive handwritten field notes were recorded by the researcher who sat in the back of the classroom. The field notes specifically recorded information concerning the teacher's movements and apparent enthusiasm, student interest, general classroom tone, teacher and student actions, student behavior, conversations not directed to the teacher, and observer impressions of the overall class proceedings. All board and overhead work was recorded as part of the field notes as well as the sequence of any written materials used during the class period. In addition, student responses to teacher questions were recorded since these were often inaudible on the tapes. To facilitate the integration of field notes with transcripts from the audiotapes, the time and "counter number" from the tape recorder was noted frequently by the researcher on the field notes. Supporting documentation such as lecture notes, handouts, lab sheets, and supplementary materials used during the previous week were collected prior to leaving the classroom.

The audiotapes generated by the classroom observations were delivered to a paid typist immediately following the lesson. The lessons were transcribed verbatim onto computer disk and were generally returned to the researcher within 48 hours. Instructions were given to record the counter number from the cassette recorder onto the transcripts at intervals of approximately 50 counts.

Data from the field notes were merged with those from the audiotapes by the researcher in order to provide the most extensive record of the class period as possible. Classroom transcripts were checked for accuracy and expanded based upon the field notes. In addition, notes concerning pre and post lesson conversations between the researcher and the teacher were recorded. These data will be described in greater detail in the Anecdotal Data section of this chapter.

Data analysis of lesson transcripts and lesson materials was continuous in order to generate descriptions of each teacher's subject matter structure as evidenced in classroom presentations. Specifically, classroom transcripts were read each week as they were completed and were used to develop a general "picture" of the content being taught by each teacher. This description consisted of a series of informal notes related to the general sequence of instructional units (creating a linear "content map"), the types of classroom activities used, and the general atmosphere and tone of the classroom. In addition, comments which related one classroom topic to another or a series of actions
which seemed to indicate the presence of a teaching theme (such as several non-consecutive days spent on hypothesis generation and critical thinking skills) were noted. Finally, situations which seemed to impact the type and/or manner of teaching (such as poor discipline, inconsistent student attendance, frequent teacher absences, etc.) were recorded. This informal data analysis created a context from which to view the teacher and the teaching situation, and helped provide a series of working hypotheses which were further explored as additional data were collected.

Two rounds of formal analysis of the classroom transcripts, conducted following the completion and transcription of all classroom observations, were conducted. This information was used to generate two separate descriptions which were incorporated into the case study of each teacher. The first was a Classroom Profile of each teacher. As the classroom transcripts of each teacher were read as a set, a general description of the format of the class, general approaches to teaching, patterns of text book use, and daily and weekly (or unit) routines was developed. In addition, a profile of the specific group of students comprising the observed class and the teacher’s opinion of the students in relation to other students was constructed. A second reading of the transcripts, used to verify the patterns described, occurred prior to the final writing of the instructional profile. When possible and practical, quotes were used to support the generated profile. This Classroom Profile appears in each teacher’s case study presented in Chapter IV.

The second description developed from the classroom transcripts related to the teachers' Classroom Subject Matter Structure as inferred from classroom observations. The reader is reminded that one of the primary purposes of this study was to determine the potential impact of a teacher’s SMS on classroom practice. In an effort not to bias the researcher, information concerning the teacher’s actual SMS was not collected (except in the case of two randomly selected teachers who were used to establish the possible presence of a testing effect. These teachers' initial SMSs were not viewed until all classroom observations were complete and a classroom SMS derived). Instead, the researcher attempted to infer each teacher’s SMS through classroom practice. Specifically, the transcripts were again read twice as a set. The first reading was used to highlight any references which a teacher made in the context of the class relating two aspects of the curriculum together. For instance, if a teacher, in the midst of a biochemistry lesson, included an explanation which related carbohydrates to metabolism, the comment was highlighted. Comments such as these were viewed as potential indicators of the nature of a teacher’s SMS. Using the listing of the units taught and the content of each unit, a “content map” was developed. The content map was considered a rough draft of the final SMS with connections among content items represented with arrows. (Due to the
complexity of the procedures used to analyze the classroom data and construct the final Classroom SMS, only an overview of the procedures, as they pertained to the rough draft, will be discussed at this time. Expanded explanations which convey the specific methodology used to generate the Classroom SMS can be found in Chapter IV, Textbook SMS: Methods.)

The second type of evidence which was used as a potential indicator of the nature of a teacher's SMS involved the presence of themes. Themes were considered to be rationales, concepts, or goals which were "laid over" the content being taught and occurred on several nonconsecutive days. Examples of themes included critical thinking, science-technology-society interactions (STS), and the various aspects of the nature of science, such as tentativeness. Again, quotes were highlighted which indicated the presence of such themes. On both the rough draft and the final SMS, themes were represented as columns which overlapped the various content units. Further explanations of the representation of themes can be found in Chapter IV, Textbook SMS: Methods. Once the "rough draft" of the SMS was constructed (including the content connections and themes), a second reading of the transcripts, as a set, occurred in order to highlight any quotes or patterns missed in the previous reading and to verify the presence of the patterns derived.

All analyses described to this point occurred prior to the final interviews which took place in Phase III of the investigation. The results of the analysis of classroom observations resulted in a rough draft of a teacher's SMS as inferred from classroom practice and provided a source of quotes and instances to support such inferences. Coupled with the information generated in the Classroom Profile, a narrative was written concerning the general conclusions about each teacher's SMS. This analysis was considered sufficient to prevent the researcher from being biased by the teacher's stated SMS in the final interview, and allowed the final interview to occur within the first six weeks following the last classroom observation. Additional analysis of this data will be discussed in the section on Triangulation of Data Sets included in this chapter.

Documents. Documents used in the normal course of teaching were collected as a second form of data in this phase of the investigation. In an effort to minimize the workload associated with the project, teachers were not asked to provide any materials which were not routinely generated, such as extensive lesson plans specifically for the benefit of the researcher.

Each teacher was asked to save all written materials provided to students (worksheets, textbooks, laboratory activities, homework assignments, tests, quizzes, and
final exams, etc.) as well as copies of lesson plans. Documents were collected and filed weekly within the framework of each teacher's written lesson plans (which were photocopied periodically) and the week's schedule as it was discussed with, or observed by, the researcher. Documents collected during classroom observations were recorded on the transcripts along with specific use and sequence and were then filed with other documents collected as part of the study.

The analysis of documents was conducted separately from the analysis of transcripts. There were three primary purposes for the collection of the stated documents. The first purpose was to provide information on the classes which were not actually observed by the researcher. It was hoped that the comparison of classroom observations and lesson plans would aid in the interpretation and portrayal of all lessons taught. Secondly, the materials collected were analyzed in order to make inferences about the nature of the teacher's SMS. These inferences also involved testing hypotheses concerning the relationship between the textbook and classroom SMS. Comparisons of the "structure" of the text to the structure observed in classroom practice acted as a test of the strength these relationships. Finally, the analysis of documents provided general descriptive data concerning the overall classroom routines and activities as well as a check for the consistency of teacher stated philosophies into practice.

The analysis of classroom documents followed the final classroom observation and occurred separately from the analysis of other data types. Materials were placed in chronological order of use and were compared to the rough draft of the SMS generated in the analysis of classroom observation data. Discrepancies were noted and new information, if applicable, was added. (Notation was used to indicate the source of various pieces of information added to the SMS.) SMSs were also generated separately from the textbook. As with the classroom transcripts, classroom materials were analyzed in a manner which highlighted activities which tied two content items together or perpetuated a theme across the curriculum. This procedure allowed for the comparison of inferred SMSs derived through classroom materials and classroom presentations. Congruence, or lack thereof, was noted and used as a basis for questioning during the final interview.

In addition, general descriptive data was generated through an analysis of the classroom materials. Specifically, the following information for each teacher was calculated through a simple tally system: the number of days spent on each unit, the number of units taught, the number of tests or quizzes given, and the number of days spent in each of the major categories of activities (lecture, lab, small group activity, etc., depending on the teacher). Finally, 20% of the test questions administered were randomly selected and judged relative to cognitive level. Questions at the knowledge or comprehension level
according to Bloom's taxonomy were considered lower level questions, and questions involving application, analysis, synthesis, or evaluation were considered higher level questions.

It should be stressed that this quantitative data was collected for general descriptive purposes and was intended only as a means of enhancing the qualitative data collected in the study. No statistical tests were performed among teachers, nor would such comparisons be meaningful.

**Anecdotal Data.** Prior to the classroom observations, each teacher was contacted by phone to determine the teaching schedule for the week and to determine potential days for observation. The general content of these phone conversations were recorded from notes taken by the researcher. In particular, information which involved the elaboration of teachers' classroom goals and expectations, discussions about student success or lack of success with content and materials, and information concerning the weekly anticipated schedule were noted.

Researcher initiated interactions with teachers before and after the classroom observations were generally kept to a minimum to decrease the imposition involved with the observation. Generally, researcher initiated conversations were limited to short pleasantries ("How are you doing today?" or "I enjoyed watching your students..."). Frequently, the teachers initiated a more extended conversation. All conversations surrounding a classroom observation were recorded from memory by the researcher, when it was appropriate to do so (prior to the start of class or once outside the school), and were documented for later analysis. In some cases these conversations were included on the tapes made during the classroom observations and were transcribed.

Anecdotal data was analyzed separately from the classroom transcript data, though it often "wrapped around" an observation. Analysis, again, focused on SMSs which could be inferred from the conversations. In particular, this data source often provided information on a teacher's general classroom philosophies and perceptions. For this reason, anecdotal data was often used to enhance the information gleaned from the pre- and post-observation interviews. Thus, anecdotal data contributed to the stated philosophies of a teacher and were compared to classroom actions and the SMSs generated by the teachers. Apparent similarities and/or contradictions were noted.
Phase III: Post-Observation Interviews

The final phase of data collection consisted of an audiotaped, semi-structured interview, scheduled to last approximately one hour. The final interview focused specifically on the teachers' perceived structure of biology (since this information could no longer influence data collection or analysis) and was audiotaped and transcribed for later analysis. Actual interviews lasted from one to three hours. The interviews, in most cases, occurred within six weeks of the final classroom observation. All interviews were conducted after the analysis of classroom data was complete. In the case of one teacher who was seriously injured in an accident, the final interview could not be conducted until late in the Spring semester.

Interviews were conducted in the teachers' classrooms at the end of the school day to decrease potential time constraints. Prior to the start of the interview the teachers were again reminded of the general "purpose" of the investigation and assured that their identities would remain anonymous. In addition, the researcher reinforced the idea that there were no right or wrong answers to the questions asked and that the focus of the interview was on understanding what the teachers thought, the reasons behind their actions in the classroom, and the factors which affected these thoughts and actions.

The first portion of the interview focused on general questions of clarification. These questions were specific for each teacher, and generally dealt with global issues which arose as a function of the classroom observations, such as final coaching schedules, responsibilities, the results of science competitions which were started during the Fall semester, etc. It was hoped that these early questions would put the teacher at ease and open lines of communication for the rest of the interview.

Following this opening series of questions, the teachers were asked about their current teaching situation (Spring semester versus Fall semester) and any changes which might have occurred. The following questions acted as guides:

Are the courses you are teaching Spring semester the same as those you taught Fall semester?

What topics are being covered in Biology this semester?

Are the students in your classes the same or different?

Do you have any specific goals for the Spring semester?

Are those goals the same or different as those of Fall semester?

As a group, how would you characterize the class observed Fall semester in terms of your other classes? (best, favorite, smartest, etc.)
If you had been observed teaching another Biology class, would the classroom instruction have differed significantly? If so, how?

These questions acted as a prelude to the discussion of information specific to the Fall semester. It is interesting to note that many of the teachers asked to be reminded of the specific units which were taught during the observation period to facilitate the answering of the following questions:

Which units from first semester did you enjoy teaching the most? Why?

Which units do you think were the most successful? Why?

Which of the units do you think the students enjoyed the most? Felt the most success with? Why?

Does the idea of student enjoyment and student success seem to correlate for your students?

What influence did my being in your room have on: Your students? Your teaching? You? (in terms of personal influence, changes in planning, time commitments, changes in behavior, etc.)

What should students know/be able to do now that they have been in Biology for more than a semester? What would be the minimum you would be happy with? What would be the best possible outcome?

Questions about content led naturally to questions concerning the teacher's perception of his own subject matter knowledge gained in school. Information concerning the teacher's perceived area of biology expertise was taken from the initial interview. The following questions explored this knowledge:

You described your area of undergraduate/graduate specialization as ____. Could you explain to me what you meant by that?

Why did you choose this description as opposed to some other?

How did you pick this particular area of content specialization?

Does this description of your content specialty affect the manner in which you teach this and other topics?

Specific information concerning a teacher's philosophy of teaching and sources of teaching ideas were collected in order to increase the understanding of the selection of classroom activities. This information also contributed to the understanding of the potential sources of the SMS observed and inferred from classroom observations. Questions varied slightly in order to create a match with the specific teaching situation observed. The following questions were used:

Why do you teach the way you teach?
How do you see the use/purpose of the following teaching activities: lecture, worksheets, labs, field trips, movies, reading from the text, homework, group work, etc?

What are the sources of the ideas and materials that you use in class for: Lecture material? Worksheets and labs?

What criteria do you use in selecting these materials?

On what basis do you prioritize material/activities when you have more material than you have days in a unit?

Now that you have taught from the text for (at least) a semester, how do you feel about it? The labs? Tests? Supplemental activities?

What role do the text-provided materials play in your teaching? Your thinking about teaching?

Has a change in text made a significant difference in your teaching?

Finally, the teachers were asked specific questions which related to the rationale (intentions versus reality) behind what actually occurred in their classrooms and the perceived situational constraints, if any, that existed. Sample questions consisted of:

Why were these units taught in this order and manner?

What advantages/disadvantages do you find with this sequencing?

How do you determine the length of time you spend on a topic?

How have you felt/used the district guidelines on the number of days per unit (if appropriate)?

What key factors affect what you teach? How you teach?

Do you plan on making any changes in your first semester teaching for next year? If so, what would the changes be and why would you make them?

If given total freedom, would you change your teaching? How and why?

Following this line of questioning, all teachers were asked to complete the questionnaire concerning subject matter structure. This questionnaire was the same one completed by two of the teachers in the initial stages of the investigation (Appendix D). Teachers were reminded again that there were no right or wrong answers to these questions. Several minutes of undisturbed time were provided for each teacher to complete this task. When the teachers felt comfortable with the answer (usually after 5 to 10 minutes), the following questions were asked to guide the discussion of the teacher generated SMS:

Describe, in words, what you have written on your paper.
How did you select the topics which you have included?

What do the connections between your topics mean (if appropriate)?

What specifically do you mean by (select a term from the subject's paper)?

If I substituted one term with another (for instance, animals for zoology), would these two terms convey the same idea? Why or why not?

Are all of the topics you listed of equal "scale" or magnitude? Please explain.

What are the most important content topics/themes that you think should be emphasized in biology?

Are those important topics/themes listed as part of your SMS? Why or why not?

Would the topics/themes fit and/or be appropriate to include in your SMS?

Have you ever thought about your subject matter in this way before? If yes: When and under what circumstances?

Have you always thought about biology in the way listed?

The teachers who completed the form for a second time were asked the above questions in addition to the following:

Have your views changed since you first completed this form at the beginning of the study? If so, how and why?

Did the act of completing this form at the beginning of the year have any influence on how you have filled it out now? On your teaching?

Once the above questions were answered, the two subjects who had previously filled out the questionnaire were provided with the original form which they completed and were asked to compare and contrast the two forms and elaborate on comments made. Lastly, both groups were asked:

How did it make you feel to fill out this form?

Do you think the structure you provided would be evident in your classroom teaching? Why or why not? How?

In some cases the following question was asked:

When I was looking through the transcripts from your classes I noticed that you made frequent references to...(physical science, past and upcoming concepts, local ecological concerns, etc.). Is that something that you did intentionally? Please explain.

Finally, many teachers had previously mentioned their dissatisfaction with their teacher preparation program. The following questions were used to explore this dissatisfaction more thoroughly:
If you could make recommendations about the preservice preparation of teachers, what would they be?

If you could make recommendations about inservice programs, what would they be?

The final moments of the interview were used to thank the teacher for his time and the opportunity to observe his class. Semester exams, if not obtained earlier, were collected, and an opportunity to make any final comments was provided.

The information generated from the final semi-structured interview was used in several ways. First, much of this information was included in each case study (Chapter IV) under the title: Classroom Specific Perceptions and Concerns. In this section, anecdotal data was combined with information obtained as part of the final interview in order to provide a description of specific concerns and perceptions of the Biology class observed as part of this study. Secondly, information included in the Academic and Professional Profile was verified and, if needed, modified. Lastly, the final interview provided data concerning each teacher's SMS. The use of this data to answer the questions posed by this study will be discussed in the following section.

Triangulation of Data Sets

All sources of data, and the results of data analysis from each phase, were considered in totality to help judge the congruence of the overall case study developed for each teacher and to answer the original research questions. For example, general statements concerning a philosophy of education described in the initial interview were judged against what actually occurred in the classroom situation and similar philosophies described in the final interview. Points of reaffirmation or contradiction were noted and discussed in the case studies. The specific uses of each data type and the details of the final analysis of the data will be described in this section.

Data analysis and triangulation were used to answer four general questions:

1. What is the nature of Biology teachers' SMS?

2. What is the source of teachers' current SMSs and what factors have influenced its formation?

3. What is the relationship between teachers' SMSs and classroom practice?

4. Is there a testing effect when attempts are made to assess the content of teacher's SMS?
The first question addressed the nature of teachers' SMS of biology and the potential consistency of this structure among teachers. Two teachers were asked to describe their SMSs of biology at the beginning of the study, and all the teachers were asked to do so during the final interview. Following the descriptions of the SMSs listed, the teachers were asked whether they had ever thought about biology in this way before. The answer to this question, and the comparison of the answers across teachers, helped to establish whether the teachers in this study possessed teacher-recognized structures of biological knowledge to which they consciously referred.

In addition, teacher-generated SMSs were analyzed in several ways. Similarities and differences in SMSs in terms of content, organization and rationale were sought among the teachers' descriptions of the SMSs. Potential reasons behind the differences and similarities noted were sought in the individual case studies and were compared in order to generate hypotheses which would account for the noted patterns.

Finally, a global analysis of the teachers' SMSs was conducted to identify the key elements selected and the formats used. This analysis was used to permit subsequent comparisons between the results of the data collection procedure used in this study with those used in other research attempts of this nature (specifically, studies using card sort tasks). Any lack of similarity between the topics mentioned by the teachers in this study and those provided by teachers in other studies was considered evidence for a lack of validity of the instruments used in other studies and is a partial validation of the procedures used here.

The second question related to the potential sources of a teacher's SMS, and the possible factors which may have influenced its formation. Hypotheses concerning the sources of a teacher's SMS were developed and tested as an ongoing part of this investigation. Specific hypotheses concerning teaching load, the role of the textbook, involvement in curriculum work, and years of teaching experience were explored. The answers to many of these questions were sought in an analysis of classroom and interview transcripts. In several cases, questions specifically addressing these issues were added to the final interview. Comparisons within and across teachers were conducted to test the stated hypotheses.

If teachers stated that they had thought about the structure of their subject matter, specific accounts of when and why were analyzed. The identification of specific situations which encouraged the creation and translation of a SMS into classroom practice were sought. Comparisons among the structures drawn by the teachers of various levels of experience and expertise were also made in order to assess the possible influence of general teaching experience and educational background.
To understand the role of the textbook in the SMSs evidenced in classroom teaching, a SMS of the textbook was derived using the same procedures used to construct those generated from the classroom data (see Chapter IV, Textbook SMS: Methods). Comparisons between these two structures then acted as an independent assessment of the influence of the textbook. This information was used in addition to the information provided by the teacher on the perceived role of the text on classroom practice.

The third question addressed the relevance of a stated structure to classroom practice. Final construction of the SMSs inferred from classroom practice were completed following the procedures described in Chapter IV, Textbook SMS: Methods. To determine the influence of SMSs on classroom practice, a comparison was made between the SMSs described by the teachers and those derived through the analysis of classroom data. The degree of consistency between the structures acted as an objective measure of the influence of SMS on classroom instruction. High congruence was taken to indicate a direct relationship between a teacher's SMS and classroom practice. Limited congruence was taken to suggest a more complicated relationship, or no relationship at all. Factors contributing to any type of relationship were sought in both classroom and interview transcripts. These factors were compared across teachers in order to generate hypotheses about the potential importance and impact of SMS on classroom practice.

The final question addressed with the possibility of a testing effect created by asking teachers about the SMS of biology at the beginning of the study (herein called the "pretest"). Two possible types of testing effects may have influenced this study as a result of such a pretest. The first testing effect had to do with the creation of a SMS as a result of the pretest. The second had to do with the possible sensitization of the teacher to a SMS (whether or not one had previously existed) which may have increased the probability of transfer of the SMS to classroom practice.

The first testing effect concerns whether asking a teacher about his subject matter structure acted as an assessment or a treatment. To address this, each teacher was asked whether they had ever thought about their subject in terms of a SMS before. This question was asked to each teacher on the first administration of the questionnaire which may have occurred prior to or following the classroom observations. Answers to this question were then compared among the teachers.

Comparing teachers' pretest SMSs to classroom practice addressed the second type of testing effect: Does stating a SMS (whether one existed previously or not) sensitize one to a SMS and, hence, increase the probability of translation into classroom practice? Questions dealing with the perceived influence of filling out a SMS prior to the start of the investigation were included in the final interviews of the two pretested teachers.
Specifically, they were asked if the answer on the pretest had any influence on the final SMS described or on their subsequent teaching. In a more objective manner of assessment, the teachers' pretest SMSs were compared to the SMSs generated as a result of classroom observation. In addition, the classroom generated SMSs of teachers who were pretested were compared to teachers who were only posttested. A higher degree of congruence in the exhibited SMSs of teachers who were pretested was considered as evidence of the second possible form of testing effect. The answer to this second question has implications for the interpretation of the results concerning the potential translation of SMS into classroom practice.
CHAPTER IV
ANALYSIS OF DATA

Introduction

Certified biology teachers in four school districts in Oregon were contacted to assess their willingness to participate in this study. Though initial interest was expressed by teachers in all six high schools, five teachers in five different high schools ultimately agreed to participate. These teachers, all male, had a range of 7 to 26 years experience ($X=12.2$) in the teaching of high school biology. (Only one biology teacher in the six school districts contacted was female. Thus, this sample was representative of the gender of biology teachers in this area.) Pseudonyms will be used to assure the anonymity of the teachers.

Three of the teachers, Alex, Don and Ed, taught in a large school district which served a population of approximately 45,000. Alex and Ed taught in the two high schools located in a town of approximately 40,000. Don taught in a rural high school in a nearby town of approximately 5,000. The final two teachers, Ben and Carl, taught in rural school districts with town populations of approximately 5,000. All schools were located within a 40 mile radius of the researcher. Demographic details specific to each teacher will be discussed in the case studies provided in this chapter.

Only one of the schools contacted chose not to participate. This school was undergoing North Central Accreditation, involved in district-wide curriculum standardization, and using a newly adopted textbook in the biology classes. Due to the number of "unusual circumstances and time commitments, this district and its teachers declined the opportunity to participate in the study.

Though some of the schools used in this study were quite small, all of the schools had at least one other faculty member who had teaching responsibilities in biology or life science. In addition, none of the teachers selected taught biology exclusively, having either two or three class preparations during the semester of observation. Interestingly, all five teachers were using the same biology textbook (*Biology: The Living World*, Prentice Hall, 1989), and taught multiple sections of biology. The fact that the same textbook was used by all teachers acted as a "natural control." Specifically, variations in the order of curricular topics and manner of presentation could be attributed to decisions made by the teachers rather than as a function of the textbook.

All teachers participated in all aspects of the study. Initial interviews were conducted within the two weeks prior to the start of the school year. These interviews lasted 45-90
minutes. Lists of subject matter and education courses taken at the college level were provided by all teachers within the first four weeks of the study. In addition, two teachers, Ben and Don, were randomly selected to complete the SMS task as a pretest. The SMSs were also collected within the first four weeks of the study.

Though it was initially intended that observations would take place once each week, exam schedules, vacations, testing, and teacher absence often prevented the realization of this schedule. Three of the teachers, Alex, Ben and Ed, were observed 15 times during the semester, Don was observed 14 times, and Carl was observed 10 times. Both Carl and Don had asked that observations not be made the first two weeks of school while they established classroom routines and rapport. Subsequent observations of Carl were interrupted by teacher illness, absence due to coaching, and a "floating" schedule in which Carl saw each class only six of every seven days. Despite these interruptions, Carl's ten observations provided the same percentage of observations to teaching days as the observation schedules of the other teachers (X=17.6% observations/teaching days, range=16.9-18.2%). Carl had 17.2% observations/teaching days. Details of classroom observations will be discussed in the specific case studies.

Overall, a total of 69 classroom observations were conducted, generating over 1100 pages of single spaced field notes. Over 250 samples of classroom materials were collected in addition to copies of the semester's lesson plans from each teacher. Copies of the textbook and lab book used by the teachers were obtained for analysis.

Final interviews lasted from one to three hours and occurred within six weeks of the last classroom observation for four of the five teachers. In the case of Carl, who was seriously hurt in an accident following the observation portion of the study, the final interview could not be conducted until late in the Spring semester. The details of this situation will be discussed in his case study.

The data described were used to generate a case study for each of the five teachers. Each case study will be divided into six sections. The titles and contents of these sections follow. In addition, the primary data sources used for each of the sections are discussed.

The first section provides an Academic and Professional Profile for each teacher. This information, gathered primarily from the initial interview, paints a general picture of the teacher and his perceptions of his career, academic training, community, and school situation. This section includes the details of data collection for each teacher.

The second section, Course Specific Perceptions and Concerns, outlines the intended biology course format as described by the teacher at the beginning of the year, and provides an accompanying rationale for the selection of such a format. In addition, information concerning teacher perceptions and concerns about the specific classroom
situation as it might affect the implementation of these plans is discussed and supported. These categories of perceptions were derived from all three phases of the study: the initial interview, anecdotal data collected during the semester of observation, and the final interview. Inconsistencies in the teachers' philosophies, concerns, characterizations, and actions are noted when appropriate.

The third section presents a Classroom Profile for each teacher. This description, created by the researcher, portrays a generalized class period in the observed classroom. Descriptive details generated from quantitative analyses of the classroom observation data are used to support the more qualitative description provided.

The fourth section describes and provides evidence for the teacher's Classroom Subject Matter Structure as inferred from the classroom observations and materials. SMSs were created to provide visual representations of the subject matter connections and themes which occurred through the mediums of classroom discourse and materials. In addition, evidence related to the relationship of the observed SMS to the SMS produced from the text are provided.

Section five, detailing the SMSs produced by each teacher, is entitled: Self-Described Subject Matter Structure. This section presents the SMSs developed by the teachers following the classroom observations, as well as for the two teachers who completed this task as part of the initial interview. Comments explaining the meaning, rationale, and impact of these SMSs are taken from the final interview.

Finally, a Summary section is provided for each teacher. In addition to a general summary of the case study, this section is used to answer the original questions of this investigation on an individual teacher basis. In particular, comparisons are made between the researcher generated and teacher described SMSs. Conclusions concerning the relationship of a teacher's SMSs to his classroom practice is discussed as well as intervening factors which may enhance or prevent such a transfer when appropriate.

Chapter V looks at the patterns of answers to these questions as they exist across the case studies and considers the implications of the findings for preservice and inservice science teacher education.

**Textbook Subject Matter Structure**

As briefly discussed in the Classroom Observation section of Chapter III, an extensive analysis of the data obtained in Phase II (i.e., classroom observations and materials) was conducted for each teacher in order to extract any potential indicators of the nature of a teacher's subject matter structure (SMS). For the purposes of this investigation, two forms
of evidence will be used as indicators of the nature of a teacher's SMS: connections and themes. The definitions of the terms 'connection' and 'theme' will be provided in the following Methods section. The connections identified for each teacher were used to construct a SMS, or graphical representation of the organization of a teacher's knowledge of biology. In addition to the generation of a SMS for each teacher, a SMS was derived for the textbook *Biology: The Living World* (Prentice Hall, 1989).

The methodology for analyzing the textbook and Phase II data to produce the SMSs will be discussed in the next section of this paper. To clarify the procedures followed and the final results produced, the specific methodological practices used will be discussed and referenced to the SMS produced for the textbook. Similar methodological practices were followed for the derivation of all SMSs reported in this investigation. In some cases, the procedures reported for the analysis of the textbook were varied when applied to the analysis of data collected during Phase II. Such deviations will be discussed in the following section when and where they exist.

The Methods portion will be followed by a description of the SMS produced. In the case studies which follow, the description and discussion of each teacher's SMS appear as a narrative under the title: Classroom Subject Matter Structure. A description of the methods utilized will not appear in the individual case studies. The reader is reminded to refer to the Methods section, which follows, to reconcile questions concerning data analysis for the purpose of constructing a teacher's SMS as inferred from classroom practice.

**Methods of Analysis and Construction of a Subject Matter Structure**

For the purposes of this study, the first step in the derivation of a SMS was to define the chapters or units covered during the semester of observation. In the case of the text, any chapter used by one or more teachers during the course of the study was identified. This resulted in the identification of Chapters 1-8 and Chapters 36-39 in the Prentice Hall text. For individual teachers, "units of instruction" were defined by specific starting and stopping points, such as the introduction of new content or a test. In many cases, these units corresponded to the chapters in the text. For the sake of consistency, a "unit" will refer to a unit of instruction, be it a chapter of the text or a definable segment of a teacher's curriculum.

All units were identified by name and numbered as to the sequence of coverage during the semester. In the case of the textbook, chapter numbers and names provided by the authors were used (i.e., "3. Basic Chemistry" means that Basic Chemistry is the name of the third chapter in the text). The notation used for the text units can be found in Appendix
When a teacher used the basic content found in a chapter of the text, a similar title was used to describe that teacher's unit of instruction. The sequence of coverage by the teacher was also indicated, which may or may not correspond to the chapter number found in the text. When a teacher's unit did not correspond (in terms of content) with a text chapter, it was given a unique descriptive title to indicate this difference.

Once units were identified, the contents of each unit were determined and listed under the unit title (Appendix E). In the case of the text, unit contents were identified through a survey of the text. An analysis of units not covered during the first semester was not conducted. In the case of classroom observations, unit contents were identified through analysis of teachers' lesson plans, anecdotal conversations, and from the content observed during classroom observations.

Graphical representations of units (initial stages of the construction of a SMS) were achieved by using a box to indicate all of the content covered in each unit (Figure 1 or Figure 15 of Appendix E). Changes in the shapes of the boxes or their orientation indicates no special meaning, but were included to enhance the clarity of the representation. Note that the sequence number and title of each unit are included in each box.

The reader is reminded that a primary focus of this investigation was to characterize the nature of a teacher's SMS as it could be inferred from classroom practice. A limitation of this study was that only the first semester of a year long class was observed. Since there is a strong probability that teachers think about biology as a unit uninterrupted by a semester break, a method was needed to indicate content which may be taught during the second semester. For the purpose of constructing the textbook SMS, unit titles, as identified by the textbook authors, were used. Thus, the term "Plants" referred to the textbook unit "Plants" and included all the content covered in Chapters 16-20 of the text. The chapters of the text which constitute these units are listed in Appendix E. Similar titles were used for the construction of SMSs from classroom data.

Second semester units were also graphically represented in the SMS by using boxes. The textbook units were further identified by the chapter numbers included under each broad title (since this sequence was predetermined by the textbook authors). Second semester units for teachers were not identified by number since the actual sequence of second semester topics was not observed.

The second step in the generation of a SMS was to identify potential indicators of the nature of the text's (or a teacher's) SMS. The textbook and the data from Phase II were read in order to find evidence of direct or implied "connections" within the content. Connections, as defined for this study, existed in two forms: content connections or themes.
The first type of connection occurred when a teacher specifically or inferentially related one content topic to another. Such connections were required to include more than just the use of previously defined vocabulary. For a portion of the text or a transcript to be considered a connection, content outside the specific unit of instruction was introduced in such a way as to build on previous content (a back-reaching reference) or allude to upcoming content in a way which states a relationship between current and upcoming content (a forward-reaching reference). For example, simply using the term "enzymes" in a chapter on digestion (i.e., "enzymes are found in the stomach") would not be sufficient to constitute a connection. However, a reminder that "enzymes can only operate on a single substrate so that there must be a wide variety of enzymes in the digestive tract," or, "enzymes can be denatured by changes in pH such as those that exist in the various portions of the digestive tract" would be considered examples of back-reaching references. Examples of back- and forward-reaching connections can be found in the second portion of Appendix E.

In addition to back- and forward-reaching references, examples used to illustrate current concepts which also introduced or reinforced content from another portion of the curriculum was considered to be a connection. For instance, in discussing Mendel and his selection of pea plants to study the principles of inheritance, the text included information concerning the anatomical structure of the pea flower and the reasons why the probability of cross fertilization without external influences was unlikely. Such an instance was considered a connection by use of an example which taught content.

The above instances illustrate examples of the first type of connections: connections between content topics. The intermediate step to producing a graphical representation of these connections involved recording the source of the connection (the unit of instruction in which it was introduced), the referent of the connection (the unit of instruction referred to, as determined through the analysis of the content of each unit), and the basic content of the reference (paraphrased from the original source). For instance, the examples of connections provided in the preceding paragraphs may have been recorded in the following manner: Human Biology -> Cell Energy: Enzymes can only work on one substrate, thus many types of enzymes are needed in the digestive tract; Genetics -> Plants: The anatomical structure of the pea flower was important in its selection for early studies of inherited characteristics. Note that the type of connection (back- or forward-reaching) can be determined by referring to the sequence of topics covered. Examples of connections made by the authors of the textbook can be seen in Appendix E.

The second type of connection involved the use of themes while teaching the content. Themes are defined as rationales, concepts or goals which provide an underlying
framework for what and how something is taught. Evidence for the presence of themes occur when actions over non-consecutive days or portions of text can be tied together by a rationale, concept or goal. For instance, in the analysis of the textbook, evidence for two themes emerged: History of Science (HofS), and Science-Technology-Society Interactions (STS). The HofS theme was evidenced by the inclusion of the historical development of a scientific concept. Such passages often included the scientists involved and the theories which they influenced. STS interactions included situations in which science was applied to develop technological solutions to a problem, where technology furthered the development of science, or where society affected or was affected by either science or technology. The above definitions will be used in all SMSs presented in this report.

Additional themes introduced by specific teachers will be defined in the case study in which they appear. Chapters which included content on the HofS or STS issues are noted in Figure 1 and in Figure 15 of Appendix E. The entry in Appendix E notes the presence of the theme, the unit in which it occurred, and the paraphrasing of the content presented.

As connections were identified within the sequence of instruction they were given a number. This number appears in front of the connection description (Appendix E) and is used to identify the sequence and specific meaning of the connection. In the case of Phase II data, classroom observations and materials were analyzed separately. To distinguish these data sources, the Appendix listing (such as in Appendix G) identifies the source of the connection. In addition, the sequence number was used in the construction of the SMSs (Figure 15). Circled numbers represent data taken from the text (in Appendix E, Figure 15) or the classroom observations (Appendices G-K, Figures 16-20). Numbers in squares represent connections identified through an analysis of the materials (Figures 16-20). The appendix for each SMS also identifies the specific source of connections identified in materials (e.g., test, worksheet, lab, etc.).

Once all units of instruction and connections were identified, this information was used to construct the final SMS. (A rough draft version of this SMS was constructed prior to conducting the final interviews.) Units and connections were drawn and rearranged until the greatest clarity of representation was found. Arrows were used to indicate references which were back- or forward-reaching. Units which had both back- and forward-reaching references between them were overlapped to show this relationship (i.e., Basic Chemistry and Cell Chemistry in Figure 1). Concentric boxes represent content which systematically builds upon itself by pervasively using back-reaching references between two or more units (i.e., the ecology chapters). Themes were listed in individual units (i.e., STS in Studying Life in Figure 1) unless extremely pervasive. In such cases (i.e., Figure 15, Evolution), themes were represented as strands through the content. To aid the reader, SMSs without
Figure 1. Textbook Subject Matter Structure.
references have been included in the case studies (Figure 1). The derivation and specific meanings of the connections can be found by locating the number on each connection and referring to its corresponding description (Figure 15 and Appendix E).

Once the SMSs were completed, a second reading of the set of transcripts for each teacher was conducted in order to verify the patterns derived in the SMSs. Narratives were developed which describe the meaning of the SMSs. The narratives provide a description of the SMS and the major types of connections found. Additionally, factors which may influence the interpretation of the SMS (such as a teacher's intentions and the accuracy of content presentation) will be discussed. The narrative for the textbook SMS will follow. The narratives for the case study SMSs are included in the section entitled: Classroom Subject Matter Structures. Methods of analyzing the data and the formation of the SMS will not be discussed except in cases of general method deviation.

Once again, the reader is reminded that a primary focus of this investigation was to characterize the nature of a teacher's SMS as it could be inferred from classroom practice. This focus has been met through the generation of the presented SMSs. Each SMS graphically represents a wealth of information which has been distilled into a final SMS and description. A comparison of the length of the section which describes the final SMS to other sections of the case study is no indication of the relative value of the sections to the purposes of this investigation.

Description of Textbook Subject Matter Structure

The reader is reminded that the creation of the SMS from the textbook included an analysis of only the chapters covered by one or more of the teachers in the study. Since the SMSs of the teachers were formed solely on the data collected during the first semester of the school year, a similar level of analysis of the textbook was selected. It was hoped that such an analysis would facilitate comparisons made between the textbook and individual teacher's SMSs. Thus, evidence of connections were sought in Chapters 1-8 and 36-39 of the text. Unit titles were included to provide a referent for connections made in the units analyzed. The resulting SMS in no way is meant to reflect the SMS of the entire book. For instance, had the entire book been analyzed, it is possible that evidence of connections would be found to or from the Classification chapter. However, no such connections were found in the analysis which was conducted.

An initial inspection of the SMS created from the textbook revealed several general patterns. First, the units of instruction introduced early in the text (Chapters 1-8) were developed in a fairly independent fashion. References, when they occur within Chapters
1-8, are generally limited to the units within close sequential proximity. However, despite the somewhat limited interactions, the references which are included contribute to a general sense of continuity. In a majority of the cases, references were forward-reaching, often implying that the current content will be used in future units and alluding to the nature of such uses.

The Chemistry chapters (Basic and Cell) and the Cell Biology and Reproduction chapters were notable exceptions to the above generalization. The integration of content from these two pairs of units, though they did not follow each other sequentially, was significant, with the content from the first forming a strong foundation for the content presented in the second. In the case of Cell Biology and Reproduction, the content concerning cell structures and functions were strongly relied upon in the second chapter. In the chemistry chapters, the concepts of energy transfer and nutrient cycling were introduced and later reinforced or more thoroughly discussed in the Ecology chapters, establishing a fairly strong link between the chemical and environmental content in the text.

A second major pattern involved the content introduced in Chapters 36-39 (Ecology). Though this unit established by the textbook was composed of four separate chapters, the integration and dependence of later content on earlier content was clearly evident. Basic concepts were introduced in early chapters (particularly biotic and abiotic factors and interdependence within ecosystems) and systematically built upon, adding greater levels of complexity to the content. Notable throughout all chapters was a strong reference to Evolution, especially in the form of natural selection as it may lead to adaptation or extinction as a result of environmental change.

A third pattern involved the use of the major phyla of organisms and issues specifically related to Human Biology as examples in the presentation of other content. Specifically, many units used interesting examples, particularly animal behavior, to illustrate a concept. Such examples seemed to be provided to capture the interest of the students. In other cases, (i.e., Human Biology and Plants), examples seemed to be provided to make the content relevant in a second context. It is unclear if these early references were reinforced in the future units (which were not analyzed since they were not taught until second semester). It is interesting to note that a large proportion of the references to organisms involved Plants rather than Animals or Human Biology. It is impossible to determine if this pattern was intentional (for instance, the authors may have felt that plant examples would be less likely to be generated by teachers or students and thus, more important to provide), or if this reflected a content specialty on the part of the authors.

Finally, evidence for two themes was established: History of Science (HofS) and Science-Technology-Society Interactions (STS). HofS examples were often provided to
illustrate the revisions or refutations of a theory, especially as a result of changes in technology or through the "appropriate" use of scientific methods. In other cases, HofS examples introduced prominent scientists of the past and showed how their work provided a framework for current scientific understanding.

STS interactions fell into three major areas. The first provided examples of how technology, especially the various forms of the microscope, have improved our ability to make observations and advance scientific knowledge. The second showed how observations made by biologists were used to improve our quality of life by advancing technology. The final type provided examples of current issues facing society, with a focus on environmental issues. Such issues were presented with the content necessary to understand the situation and often identified the multitude of consequences which must be considered before changes could be made (environmental, economic, quality of life, etc.).
Alex was suggested for inclusion in the study by a local teacher. Upon being contacted in the spring about the purpose and intent of the study, Alex enthusiastically agreed to participate.

Alex is a tall man of imposing build, with a business like manner and good sense of humor. Describing himself as "a bit of a rebel," Alex seemed as comfortable with expressing his ideas and opinions about teaching, of which there were many, as he was in admitting that his ideas did not necessarily meet with the general approval of his department. The "uniqueness" of his point of view sometimes concerned him, but he felt strongly about the philosophical stance which he had developed over his 26 years of teaching and was unwilling to compromise his beliefs without a sound rationale. During the interviews, Alex was open, candid and willing to discuss a wide range of topics. The initial interview lasted approximately two hours.

Alex began his undergraduate training at a state university in the West. After taking coursework in general science for two years, Alex still lacked direction concerning a career. Two factors influenced his selection of a teaching career:

Two things happened. One, I had a good biology teacher that made the course interesting. And two, I happened to take a counseling test, of all things. And it had teaching down as the thing for me. How they would determine that from a stupid test was beyond me! But I thought, "What the heck, I'll try that."

Alex received a BA three years later with a major in Science Education and a minor in Social Science. After teaching for several years, Alex returned to the same institution to complete a MA in Science Education. In addition to this formal coursework, Alex took several additional courses and workshops at other institutions throughout his teaching career.

Alex's science content background is composed of a fairly even distribution of coursework in four major areas: botany, zoology, ecology/natural history, and geology. In addition to these general areas of "concentration," Alex also had one or two classes in microbiology, oceanography, genetics, and physiology, providing him with a diverse background in the biological sciences. When asked to describe his own content background, Alex admitted:
Pretty broad.... I sort of liked everything. I was into animals for a while, and then I sort of phased over to plants. But my overriding interest has been ecology, and that has really been infused in my courses.

Alex felt that this broad background was generally appropriate for teaching, and allowed him to tie together coursework with process oriented themes and interests, as the following statement illustrates:

I feel that the broad background that I have is just right for what I am doing now.... I think with a broad background you know where to find what you need.... I just like the general aspects of it, I really do. And I like the labs. And I like the investigation, the process.

Though Alex seemed to feel that this broad biology background was appropriate for his current teaching needs, he did not necessarily feel that the coursework at the university provided a perfect match with the content knowledge needed in the schools. Alex described his struggle to turn the theoretical understandings gained at the university into the practical knowledge needed for teaching in the following manner:

I got into student teaching, and I felt like I was a dummy. I think a lot of student teachers have that feeling. I came out of five years of college and the first thing I had to do was teach a unit on protozoa. I knew the textbook stuff. I spent many, many hours learning everything and found it fascinating. But there was a lot of pressure there. I found that my background lacked the practical end of biology. And some of the things that you do at college are completely inappropriate for the high school level. There is a lot of adjustment in that first year or two. Overall though, I felt, content-wise, that I was in good shape.

During the final interview, Alex was asked whether more coursework in the sciences, or a greater concentration in a single area, would have prevented some of these early feelings of inadequacy in terms of practical preparation. Alex observed:

It depends upon the individual. Sometimes I find an inverse relationship [in teachers] between the amount of academic knowledge and the ability [to teach] from that. That squeaks of being a generalization, but the best people I have known have been real generalists. I think it is more important to have an interest in teaching, and an interest in conveying the stuff. I think that is more important than your academic background, by far.

Alex's major in Science Education resulted in approximately half of his education courses being taught generically through a School of Education, and half being taught in a content specific manner through a Science Education Department. Concerning the value of early classes in the School of Education, Alex stated:

I'm not saying that they were worthless, but basically, I think it was a terrible way to get anybody excited about teaching. The content was 10-20 years out of date. [But, my dissatisfaction was] partly a reflection of my own personality... I want to be able to use the stuff, not just get a bunch of theories.
Alex's memories of his content specific courses were not quite as negative. In particular, he appreciated opportunities where students could work on "very practical exercises," such as "writing units." He also specifically commented on what he felt was an overall philosophy and commitment to process-oriented teaching, an orientation which provided him with an introduction to the Biological Science Curriculum Study (BSCS) materials and approach. Alex felt that these philosophies and orientations matched his own, though it may be that the university was the original source of the orientation which Alex later adopted.

Alex felt that the most significant experience of his college career was student teaching. He describes this as a "wonderful situation" in which his supervising teacher was key. Alex elaborated:

I had an outstanding supervisor when I was a student teacher, and I still feel that that is a real key in anybody's development. Unfortunately, in the educational game, it is the roll of the dice as to who you are going to get...I have often wondered, what would have happened if I had gotten the other guy? He might have just killed my entire interest [in teaching].

In particular, Alex credited his supervising teacher with reinforcing many of the ideas with which he had become familiar at the university (such as a process orientation), giving him the encouragement to try new ideas in the classroom, and being receptive to his ideas. When asked specifically about what he had learned from his supervising teacher, Alex replied:

She is the one who taught me that you don't just go through the lab book and use the lab. You modify it and tailor it to your kids. I still do that...She was an outstanding biology teacher...excellent, excellent teacher....I got hooked into her just at the time BSCS was coming out. She really thought that was all neat and was just going crazy with all the labs and things. Some of that was kind of new to her, to do that much lab work. But I really picked up from her the idea of pursuing ideas and questions and open ended things for a period of time, not worried about a stopping point....My philosophy fell more into, whether I was born with it or what I don't know, but I felt more comfortable with what she did....Again, I think I was in a very unique position. I think I was pushed ahead, that sounds conceited, but ahead of my time really, for a long time. And there are things that I don't do well. But in terms of process and critical thinking and all that, God, I was buying dunking birds years ago!

Consequently, of greatest importance to Alex's development into a teacher seemed to be the ideas of early reinforcement of his own philosophy of teaching science, and the positive experiences that he had while student teaching. When Alex later took his first teaching job in a western state, he described himself as being "basically on my own in a little po-dunk place. But I had enough going for me [philosophically which was reinforced] from my student teaching that it carried me through."
At the time of the interview, Alex had been teaching 26 years. His current teaching position, in which he had been employed for the last 11 years, was the fourth high school in which Alex taught. During the early portion of Alex's career, he had the opportunity to work, once again, with his supervising teacher from student teaching. Alex described this job as "extremely stimulating." This job occurred during a period of rapid reform in education in general and science education in particular. Such reforms created a diversity of programs in the state and a "honeymoon experience" for Alex. Alex described this phase of his career as a time of experimentation for him and the rest of his department. With similar philosophies, the department reinforced each other's ideas and facilitated personal growth. This experience, in conjunction with his student teaching experience, are the two most cited and fondly remembered periods of time in Alex's professional development.

During Alex's career he has taught courses in biology, botany, zoology, environmental studies, natural science, greenhouse gardening (in what Alex described as his "plant phase"), ninth grade physical science, and oceanography. Alex taught at least one section of biology in each of his 26 years of teaching. During the year of the investigation, Alex taught two sections of Biology, two sections of ninth grade Physical Science, and two sections of Natural Science/Oceanography, for a total of three preparations per semester. The final courses listed were offered as semester long science electives to replace the traditional biology sequence.

When asked about his favorite course to teach, Alex easily replied: "Biology, always. I have a rapport with biology." As one of six science teachers in the department and one of three with a background in biology, Alex described the assignment of biology courses as being a "dog fight almost every year." Making this statement, Alex quickly makes a qualification: "Basically we [the department] get along fine....I think everybody basically respects everybody else, and we have some good people. You couldn't ask for much more than that."

Being the senior department member, Alex described seeing many changes, both in the teaching of biology and in the content which was considered important. On occasion, these changes in emphasis created friction within the department. Of particular concern for Alex were changes which potentially affected student interest and motivation. Alex reflected:

"I will say that biology has changed in the last few years. It is starting to change or accelerate. I have concerns about the [direction of the] content area....I often wonder if I would have gotten into biology or enjoyed biology as much in college if they put the stress on the molecular biology [DNA/RNA]. Back then, it was more the traditional plants, animals and"
other things that I think these kids can relate to more. I think you [by teaching molecular biology] can scare them out of the interest [in biology].

Alex taught in a community with a population of approximately 40,000. Alex's school served approximately 1050 students in grades 9-12 and was one of two high schools in the community, one of three in the district. Though the community had not always been financially stable, recent increases in a recreation-based economy had improved the town's financial situation and had increased the size of the student population. When asked about the effects of such changes, Alex observed:

I think [the town] is suffering from a lack of direction right now. If you go out and talk to 40 parents, you get 40 different opinions to what we should be doing with their children.

Alex felt that this lack of direction transferred to the students. In particular, he had grave reservations concerning students' goals for the future, especially when it came to college. Alex explained:

Our percentage of kids that go on to college is 40%. [But] I really don't feel the college pressure here for kids, or the motivation. Here I find more of them are really kind of confused about it. They are supposed to go to college, but don't know what that means....It's amazing how many sophomores really think they want to go to college, when it's more their parents that want them to go to college. They [the students] really haven't thought about it.

Paramount in Alex's concerns are the students' poor study skills, the lack of time spent on school work, and the low priority placed on school (as opposed to work, from which students return to school "tired and unprepared"). Alex felt that these factors led to a general lack of preparation for college, and that this was reflected in his students' success in "academic courses like Biology." Alex explained that for many of his students Biology would be the course where "they start finding out whether they really do want to develop that academic toughness needed for college." For example, Alex illustrated the low priority placed on school work when he talked about his lack of success with homework:

Homework? Almost half don't, and won't, do it. That's extremely frustrating, and I don't think our school takes that problem seriously.... If you are realistic, you anticipate that you will have a whole bunch of unprepared kids, and so you try and design your lesson to that end.

In light of the level of student interest and motivation, Alex was asked how he taught science, the techniques he felt worked best for this particular student population, and what challenges this presented. He replied:

I think you have to be like the quarterback, I think you have to mix your plays. I find that one weakness in our students is inquiry. It is very difficult for them. That is one of my biggest challenges. Some kids really don't know where I am coming from: why it is important that you hypothesize, why I push them to think things through. You ask our average kid what a hypothesis is for and they can answer that. But if you ask them why is it
used, one in a 100 might have the slightest idea. I tend to pursue those kinds of things.... Our kids have not had as much of that open-ended kind of thing. And that goes back to what we are trying to do with these kids: teach them to be self learners.

Alex's allusion to the goal of developing students who are self learners is central to understanding all of his goals for science students. Within this overriding goal is the importance of having students well versed in process and inquiry skills. Alex described his goals for students and how they relate to the larger goal of being a self-learner as follows:

Number one: process. I hope they [students] feel more comfortable with processes, and not intimidated when somebody raises a question in which they don't know the answer right off. Because they are going to get those kinds of questions for the rest of their life. That would probably be number one. And then basic skills, like using the microscope, having the motivation to complete work, to do the best on it, that kind of thing.

Alex continued as he described how these goals could be translated into classroom practice and how students react to such teaching techniques:

You'll find, if you observe me, that more and more I am giving them, hopefully, not just lectures but background information to try and help them clarify their own thinking. You see a lot of depressed kids after a while. I am not one who thinks that a course should be fun all the time. I think it should be interesting. I think it should be exciting periodically. I think the teacher should be enthusiastic. But my personal feeling is that we do kids a disservice if we set them up with the idea that "this is going to be fun." It is not going to be OMSI [Oregon Museum of Science and Industry] everyday. I think kids have to take responsibility and develop a seriousness to make it....

Students should have a somewhat realistic appraisal of their own abilities and interests.....If they are going onto college I want them to know schools. I want them to know careers. I want them to be responsible too. The non-college type kid, I want them to know interests, opportunities [that are available to them]. I don't want them to stop. And ideally, I want them to be life-long learners.... If I were to pick one goal for any student graduating from school it is that they would be self-starters, self-learners, because then they can kick into gear almost anything they want to.

When asked about specific goals for biology students, Alex repeated many of the goals that he has for science students in general. But, in addition to the importance of process skills to aid students in critical thinking and decision making, Alex included the specific application of these skills to decisions regarding the interaction of science, technology and society. Alex described his specific goals for biology students as follows:

My big emphasis would be on process. I want them to be able to do things in science. And I want them to be able to understand our society, and how science affects our society, and vice-versa. I really believe that. I think our society is so driven by science and science has had such a big impact, both negative and positive, that I think kids need to understand that....
I would like these kids to come through with some interest in biology. I am very sensitive to that...I would like them to come out, ideally, wanting to pursue more information. That's a tough one, too. But I don't want my course to be the end point. I want them to go on and want to take oceanography, to take other courses. I want them to be involved with issues. I want them to know what is going on in society, to be able to relate the course to what is going on out there [in the world], and not see biology as something that this small group of nerds does. This [biology] is something that we all need to be involved with. How successful I am in that, I don't know.

Alex's concern for success was greater than what he felt he could achieve within the boundaries of his classroom. He was concerned with how the department and the school dealt with such issues. Since his own development as a teacher was affected in such a positive manner by the reinforcement of certain teaching techniques, it is possible that he felt that the consistency of such approaches throughout the school would be equally important and effective. Unfortunately, Alex did not feel that his opinions were widely shared among members of the department. Though the department tried to "teach about the same things and end the semester about the same time," they differed on classroom implementation of vaguely agreed upon goals:

I think part of the problem in our department is that everybody says process is important, and everybody says the kids should be involved, but when you get down to the practice I think sometimes we are a ways apart in the application of those ideas. I am sort of on one end because I feel you should immerse kids [in a concept] and give them a chance to deal with an idea several ways. I want them to pick up something, but they don't have to remember everything. I don't think as a science staff we have quite figured out how to deal with our differences.

Alex was observed 15 times over the course of the semester of investigation (18.7% of the totals days in which Alex taught). In addition to classroom observations, Alex's classroom materials were collected for analysis. These materials included worksheets, study guides, laboratory investigations and tests. The final interview with Alex was conducted six weeks after his final classroom observation and lasted approximately three hours.

Course Specific Perceptions and Concerns

At the time the classroom observations had begun, Alex was embroiled in a lengthy and frustrating discussion with his department. The biology teachers in the department had been involved in a district-wide meeting concerning the scope, sequence, and length of biology units which would be taught during the upcoming year. (Don and Ed, who also taught in this district but at different high schools, were also involved in these meetings.)
Neither Alex nor the other members of the department agreed with the proposed sequence of topics which was recommended (Appendix F), but realized that, as a department, similar topics needed to be taught during the first semester to facilitate students who may transfer between sections. Thus, the department had decided to design its own sequence.

The construction of a sequence which could be agreed upon by all members of the department turned out to be an impossible task. As Alex explained during the final interview: "Sometimes you can coordinate things between two people, but when you start to throw in a third or a fourth, it just gets impossible to get any sort of agreement." The department's concern with the district-proposed sequence had to do with the placement of ecology at the beginning of the school year. Alex explained: "Some of the people in our department feel very uncomfortable in straying from the textbook or the order of the textbook," which placed ecology at the end of the year. Alex felt strongly about maintaining a sequence similar to that which he had taught in the past. His rationale for his choice was as follows:

Essentially, if I go with the district outline, I am going to be changing my whole sequence. The major change they want is to teach ecology at the first of the year. Most of them have not done that before; I have. My course is developed in such a way that there are certain major ideas, like photosynthesis. I feel I hit them several times during the year in different contexts, and hopefully [this will] convey these ideas successfully. If you mix the whole thing up, it's almost like being a new teacher again. You have to re-think carefully about how you are articulating these ideas throughout the year.

With the issue of content sequencing on his mind, Alex volunteered his preference for content order and structure one day after class. Alex saw the content of biology as "naturally falling together into a series of blocks." The blocks of content which Alex envisioned can be seen in Figure 2. According to Alex, "each block needs to be taught in a set sequence to maintain the integrity of the descriptive material, but the blocks themselves can be mixed together into almost any sequence." Alex elaborated on this thought during the final interview:

I tried a whole bunch of them [sequences], and what it boils down to are that there are advantages any way you try it. I don't see just one system....I'm sure that one thing that's going to happen if I do ecology early is that I am going to find myself saying for the rest of the year: "do you remember?" and then link that particular environmental idea, population or whatever, and keep building that into the rest of the course. I think it's up to the teacher to do that.

Once Alex determined his sequence of topics, he described working at building upon content previously taught and reinforcing those concepts through repetition. For Alex, this building and relating process is the responsibility of the teacher, though the quality of this "depends on the teacher's ability to relate back and forth." Alex explained:
Methods and Process
Microscopes and Measurement

Cell - Anatomy
- Chemistry
- Energy

Mitosis

Classification
Protists

Meiosis
DNA
Genetics
Evolution

Animals
Plants

Ecology

Figure 2. Alex's Volunteered Subject Matter Structure.
I would hope that they [the students] would... remember some of the basic descriptive material, like the cell and so on, so that we can keep building on that. I will never assume for a moment that they remember all that stuff. I'm trying to organize a sequence in my course where they have the opportunity to bring up these things more than once. Really, I think that has to be done, but it's more time consuming. You don't cover as much. One of my goals would be, okay, so I cover less but I hope it is more of a quality experience for them....I think for our kids, at this level, I think rather than just try and teach them everything in the world, I would rather that they be able to use some of this information.

For Alex, the sequence of the units was not as important as building the connections within the sequence that was chosen and maintaining a process orientation. (Though is should be noted that Alex preferred to use the sequence to which he had become accustomed since he had already established these connections to his satisfaction.) Alex continued:

I don't think it [sequence] is as critical, frankly, if you have more [emphasis] in process. Because if your emphasis is on observing, hypothesis [generation], and experimentation, that builds no matter what the unit is. It builds. So who cares when you do it? In the descriptive stuff, you have got to be a little more careful how you work that in and how you integrate it. Sometimes if I’m trying a new sequence, maybe I have to take 20 minutes to build a background.

Despite Alex's personal reluctance to change the sequence of biology from the one which he had taught in the past, he recognized that the final sequence selected was of greater value to the teacher than the student:

As a teacher, the sequence that you choose helps you decide the types of connections that you want to make and where to do them. I'm sure the students don't know the difference as long as you're relating the topics. But the other members of the department, they think that the textbook has been set up according to some great learning theory. All you have to do is look at it and you will see that that's not the case. But they are afraid to leave [the sequence of] the book because they think it will hurt student learning. What are they going to do when the textbook is five inches thick and looks even more like an encyclopedia than it does now? They will probably still try and teach all of the book, in order. But they'll never be able to do that!

Alex's preferred sequence of biology topics (as listed on the classroom board in preparation for a department meeting) were as follows: process, microscopes, cells, energy relationships, ecology, classification, animals, plants, genetics, and evolution. Alex enjoyed starting the year with the process unit because he felt that he was "setting the stage for the future. I am going to pick up on it [process] again." The department agreed that a general introductory unit of this nature was appropriate.

By the time the introductory units were completed, the department had agreed to teach the topics related to the cell next, which was in keeping with Alex's preferred
sequence. The topics which would be taught during the remainder of the first semester included: microscope skills, cell biology, basic and organic chemistry, cellular energy, and cell division. In addition to these topics, Alex digressed from the standard curriculum in two instances where he included a short unit on science careers and a debate on nuclear power which was based on a ballot measure that was about to be put before the voters.

Alex's stated rationale for including the aforementioned digressions was to "help break up" the cellular material in order to maintain student interest. As Alex noted: "The biggest feedback I get is that the semester of cell study in not that interesting to a lot of kids." Potential solutions which Alex mentioned included teaching cell study in a different way, breaking the unit up with other topics, or moving the unit to the middle of the year. Following similar logic and reinforcing his idea of repetition and building on ideas, Alex considered splitting up mitosis and meiosis - teaching mitosis with cell biology and meiosis later in the year with genetics. Though this sequence was not ultimately used, Alex felt that it would prevent some of the cell biology "overkill" and would introduce a natural opportunity to teach and review cell division for a second time.

Of the topics during the first semester, Alex described liking the process and photosynthesis units the best. His preferences for the process unit have been previously discussed. As for photosynthesis, Alex explained: "Photosynthesis work I always enjoy because, again, there is a lot of process emphasis and it calls for creativity on their part...And, maybe I consider it more of a challenge to teach, too" (as opposed to the cell unit which he enjoyed but was a bit bored with).

Alex's greatest reservation and source of conversation concerning the scope of the biology course had to do with the teaching of DNA and protein synthesis. As stated earlier in this case study, Alex wondered if he might have enjoyed biology as much if the content had involved as much biochemistry. His own lack of interest in this aspect of biology and a sensitivity to an apparent lack of student interest convinced him to cut this topic from the biology course. His rationale for this cut was explained as follows:

I know that what they put on paper [the district scope and sequence] is far more than we can ever do. So something has got to go....With biology I do keep in mind, a little bit, what the college is asking [that students know]....I do hit the molecular end fairly hard because some of these kids are going to go on to college. But with the exception of a few kids, it [DNA and protein synthesis] is not the highest area of interest.

Finalizing the plans for first semester did not end the departmental discussion about the sequence of the course. For Alex, a major concern was the department's current leanings toward placing ecology at the end of the year. Alex described three reasons for his preference to do ecology at the beginning of the second semester. First, it alleviated the focus on the chemical aspects of biology (which might be "turning the kids off").
Second, it provided an opportunity to include current events in the curriculum: "It has a lot of process in it. What the heck, slip it in. Plus, it has relevancy to current issues." Third, and maybe most important, this early placement in the semester helped guarantee the adequate coverage of ecology. As Alex explained: "If I had an area that I would probably defend, it would be ecology."

Alex seemed to feel strongly about ecology for two reasons. First, ecology was a personal interest area for him and, "I think there is a tendency for any teacher to emphasize their strengths and the things they like." Second, Alex felt that the study of ecology greatly influenced his own learning, especially in the areas of critical thinking and life-long learning. Alex elaborated:

I think my interest in ecology probably has influenced my way of teaching, because very little of what I know about ecology did I learn about in college.... The environmental emphasis did not start until I was just getting out of graduate school.... Just about that time, people were talking about air pollution, water pollution, and it all [biology] tied in for me. It clicked. It occurs to me now that....these kids are going to face problems that we don't even know about yet. And if we don't develop more of a [scientific] literacy and an open-ended approach, they won't be prepared for the future.

Beyond the placement of ecology, Alex had few strong opinions about the remaining content that needed to be taught. His hope to teach ecology first during the second semester was not realized. Instead, Alex followed the department decision to start with classification in which he hoped to incorporate a Protists unit in order to reinforce microscope skills. Though Alex admitted that the remainder of the semester could "probably go a lot of different ways," the following sequence was planned: animals (vertebrates and invertebrates), ecology, plants, genetics, and evolution. Again, Alex did not consider this an odd order because it still kept his "blocks" of content relatively intact and allowed him multiple opportunities to reinforce previously taught content.

Alex was observed teaching his first period Biology class. There were 27 students enrolled in this class with approximately 30% female students and 70% male students. Upon reflection during the final interview, Alex described this class as:

Very average. Maybe slightly below average in terms of interest....Academically in the ball park, in the middle....Some of them are giving it their best but science, so far, is not the thing for some of those kids.

Though Alex did not seem particularly concerned about his overall impression of these students, he was very concerned about their reactions to the curriculum. As discussed earlier, Alex sees Biology as an "academic" course which allows students the opportunity to realistically assess their willingness to develop the "academic toughness" that
college demands. Through the structuring of the Biology sequence, many of the more
difficult topics are dealt with early in the first semester. As Alex admitted:

The tougher material is in the first semester....I think they [students]
probably feel pretty good about the process [unit]....[It's early in the year
so] you haven't talked about grades yet and they are not as threatened or
withdrawn about things....That first unit really gets some kids [excited]. If
they like science at all they tend to really get into it. And suddenly you get
into the cell and it gets descriptive and you can see the attitudes going
down. And no matter how you try, you can't make it fun and games every
day. You have got to get serious, or maybe not serious, but committed to
the broader aspects somewhere along the line....I am not sure they would
rank photosynthesis and respiration as highly as I do because it is more
rigorous, it is more difficult, and I think, intimidating. I think they get
intimidated about it and their success level drops....That has always been a
concern of mine about the first semester. It is a long drain for those kids.
And the kids who are borderline in interest or academics, that is a lot of
time for them to be academic.

Almost as if in support of Alex's comment, one of the female students was overheard
in a conversation with another student. She admitted to liking seventh grade life science
because she enjoyed learning about animals. But now, after two weeks of the cell unit, she
had decided that she no longer liked Biology because it is boring.

Alex seemed to be sensitive to such feelings, but also seemed to feel a commitment
to teach these basic concepts. As discussed earlier, Alex had considered various
alternatives which would make the cell unit more exciting. Though he "hated to make the
class a drudgery," he felt that many of the students did not have the study skills necessary
in order to succeed in this unit. For this reason, Alex was committed to providing his
students with opportunities to learn and practice appropriate study habits. Unfortunately,
Alex realized that this approach was not enough. He lamented:

I have come to the conclusion in the last five years, I did not think this
earlier on, but there are some things that will never reach some kids. Some
of these kids are so turned off to everything. They have got so many
problems [outside of school].

From Alex's comments it was obvious that the teaching techniques he used in his
classroom were based on several key factors: variety in the classroom, maintaining student
interest, involving students in process-based activities, repetition of ideas, and allowing
students time to deal with current issues from a scientifically based perspective. Each of
these techniques, and the rationale behind their use, will be discussed in the following
paragraphs.

When asked specifically about teaching techniques, Alex quickly replied: "I don't think
there's any one magic approach." To elaborate, Alex used an analogy which he had used
before:
I think, number one, a good science teacher has to be like a good quarterback: you have got to make some good plays. There are so many [options], but so many variables. You have to be sensitive to your kids for one thing. You can always tell when you are going on too long with one approach. They will get sick of doing labs, as you know, but it depends on what you are trying to do. In some units my emphasis is process. I can't teach them to be good observers by talking about it. You have got to get them out there, get them into some exercise, try and give them feedback. If I am trying to convey content, and in some areas that is very justified, maybe it is better to just lecture for a couple days on whatever it is you are going to do. It sort of depends on my goal for a particular area, but as I look forward [in the unit], I try and mix [approaches].

The idea that students create an important variable in terms of planning is a very real concern for Alex. He complained that many teachers, under the guise of being organized, plan out their entire year the summer prior to teaching. For Alex: "Lets just say that I can't make that work... To me, that's eliminating a whole bunch of variables that are real." One of those "real" variables included student interest. Alex explained:

I get those bored looks once in a while, and I will live with it. But if a teacher is sensitive to that, and I am, then that is going to sort of dictate which way you go. Obviously you temper that. Sometimes getting this [teaching technique] is good for you. Maybe you don't like it, but you need to lecture another day.

But sometimes I am spontaneous. Let's say that I look back on the last unit and I suddenly find I have evolved to a more descriptive thing and the kids have just sat there. Then I kind of analyze what we have covered and what we are about to cover and, unless the descriptive material that we are about to cover that is coming up is really important, I may say "it is time to switch and balance this course" by giving them more of whatever [teaching technique] I think they haven't had.

But as you know, the big variable would be the kids you have, because what works one time does not necessarily work again. And so each year it is experimentation all over again with the kids you have got.

In addition to being sensitive to student interests in terms of what was taking place within the classroom, Alex was equally concerned that biology and the ideas discussed in it made a strong connection to students' lives. For instance, Alex felt that students who earned an A in his class needed to do more than just complete the daily class work. He devised a system which he called "advanced credit" in which students needed to do something beyond the class (in a fairly open-ended manner) to earn an A. Some projects were teacher suggested, others were designed by the students. Alex felt that this system allowed students to take initiative, pushed the grade spread, and encouraged the bright students to do more (but not at the expense of the slower students). Alex felt that this system was "one of the strong suits" in his program, not so much for the extra content that
students may learn, but for the manner in which they may choose to earn their advance credit. Alex explained:

As I get to know the kids later on [in the semester], I find it [advanced credit assignments] forces me to tailor ideas to the individual kid, because not all kids are going to want to do certain things. So I find out if the kid is a sculptor, a painter, or a musician, and once you do that...you can connect the content to their interests....If you can makes that kind of connection once in a while with some kids, it make a subject that may not be their thing at least endurable, and maybe even enjoyable.

A second way that Alex tried to connect biology with students' lives was by including current issues which involved the use of science knowledge in order to make informed decisions. As potential topics, Alex mentioned nuclear power, shooting "varmints" for sport, and the definition of life in terms of abortion and euthanasia. Though Alex described his class as "block and tackle, primarily dealing with the more basic topics," he felt that the inclusion of current issues were necessary and important. Alex described the importance of STS issues as follows:

Alex: The biology class never gets into those kinds of issues [STS], but I am trying to bring them in....I think it is a mistake not to bring those issues in, because you want the kids to apply rational, objective thinking to these emotional issues. That is when you find out [from your students] it is not happening. You get people [thinking].

Researcher: Do you think that the students relate these topics back to the science content that they have learned, or are the ideas kept as two separate things?

Alex: There is a real tendency, I think, for them to keep them separate unless you work on it. And unless you keep bringing it up. I don't think you accomplish an awful lot in one discussion. But if you can bring them [STS topics] up every quarter, by the end of the year, I think you have got more of them [students, making the connection between content and current issues]. And, you never know what tie-ins they are going to carry away. I firmly believe that you have got to make as many of these broad tie-ins as possible, because I think a narrow perspective just doesn't do it.

Alex's comment concerning the need for repeated exposure to ideas can also be found in other aspects of his philosophy of teaching biology. According to Alex: "There has just got to be a way of hitting a topic as many ways as possible." For him, this included not only using various styles of presentation but also the building on previous content and reviewing previously taught concepts. When explaining the sequence of topics for the year, Alex stated:

We will be coming back and hitting the microscopes again [in the Protists unit], and at that time we will review some of that [microscope skills]. We will talk about plants again [second semester], so we are going to talk about photosynthesis [again], and some of those [related] descriptive processes, and keep building on it as we go along.
Alex consistently maintained a philosophy of repetition and reinforcement when it came to testing. Alex included one or two questions on each test which referred to content taught in previous units. In addition, he carried through with a strong orientation toward process skills by having students apply these skills in testing situations throughout many of the units. Alex described the implementation of this orientation into practice as follows:

I think the biggest telling factor [about my philosophy] is that I have, on some of my tests, questions designed just for process, problem oriented. "Here is a problem kids, figure this out. Was this a good experiment?"...I have had kids criticize me because, on some of these process oriented questions on tests, the kids say "but we have never had this problem before." But I say, "we have dealt with hypothesis. Can't you write a hypothesis?" "But we have never dealt with this problem..." Then you know you haven't clicked yet with that kid. That is when I learned that one time doesn't do it. You have got to keep repeating it, and repeating it.

Alex's orientation toward process skills seemed obvious when reading many of the statements presented throughout this case study. As Alex had previously alluded, process cannot be taught unless students are actively involved in a laboratory situation. For this reason, labs were an important teaching technique for Alex. To Alex, process labs are "just good science." In support of this view, Alex stated:

I think the process is important. And I think these kids need to learn to think on their feet a little bit. They need to get out of their shell. Their whole idea is that everything is in this textbook and stuff. It's not real to me. Critical thinking and process skills are important. What is the good of sending out a bunch of kids that know a frogs guts, if they can't respond to the slightest problem? Anything that comes up in their lives. And the trick is to try and get them to relate [life to science]. To use some of these [process skills].

The use of process skills in the classroom, besides providing students with the necessary skills to think critically and make decisions, included "letting kids experience it [biology] and get involved with it," as a "gimmick" to make the content "fun," or to "break up the routine." But perhaps more importantly, the process orientation was a natural outgrowth of the content. As Alex explained:

I always have the feeling that [with other teachers] certain days are lab days. I have never thought that way. Never. That Monday is lab day? It's like you carved it out two years ago... To me, the process, the activities and so on should flow... in theory I think it should just roll, content IS process.

For Alex, the process orientation should provide students the chance to explore and "get lost" in the activity, to "sometimes forget that they were even doing science." He continued:

[When students are doing process labs] they are applying all this stuff [content] and seeing if it really works and making inferences and hypotheses....Sometimes they didn't even realize till we went back and
recapped it that they were making observations and inferences. They were just doing it.

For Alex, such involvement represented a well conceived lab. A lab where "if it [the lab] is doing what it is supposed to be doing, the kids will be active and self directed enough that I could leave the room and they won't even notice. They will run themselves."

One influence on the curriculum which was notably absent from Alex's conversations was the role of the textbook. When asked specifically about the effect that a new textbook might have on his teaching, Alex replied: "I am not a textbook person." Though he saw the value of a textbook for his students, the text had little effect on what he did, especially in terms of sequence. Alex elaborated:

To me, the textbook is a resource. I call it a "friend." It is to be used [by students] to help them do the activities. But I am constantly throwing other books in front of them and saying, "This one is just as good."

Though Alex sometimes felt that his lack of reliance on the textbook could be a liability for his students, ("I have to remind myself that these kids don't necessarily know where to go and look for [information]"), it allowed him the freedom to select topics which he felt were important. Thus, rather than using the text to outline the important topics in the curriculum, Alex used self designed study guides which he provided for the students. He emphasized:

There might be an important concept that is not in our textbook. But I want to keep it on my study guide. So I am trying to do a better job of indicating on the study guide: "Check Modern Biology" (a supplemental textbook) for this one.

As indicated earlier, the factors which affected Alex's classroom performance and teaching techniques had to do primarily with his sensitivity to student interests and his own overriding philosophy concerning the importance of process skills, critical thinking, and repetition. However, Alex did have many concerns about other factors which in a less direct way affected the quality of what Alex was able to do. These factors were primarily "political," stemming from situations and decisions made at the department, school or district level. Of primary influence were concerns about the time needed to prioritize and implement professional change, time for student learning, a feeling of philosophical isolation, too many classroom preparations and students per class, and inadequate laboratory facilities.

In many instances, Alex described himself as being a "rebel," implying that the philosophical stances which he valued were not widely accepted by others with whom he worked. Differences in philosophy bothered Alex, especially in light of the strong consistency of orientation that he had experienced at other schools during his career. Alex reflected: "I think as one matures in their profession there is a tendency to do more
comparing with past situations." Such differences created stress within the department and personally for Alex. As Alex admitted:

I can work with anybody as long as I don't have to have their system imposed on me...But I do get irritated when limitations are imposed on me [by others] that do not allow me to perform the way I want to perform.

Insights concerning these feelings of constraints and imposed limitations may be found in comments that Alex made concerning teaching techniques which he used with his own students. When talking about wanting to institute more "independent" projects, Alex commented: "I always feel if you can give them [students] an element of choice once in a while on what they do you tend to get them more on your side." This attitude may reflect Alex's own desire for more personal control over his teaching situation.

One of Alex's major concerns early in the semester of observation had to do with the scope and sequence of topics to be taught in the Biology course (details of these concerns were discussed earlier in this section). Central to this "battle" was the "very specific mind set" held by some of the members of the department "that forces everybody to do the same thing at essentially the same time." Alex resented such an attitude as well as the lack of a sound rationale for sequencing held by the members of the department (textbook or district recommended sequence). Alex was also concerned about the length of time it was taking to make the decision. In exasperation, he stated:

I hate to sound like a rebel, but I'm eventually just going to do what I think is best for the students and not worry about the rest of the department - especially if they take much longer in making a decision.

Related to the concern about sequencing was a concern about the amount of time each unit should take. Alex described his preferred mode of teaching as teaching one topic a day and doing it very completely by "hitting it several different ways." With the need to teach the same approximate content during the first semester as the other teachers, Alex sometimes felt rushed to get the content covered. Despite feelings of being rushed on individual days, Alex did not feel compelled to start and end his units with the rest of the department. He explained:

Alex: As some of the other science teachers can tell you, I have never felt bound by ending a unit on such and such a date. It just doesn't make sense to me.

Researcher: How do you decide when to move on?

Alex: Believe it or not, I have objectives in my mind. At least for what I want to cover, major ideas that I want to get across or processes or labs or whatever. I feel like I constantly have feedback, verbal feedback, interest feedback, everything from the kids. If I feel they have most of the concepts and stuff or maybe we have milked the unit to death then it is time to move on.
Time was also an issue in Alex's perceptions of departmental and district level attempts at program coordination. As a district, decisions had been made to incorporate units which involved Oregon's Common Curriculum Goals (CCGs). These goals, based on the concept of a spiral curriculum, identified several key concepts which should be taught in every science classroom. The biology teachers at the district level chose to work on the concepts of cycles, evolution and models over the next several years. Alex was excited about this move because they were "important concepts...and I think it is neat because it is pulling more people toward what I have always believed." But Alex feared that change would not occur due to pressures of time:

What is happening, I'm afraid, is there are too many things going on. We have the State, and then the school is also trying to change. And yet they are not giving anybody any more time....it is overwhelming. If the state of Oregon was in a position where teachers actually had time to think about some of this stuff for a while, I think it would be great. But right now, I hope they don't push too fast, because it is going to kill the interest in it....

After this year, if I can concentrate on them [the same CCGs] again next year without somebody saying "you have got to do five more," if they give me a chance, it will gradually become ingrained. Just like teaching the cell becomes ingrained year after year after year. If you give it a chance and let us put it in place I think it will really enhance science education... But as far as I am concerned, to make this system work they are going to have to do it for five to eight years and keep coming back and giving teachers time to do it and do it and do it until it is integrated.

It sounds a little conceited, but I think it [the CCGs] will be of great help to the new teachers coming in because it will help them see what is supposedly important. And maybe to your mediocre teachers too in that you are giving them stuff they may not have otherwise thought of.

Though Alex admitted to being quite excited about the introduction of the CCGs which were closer to his own personal philosophy, he felt isolated in his beliefs:

One of the bigger frustrations that I have faced in my teaching career is that I have always felt like I was kind of the Lone Ranger out there....[At other schools where I've taught] people were just talking the same lingo. It has never been that way for me here, never.... And I have to admit, that there is some of that [my own philosophy] that I am not doing to the extent that I want to do it. I will tell you this, it really helps if you have a department with at least one other person that shares that [philosophy] to reinforce it.

Alex felt a particular lack of support when it came to the recognition of what was needed to adequately conduct a lab course. With another teacher using his room in the afternoon, Alex was unable to set up labs the night before. He also did not have the classroom or storage space to have several labs set up at the same time. This last concern is directly tied to one of Alex's greatest complaints: too many classroom
preparations. Alex lamented about the effect that three classroom preparations had on his teaching effectiveness:

That is not to say that what I am doing here is what I want to be doing. I hope you understand that. I feel very constrained sometimes....I am not the type who can do three labs. I really can't....When they give me a third lab class they have cut my efficiency by 40%, especially when I can't prep in there [my room]. Maybe other people are more flexible or spontaneous than I am, but I have to plan. I have to know where stuff is....When you are trying to do these open-ended labs, and trying to anticipate all the things the kids will need and stuff, you are always going like crazy. And then, you have three minutes till the next class comes in. There are days when I would just as soon shove that movie projector out there. It would be more relaxing....I have always maintained that you could put a drone in a classroom and they could show films and lecture and stuff. But this other stuff [open-ended labs] takes a heck of a lot of planning: how to incorporate it, how to evaluate it, and the paperwork.

In addition, Alex was concerned about the number of classes each teacher was expected to teach each day (six) and the number of students the administration was willing to put into each class (a number approaching 30). The combination of all of these constraints was contributing toward what Alex termed "teacher burnout."

Classroom Profile

Alex was observed teaching his first period class. Since this was Alex's first opportunity to be in the classroom since the previous morning, he often used this time to set up lab or demonstration materials or to draw diagrams on the board which would be used to illustrate points in the upcoming discussion. Alex also used this time to add comments to the "assignment board," a section of chalkboard located at the side of the room sectioned into vertical columns for each of Alex's classes. Horizontal lines were drawn to indicate the days of the week. In the appropriate sections the assignments which were expected to be complete for each day of the week were recorded.

The students randomly wandered into the room during the time that the room was open. Several early arrivals used this quiet time to complete homework or study. On some occasions students actually worked on material related to the upcoming class. The more talkative students came in closer to the bell and usually used the time before class to talk about high school sports and other topics of social interest.

The first portion of each day's class was occupied by the reading of the announcements over the intercom. Though Alex tried to maintain a low enough noise level so that the announcements could be heard, he often became wrapped up in his own classroom preparation and failed to notice the increasing volume of student conversation.
This increase was usually noticed once every two weeks when Alex spent a brief moment of class time reminding students of the appropriate noise level which was expected to be maintained.

While the announcements were being read, Alex tried to take attendance, though he sometimes forgot to do this task if he was involved in a particularly lengthy lab set up (for instance, one that involved the collection and display of live animals and plants from various locations around the room). There were no specific expectations for the students during this time (in terms of a warm up exercise), but Alex did seem to indicate the expectation that the students would have their materials out and ready for the day. As Alex would explain to his students: "It is important [to be prepared] because if you have a mental attitude of readiness it can make a difference in your performance. Just like in athletics." Unfortunately, Alex did not reinforce this level of preparation consistently. Occasionally, he did make comments such as the following to his students:

Ladies and gentleman, our super student index has increased this morning. We have 11 of you with your homework out and ready to go without me even asking. In the last couple of weeks, that has doubled. Very good.

Such comments were moderately effective in improving student preparation for class.

A large majority of Alex's class centered around some sort of classroom discussion. On 33% of all class days (as determined through the analysis of classroom transcripts) some sort of formal lecture was presented for at least part of the period. On 14% of the days, lectures were presented in conjunction with the discussion of laboratory results.

As Alex stated earlier, his preferred method of teaching involved the presentation of a single topic through multiple techniques. This described method was observed on a large number of occasions thus explaining the combination of lecture and lab discussion. One example of this preference translated into practice was observed early in the school year. In a lesson aimed at demonstrating the concept of experimental error, accuracy and bias, Alex included the following lesson segments: estimating lengths in metrics, measuring a sheet of paper in metrics, looking at data concerning the length of a metal bar collected by fictitious students, having two students take a measurement of the same line with the same ruler from different visual vantage points, and the discussion of a recently completed lab which involved taking measurements of potato cores placed overnight in different concentrations of salt water.

During these presentations, Alex usually did a good job of moving around the classroom, maintaining eye contact with his students, and providing diagrams which aided the explanations which either he or his students delivered. In most cases the students did not meet his attempts with overt enthusiasm but they were not openly disrespectful. Many students either listened or quietly engaged in some off task behavior such as day
dreaming. Alex's classroom demeanor did not typically "demand" greater levels of student attention.

Students were often involved in the classroom presentations through questioning. Alex often seemed uncomfortable calling on students who were non-volunteers, which may have contributed to a large number of students day dreaming in his class. When he did call on a non-volunteer, this request for participation was often preceded by the apology: "Now, I don't want you to think that I'm picking on you, but..." Instead, most questions were answered by volunteers. Many questions were initially answered through call-outs. When Alex recognized a student willing to participate (typically the same six or seven students), he often utilized that student for several questions in a row. These questions, usually closely related, were used to develop a thought. The following classroom conversation illustrates Alex's use of a single student in answering a series of questions. This lesson segment occurred during the discussion of a lab in which students were to determine if pea seeds were living or dead. Seeds were placed overnight in a test tube of bromothymol blue. It was explained to the students that bromothymol blue is an indicator for acidic conditions which can be created by an increase in carbon dioxide, and how the presence of this gas could be related to the ideas of living and non-living. A second test tube was filled to the same level with bromothymol blue and was used as a control. Note the emphasis on process skills and the use of these skills and classroom verbalization to help the student clarify her thoughts:

Alex: What would happen if we boiled five pea seeds and repeated that experiment? Would the results be the same? (Pause. Alex notes a female student in the room shaking her head "no"). I see you shaking your head. What do you mean?

Sue: The stuff in the test tube wouldn't change colors.

Alex: They would be dead, therefore...

Sue: I don't know.

Alex: They would turn a different color possibly, or it wouldn't turn at all?

Sue: Probably not.

Alex: The reasoning, then, is we have dead seeds because they have been boiled and that is why there would be no color change? What if you did get a color change?

Sue: But I don't think that they'd be alive.

Alex: You could assume that they are alive or would it make you reflect on the results that we had in the first experiment?
Callout: Yes.

Alex continued the above conversation in a pattern typical of many of his classes. Conversations with a single student continued in order to develop a line of reasoning. During this time the other students passively listened to the interaction. When the discussion was completed, Alex typically tried to tie the various ideas which had been presented together with a monologue. In the discussion, note how tried to entice students to extend the classroom activity for Advance Credit, his comments relating to student study skills (particularly reading), and the comments which prepared students in advance for the idea that the topic being discussed today would be dealt with again in the current chapter as well as later in the year:

Dead seeds could turn it yellow? Does that shake you up a little bit? Guess what, I have never done it! If someone in here would like to try that, I will reward you with a little carrot which I call Advance Credit. We have a stove. We have hot plates. All you have to do is boil them [the peas] for a few minutes. It would be kind of fun to see what happens. Like I say, I am curious because I have never done this with these peas.

[In the lab], one set up had peas, one did not. The variable in the experiment was the fact that you had two seeds in one tube and did not in the other. The point is, if you get a difference in results it has to be due to the fact that you had seeds in one and did not have seeds in the other.

Does that makes sense? To a lot of students it does not. If you do your reading it will explain "variable" in your text. And we will deal with another experiment in about five days. That will give you another example of variable and I think will help you understand that concept.

It takes practice to really understand why we have controls, and what the variables are. Before the year is out you are going to have a chance to design some of your own experiments. And that is when, I think, it makes a lot more sense, when you do the designing. The statements that several of you made about the hypotheses are true. They will become even more real for some of you when you are designing a procedure from your own hypothesis.

Do any of you have questions on the pea lab, at least as far as we have gone? Remember, we are not done with it. We will come back to the last part and review it, most likely on Monday, and then I will collect it.

The most common activity which occurred in Alex's classroom were labs. Lab activities were conducted on 29% of all class days, and discussion of the labs on an additional 14% of the days. This as a result, 43% of all class days (as determined through analysis of Alex's lesson plans) were utilized for some aspect of laboratory work. It is important to note the prevalence of labs in Alex's class even though the classroom in which he taught was not designed for lab work. Students sat at "regular" classroom desks. Counter and storage space in the room was limited. Only one sink and a few electrical
outlets were located in the room. Alex obviously felt strongly enough about the importance of labs to not let the poor classroom facilities discourage him from their use.

As discussed in an earlier quote, Alex felt that one of the most influential teaching techniques which he had learned from his supervising teacher in student teaching was the idea of rewriting labs so that they fit the specific needs of the class and the students. Alex continued this practice throughout his career including the semester of observation. Procedures were combined from a large number of commercially produced labs, sequenced to meet Alex's specific classroom objectives, and then retyped with the addition of background information for use by his students. Alex felt that this method of lab production insured the coverage of the topics he felt were important to the appropriate depth of coverage.

When reworking these labs Alex maintained a strong orientation toward process skills. Many of the labs were given an inquiry oriented slant which did not originally exist. For example, Alex used portions of a lab in which students identified various types of organic molecules (carbohydrates, fats and proteins) through the use of various indicators. Rather than telling the students the combination of indicators which identified a specific organic molecule, Alex let the students determine the best set of indicators for themselves as part of the lab activity.

When using the labs in class, Alex always provided the students with an extensive prelab, tying many of the concepts which had been studied in class and the appropriate process skills to the lab. During the lab, Alex actively monitored the class' progress, both initiating conversations with students about the lab procedures and their findings and answering questions originating with the students. Following the lab, Alex spent at least one day having students report on their findings, discuss experimental error, and evaluate their results.

One of Alex's self-described favorite labs was one in which the students designed, for themselves, an experiment to test the effects of light on the rate of photosynthesis. Using apparatus Alex had designed while in college, small groups of students wrote a hypothesis, designed an experiment, and collected data. Upon discussion of the results, focusing on the value of controls and the sources of experimental error, Alex provided students with an opportunity to redesign and reconduct the lab in order to compare the results. Final results were discussed in a "seminar" fashion and classroom consensus on the meaning of the results were reached through discussion. Alex felt that labs such as these best represented his own preferences for labs, but found such labs difficult to conduct on a regular basis. Constraints included prep time, lab storage space, and student knowledge. Alex described what occurred in his classroom as often being limited to "block and tackle,
only the most basic concepts." This level of content coverage limited what could be done in class because "the labs which are really fun often depend upon students understanding a wider range of topics than we can cover in this course."

Alex's reluctance to just use the textbooks or any other framework was evidenced again in his use of study guides and worksheets. At the beginning of each unit, Alex handed out a study guide. This study guide outlined Alex's major objectives for the unit and allowed the students the opportunity to practice the concepts which Alex felt were important. As Alex reminded his students: "Remember, the study guide reflects my goals."

In some cases, this "practice" was as simple as listing a definition. But in the large majority of cases, the "practice" involved the application of an idea discussed in class to a new situation. Alex used these study guides as his primary source of homework assignments, assigning specific objectives during the week. Rarely were assignments other than reading given from the text. The study guides were also used as the organizing framework for his class and as a source of student feedback. Alex often used the student answers on these sheets as a source of discussion and review during the unit. Finally, Alex used the study guides as a means of teaching students study skills as the following classroom conversation, occurring the day be for a test, illustrated:

The reason I tell you that the study guides should be complete now is that if you are still working on it for tomorrow [the day of the test] that means you don't have the opportunity to sit down and relax and study for the test. You really have already studied for the test if you have done your part [the study guide]. But what I hate to see is a student who has a third of the study guide left and is sitting up tonight trying to get that one third done. That leads to frustration. That is called cramming. You come in here and you are not sure whether you are prepared or not. If your study guide is now complete then, in a more relaxed way, you can go back through and pick up on those areas where you are a little unsure, if there are any areas like that, and then try and be in a position to do even better on the test.

Obviously, study skills as well as process skills and critical thinking were philosophical orientations which Alex translated directly into practice. Other important issues, such as STS and science careers also became the focus of classroom work. The following list is just a small sample of the implementation of these orientations into the classroom: Two days spent on reading skills, one day spent on study and review skills, one day spent on using glossaries and other supplemental sources of science information, six days spent on STS issues, including a 3 day unit on nuclear energy, a day on the definition of life as it influences decision on abortion and euthanasia, a day on hunting ethics, and a five day unit on science careers and educational options found in various types of post-secondary education. This listing alone accounts for 18.7% of all class days. These days were often exclusively related to the issues described above.
Alex's primary unit routines had to do with the distribution of study guides, the presentation of biology content through lectures, discussions and laboratory exercises, and the final evaluation of student knowledge. Prior to the final assessment, Alex usually gave his students two or three ungraded quizzes, as both teacher and student feedback. The actual tests were teacher-constructed.

Tests given early in the year were usually short (10-15 questions) and structured for student success, which somewhat matched the early emphasis on process skills rather than content knowledge. Later tests were longer (20-30 questions) and focused on content knowledge, the application of this knowledge, and process skills. Most tests had one page focusing on content knowledge, which the students answered early in the period. This portion of the test typically consisted of multiple choice or matching questions. When this page was completed, the students turned it in and picked up a second page which focused on application and process skills. For this page, they could use their notes for reference. In many instances, this portion of the test asked students to respond to a partially reported experiment.

Alex also was required to give his students a semester exam. He was concerned that the final overemphasized lower level questions, many of which came from the text's test bank. Alex expressed dissatisfaction with this questioning level, but pointed to inadequate time to prepare the test. He promised that this situation would be remedied in the future.

An analysis of Alex's tests (including the final) indicates that 78% of the questions were lower level and 22% higher level. This proportion of higher level questions does not seem in line with Alex's classroom emphasis on higher level objectives. However, these questions carried a larger portion of weight in the students' final grade than the simple analysis of question level reveals. Also, distinctly different from the other teachers in this study, Alex's higher level questions included those which assessed application, analysis, synthesis and evaluation levels. This range of cognitive levels of questioning is in contrast to other teachers who primarily relied on application questions which came from the test bank provided with the textbook.

Classroom Subject Matter Structure

Alex taught the following units in the sequence listed during the semester of observation: Introduction to Biology, Cell Biology, Biochemistry, Nuclear Power, Translocation, Cell Energy, Mitosis, Science Careers, Meiosis. Based on the data collected from these units, Alex's classroom SMS (Figure 3) was generated. Methods for the derivation of this SMS can be found in Chapter IV, Textbook Subject Matter Structure:
Methods. The reader is referred to this section if questions concerning methodology arise. In addition, the evidence used for the generation of the SMS can be found in Appendix G and cross referenced to Figure 16.

Rather than being tied to the content and format of the textbook, Alex had strong opinions on what was essential to teach and how this content should be taught (as presented elsewhere in this case study). This philosophical stance was obvious in the manner in which he sequenced his units and the content included (the content contained in each unit can be found in Appendix G). It should be noted that Alex’s content selection represented a reduction from that provided in the text.

Alex’s Introduction unit set the tone for the rest of the semester. This highly lab-oriented unit introduced students to the methods of science, science process skills, and the nature of science. The content established themes which were reinforced throughout the rest of the semester. (The content and orientation of these themes will be described with the rest of the SMS.) This unit was followed by two more traditional units: Cell Biology and Biochemistry. It should be noted that neither the content nor the sequence of these units follows that found in the textbook.

A short, three day, less traditional unit was introduced on Nuclear Power following the test over Biochemistry. Alex described this unit as having two functions: to introduce students to the issues surrounding a ballot measure which was to be voted on during the next several days, and to decrease “student fatigue” by providing a break from the cell biology and chemistry content. The Nuclear Power unit included information on nuclear energy, how nuclear power plants operate, nuclear waste, safety concerns related to nuclear energy, plant and personal safety, environmental hazards, and a discussion of the information needed in order for a voter to make an informed decision. Assessment of this unit consisted of a position paper written by each student prior to the tallying of the state-wide vote.

Translocation, a topic presented with the Cell Biology unit in the text, followed the unit on Biochemistry. As before, traditional units of Cell Energy and Mitosis followed, but this more traditional sequence was interrupted by a five day unit on Science Careers. Following this unit, Alex returned to a more traditional sequence and followed Science Careers with a unit on Meiosis. As in the previous instance of an interruption from a traditional biology sequence, Alex used the Science Careers unit as a break and to introduce material which he felt was important for students to know.

Observations were made in all units except those on Nuclear Power and Science Careers (though, by Alex’s request, the researcher was a speaker in the latter unit). As mentioned by Alex earlier in this case study, the textbook was used as a reference
Figure 3. Alex's Classroom Subject Matter Structure.
throughout the semester. Units were structured around study guides provided to students at the beginning of each unit. Additional texts were provided for in-class use by Alex when he deemed it necessary.

Alex's SMS as derived from the classroom data can best be described as a matrix. The horizontal members are formed by the units taught during the first semester. The more traditional units make up the core of this matrix and have been arranged in the sequence in which they were taught. For ease of representation (Figure 3 and Appendix G), the Mitosis and Meiosis units have been combined under the title Cell Division. This format was considered appropriate since the units were related by content, adjacent in the sequence of units (though interrupted by the Science Careers unit), and provided a manner in which generic Cell Division references could be accommodated within the SMS. In addition, the less traditional units of Nuclear Power and Science Careers have been given unit status as horizontal members of the matrix, but have been removed from the core of science topics since they had limited interactions with the more traditional units.

Strong interactions existed among all of the traditional units listed in Alex's SMS (Appendix G). This high degree of interaction among the molecular and cellular biology units contrasts the level of interaction found in the text. Perhaps this interaction was created through Alex's own careful analysis of the content and/or through conscious effort on his part. Regardless of the actual source of connections, it is obvious that such connections were not provided solely by the text since the text was used only in a limited manner.

It should be noted that the convention of using concentric boxes to represent units which closely depend on each other and which build on previous content had been established (see Chapter IV, Textbook SMS: Methods). This description was appropriate for Alex's SMS, however, the complexity of Alex's SMS could not be accommodated using this format. Thus, the matrix format was selected since it allowed for the representation of a closely related set of units while still allowing for connections to be made to units which were not taught during the first semester. The convention of concentric boxes will be followed in all other SMSs generated as a product of this report.

Each of the traditional units, in addition to connections in and among themselves, have additional connections to other units which may or may not be taught during the second semester. Connections to these units, represented as boxes near the sides of the matrix, were often used to provide concrete examples and sources of application of the content presented in the core of units. Though there do not seem to be a particularly large number of examples from outside the core content, each example used was often
developed over a period of 10-35 minutes, making each a valuable and integral part of the content taught.

The strong integration of the units which made up the core of Alex's content may be explained by the fact that Alex exerted personal control over what occurred in his classroom. Even though a textbook was available, Alex felt strongly about the biology program that he had developed. With this program, Alex may have purposely sequenced topics in order to form the tightest integration of ideas as possible, or have taken the time to "build up the background" so that the content could be connected. This goal of integration was apparently not followed as rigorously by the textbook authors.

To form the connections among units, Alex took the time to relate topics in each unit to topics found elsewhere in the curriculum or to the themes which he felt were important. The following example occurred during the Cell Biology unit. Notice how Alex takes the time to remind students that cell structures and functions have a relationship to their bodies, and thus, are important to understand:

Mitochondria. Again, tie it back to the cell. I know we're not used to doing that. And I don't expect you to wake up in the morning and say, "Oh boy, the cell's a great thing." But at the same time you are made of cells. Much of what you do in your daily life is related back to that cell. What are you doing right now? You're breathing. So what? You don't even think about it but you know that oxygen is eventually going to your cells to be used by the mitochondria to produce energy through respiration. You can learn a lot about yourself... if you know something about the cell.

Another method that Alex used to tie together the content of biology was to "recycle" content by bringing it up over and over again, both within classroom discussions and on tests. As Alex explained to his students: "Remember, I hold about 10-15% of the questions from previous tests onto the current tests just so we sort of stay current with previous material."

Tying together concepts in biology was important for Alex. In fact, the idea that much of biology content is interconnected was sometimes a source of frustration. As Alex admitted one day after class: "How are students really supposed to understand the importance of mitochondria if they don't really understand what respiration is all about?"

Though Alex felt that the introductory material such as the structures in the cell was important, his preference would have been to teach more content which tied everything together, such as respiration. Unfortunately, his students' need for the basic content prevented him from moving any faster, even though some students brought up questions which ignited this desire to move beyond the introductory material. Some of Alex's frustration was expressed in a comment made to his students during the Cell Biology unit: I know that it can be frustrating dealing with introductory material because sometimes we don't have time to develop a full idea. Remember, we are
introducing the cell right now. We are going to spend weeks and weeks and weeks further down the line going into more detail on some of the functions of these structures. Some of your questions will just have to wait until then when they can be covered more appropriately.

Evidence for five themes was found in the analysis of Alex’s classroom data: the Nature of Science, Scientific Methods and Process Skills (SM/PS), Study Skills, Science, Technology and Society interactions (STS), and Science Careers. Themes were graphically represented as vertical members of the matrix. Each of these themes, their definitions, and their translation into classroom practice will be discussed in the following paragraphs.

The themes of the Nature of Science and Scientific Methods and Process Skills were unique in that the represent both content which was taught by Alex in his Introduction to Biology unit and themes which were reinforced throughout many of the other units. To graphically represent this dual exposure, the cross members between these themes and the Introduction to Biology unit have been left open (Figure 3).

The theme of the Nature of Science was defined as all content related to the definitions and distinctions between observations, inferences, facts, laws and theories, the development and tentativeness of scientific knowledge, and the role of modeling in science. Many of the components of the above definition were taught directly by Alex as part of the opening unit. In future units, the most ubiquitous recurrence of this theme was the role of modeling in science. Alex always carefully identified when a diagram or description which was being used was a model (i.e., diagrams of atoms and cells, descriptions of the composition of the cell membrane, and the "cell" made of dialysis tubing for the study of osmosis and diffusion). In addition to the use of the term model, Alex often discussed how the identification of something as a model should influence the interpretation of the information provided. For example, Alex discussed the limitations of models for the cell and the solar system. In both cases, errors of scale have been created in order to provide more information in a single model. Alex also discussed the advantages that models provided in terms of aiding our understanding through the convenient representation of knowledge.

Examples of the development of the Scientific Methods and Process Skills theme were pervasive throughout Alex’s teaching. SM/PS were defined as the skills needed to be actively involved in science (measuring, observing, using the tools of science), the intellectual tools needed to interpret information in ways consistent with science (separating observation from inference, hypothesis generation and testing), and methods of assessing the quality of information obtained in order to make decisions and judgements (the role of experimental error, controlling variables, the need for controls). It could be stated that components within this theme deal with the processes of science and other skills important
for critical thinking. In the case of critical thinking skills, it could be argued that the skills and practice gained could be transferred to situations outside the realm of science.

Alex provided many examples of the theme SM/PS in his teaching. In almost every unit, Alex involved his students in making some sort of observations and then fostered the evaluation of these observations (or the data provided for them) in terms of using the information for decision making. These episodes often involved the concentrated questioning of a single student on their thoughts or opinions, the rationale behind these opinions, and the assessment of the additional forms of evidence needed in order to make an informed decision. As mentioned in terms of critical thinking, many of the expanded examples which Alex used were not directly related to science. For instance, when providing students with the opportunity to examine the claims of a hypothetical producer of a plant fertilizer, Alex stimulated his students to bring up the need for controls, multiple tests, and the evaluation of the appropriateness of the product for consumer needs. Alex then took these concerns and applied them to the process of buying a new car, including the examination of claims made by auto manufactures.

Study Skills were the third major theme found in Alex's teaching. Alex considered his biology class to be the first true "academically challenging" course that students were exposed to. This perception may explain why Alex spent some time during each unit teaching specific techniques which could be used to improve student use of study time, ways to read more effectively, or ways to assess what information students knew versus what they still needed to study. In some instances, Alex would spend two or three days within a unit working with one or two study skills, followed by handouts which outlined or reinforced the information presented.

The last two themes evident in Alex's teaching were STS and Science Careers. Though these two themes may be slightly less prevalent throughout the curriculum than the other themes discussed, they were each complimented by a full unit within the biology content sequence, reaffirming their importance to Alex.

STS issues usually appeared as applications of the current science content to some social issue or decision confronting society. In most cases, these issues were tied tightly to the science content. The following lesson segment taken from a lesson on meiosis illustrated such a connection:

Once you fully understand what goes on in this duplication process [meiosis] and how sensitive it is and once you understand how marvelous this process of division is you will be able to appreciate the problems presented by drugs, excessive radiation, etc. Now they are talking about electromagnetic fields and so on as maybe affecting some of these [meiotic] processes. They're even recommending not to use electric blankets! But it should not surprise any of you who have a background in
biology because these processes are very delicate. You don't want to fool around with Mother Nature anymore than you have to....We will do a lot more of this [environmental risks and genetic defects] when we get into genetics. But for now, you need to know the vocabulary. You need to know the process.

Alex's Nuclear Power unit established many similar ties in terms of the needs of society for energy and the balance that must be created in terms of human health and safety. To accomplish this task, Alex provided his students with as many sources of information that he could obtain on Nuclear Power. It was up to the students, through class discussion, to determine what types of information they needed in order to make an informed decision on the closure of a local nuclear power plant and the ultimate impact of those decisions. Even though this content did not directly relate to biology content, Alex felt that the practice provided by collecting and evaluating scientific information based on a real problem was an important skill to which his students needed exposure.

The last theme, Science Careers, was developed early in the year on a worksheet in which Alex had his students identify science careers and hobbies and later in a more formal way through the presentation of a five day unit on science careers. As previously mentioned in terms of study skills, Alex's desire for the inclusion of such a unit may be fostered by his perception that Biology was the first real "academic" course that his students would be taking.

Alex's program was consistent with the philosophical statements made during the both his interviews. Possible reasons for this consistency will be discussed in the summary section of this case study.

Self-Described Subject Matter Structure

Alex was asked to draw his conception of the content of biology and the manner in which the topics were related (Appendix D) for the first time as part of the post-observation interview. Alex immediately asked about the meaning of the term "topics." For Alex, the term "topics" implied a "descriptive statement of what should be taught, a scope and sequence of units." When told that the term was meant to be flexible, he stated that he was going to approach the task in the same manner he would if he was "going to develop a course in biology. What would I want covered at some time, some where." Later, Alex admitted that his final product had gone beyond his initial conception of the term "topics" and had "slipped into the philosophy of how this [the teaching of the content] should be done." Both of these aspects appear in Alex's final SMS.
Alex's initial description of the SMS which he created was that it "really looking pretty standard, what you would expect most people to write down." However, Alex qualified this description by stating that the SMS which he had recorded, standard or not, was representative of what he was "pushing" for in his classroom. As a result of the questionnaire on SMS (Appendix D), Alex produced two lists (Figure 4). One list was titled "Descriptive Material," the other list remained untitled. When describing the SMS recorded, Alex often referred to the topics in one list or the other by pointing to the lists. To facilitate the comprehension of Alex's comments concerning the SMS, the columns will be designated "D" for the Descriptive Materials column, and "T" for the Teaching Themes listed in the second column.

Once Alex completed the two lists, he began to describe his product as follows:

I suppose I could have done this in a matrix. And I may have left something out. Anyway, I am breaking this down for you in little bits and pieces but I would of course integrate them if I were teaching a course. I am giving you basically a course outline and I will do a little more with it later.

Alex began the description of his SMS with a discussion of the teaching themes. In the interest of clarity, this description will follow that provided of the content portion of the SMS. Thus, the content components of Alex's matrix are described first.

Alex described the list of Descriptive Materials as being "pretty standard" in terms of the types of topics which would be covered in a typical biology course. Though he felt that there was a lot of material implied by the list, he felt confident that most of it would be covered in the course of the school year. In addition, Alex described the order that the content topics were listed in as "flexible" with no one topic being a necessary prerequisite to another or of greater importance than any other. As Alex examined this list he explained:

You can give an argument, a plus or minus, for every one of these units here. Why it's good to teach. Like plant physiology reinforces what we did here with photosynthesis and the cell is important with a lot of stuff. And, maybe if there were a negative, maybe this one is a little more boring or this doesn't offer as much opportunity for the integration of process [and the other teaching themes].

Upon further examination of his list, Alex added the units of Protists and DNA/RNA. With these additions he commented: "For some reason I don't teach these so maybe I don't think they are as important as the rest of this." In terms of Protists, Alex cites that labs in microbiology require "a lot of lab prep," materials and equipment that he does not have, and careful timing with the weather. Alex explained: "Not to make that sound like an excuse, but maybe those are the reasons I gave up on it [Protists]. But I am consciously looking to work it back in."
Figure 4. Alex's Self-described Subject Matter Structure.

**Descriptive Materials**

1. Cell - Parts and Function
2. Compounds of the Cell
3. Translocation - Cell
4. Photosynthesis and Respiration
5. Taxonomy
6. Invertebrates
7. Vertebrates
8. Plant Diversity
9. Plant Physiology
10. Ecology
11. Reproduction (Meiosis and Mitosis)
12. Genetics
13. Evolution

**Process**

- Observation
- Inference
- Measurement
- Experimentation
- Prediction

**Critical Thinking**

**Current Events**

**Ethics**

**Study Skills**

Protists

DNA/RNA
Pointing at the DNA/RNA unit, Alex seemed a bit more disturbed:

I haven't got that in yet. I know it's important and I sit and I think 'Why haven't I done that?' One [reason], I know that some of them get it in AP biology. Two, there is such resistance [from the students]. But that is not a reason not to teach a unit, just because the kids don't like it. But I have to admit that has influenced me on this. And it's the matter of having the time to sit down and present it in a way that they will like it a little bit better.

Alex continued:

Ten years ago I wouldn't have been doing half as much with this [biochemistry and DNA/RNA]. The biochem wasn't stressed half as much as it is now. We spent a lot more time on plants and animals and genetics and protists. But those units got squeezed when I expanded the biochem units. But, I have to admit, I am influenced a little bit by the colleges. Many of the colleges teach full quarters of DNA, RNA, etc....I'm not going to teach to the college but, at the same time, you are foolish if you don't give the kids some background. I want them to go in there so they have a good fighting chance of understanding a lot of that. So this part [biochemistry] has been enlarged considerably.

For Alex, it seemed that the content, the descriptive material, was important in terms of providing students with a fairly broad background in the biological science. No one content item was more important than another though some units were more interesting, more fundamental, reinforced other topics that were taught, or lent themselves better to the integration of process skills and the other teaching themes. In final reflection on the content portion of his matrix, Alex admitted:

For sophomores in high school, I think they can miss any one of those units on there [the list] and most likely do just fine in life. Even ecology, which I hold dear and true because I think our world is in serious trouble.

Alex's casual survey of the content portion of his matrix was in stark contrast to his description of the Teaching Themes list. The reader is reminded that Alex began his discussion of his SMS with a description of this list. When initially surveying the list which he had recorded in response to the questions concerning his views of biology, Alex commented:

This [diagram] looks like this [D, the descriptive material] is the most important because it's a longer list. Actually, for me, this [T, the teaching themes] is more important. This [T] is more of what I would like to be doing and I would like to be conveying these ideas [D], these concepts, using all this [T]. In other words, if I can, I would like to use a current event to convey some concept over here [D]. I tend to like to think that I convey this [D] using all of this [T] over here, these processes.

Without the prompting of a request, Alex readily described the rationale behind the use of the teaching themes to teach the Descriptive Material and provided examples of how this could be accomplished:

I believe strongly in killing two birds with one stone. Integrate two things with one shot. So okay, if I'm teaching photosynthesis maybe I see a way
of conveying some kind of study skill. I can do both in the same shot and I feel better because I think I've done more than just teach photosynthesis. I am also teaching them how to study.

Another example may be in ethics. [In class], we will talk about "should we be dissecting these critters?" Like in the chick egg dissections. Should we be killing these animals? Or hey, Rowe vs. Wade. I think you are crazy if you don't make those tie ins.

Alex obviously believed in the importance of the teaching themes listed. They were mentioned first in his discussion of his SMS and defended in terms of accomplishing more with a single action and being important in terms of teaching content. When asked about when and how these themes should be used, Alex stated: "If I were to develop a matrix [for someone else's use], I would like to see a lot of this [T] integrated into this [D] teaching on a weekly basis." For Alex, there did not seem to be a hierarchy inherent in the themes listed and so the most effective manner of incorporating the themes into the content was to introduce several of the themes simultaneously within a single unit. To illustrate such a use, Alex provided the following illustration:

For example, the second observation lab that we do [during the first week of school] reportedly teaches them to observe. In it I take a plant, cut the roots off, put it in potting soil, and ask the students to make observations. They invariably tell me that it has roots. Then I pull it out and show them that it doesn't. That lab has more impact than anything else I do. And not only do I work in observational skills, I work in critical thinking, a type of critical thinking anyway. As a result I hope they are more prone to think about things, not to make blind assumptions without really looking at the situation. But you're not going to teach a kid critical thinking in one exercise. Teaching like this has to occur in all units to make a difference.

Alex saw several threats to the integration of the identified teaching themes across the curriculum. The first two threats had to do with students' reactions. In some cases, particularly in the area of Ethics, Alex worried that little could be done until his students knew him. He explained:

[When including questions that deal with ethics] I try not to answer the question [for students]. It [the answer] is a personal opinion. "What do you think?"...I think with my biology kids I feel much more comfortable about doing this [including ethics] now because I think they feel more comfortable with me. [They] know my motives. I must feel good about that [knowing that they trust me] before I can accomplish some of these goals.

Needing to wait until students felt like they "knew his motives" sometimes limited the number of Ethics related issues which Alex felt comfortable presenting early in the year, but he felt that the frequency of use of this theme increased as the year progressed.

In addition to trust, Alex was also concerned with the students' sometimes negative reactions to asking them "to think. They're not used to being asked to think very often." For that reason, Alex tried to be sensitive to student reactions. He explained:
The danger of the approach I take to critical thinking is that, if you are not careful, you can overwhelm the kids. I think you have got to be very careful, very skillful. I think that is why a lot of us [teachers] back off from this [T] part.

Finally, Alex was concerned about his ability and the ability of others to accomplish his stated goals of content integration with the teaching themes. As Alex lamented: "You have got to integrate it [T], and that takes time." When reflecting on other teachers and the probability of their incorporation of the teaching themes which he listed, Alex seemed doubtful:

My gut feeling is that with a lot of teachers this [T] is hardly ever done. I think some teachers model this [T], but I think it is just talked about more....This [T] is the stuff you tend to let slide to when you get pressured.... [For instance], if you are a new teacher you are struggling just to survive. This [D] is there for you in a book.

For Alex, pressure was synonymous with time - time to think and plan the integration of the teaching themes across the biology content. Upon reflection, Alex remembered having time at an earlier point in career:

When I used to teach just one prep I could sit there and think [about integration]. I'm potentially a far better teacher now than I was in my first ten years, but I feel far more [time] constraints. In some things I feel like I'm doing a better job. In other things I don't feel like I'm real effective because I'm so stressed to try and get everything done....And that's why I get frustrated with three preps. Because this [integration] doesn't always come easy. I have to think. I have to be ready. I think it's a deficient course that just does that [the descriptive material]. If one is just talking about all of this stuff [D], then you can get a robot [to teach].

When asked about where the SMS which he had generated had come from, Alex quickly replied, "Twenty-seven years of teaching." Alex described the process of obtaining his SMS as developmental and went on to describe some of the experiences which he felt contributed to the SMS which he has today:

For the first job I had, I remember sitting down that summer with a copy of the textbook and I can remember asking myself, "What am I going to teach?" I can remember the first time [looking] though the text. There was a page or two where they talked about scientific methods. I can remember thinking right off, "That's boring." I've seen so many teachers just have students memorize the steps. But I knew it could be different. Maybe you have to see both good and bad teaching of a topic. And maybe you have to look around at a lot of bored kids who are thinking "Gee, is that the way scientists think? How boring!"

Alex attributed the difference in his own thinking about the "scientific methods" to his student teaching experience and early exposure to the BSCS curricula. Alex felt that his exposure to both "good and bad teaching" early in his career gave him a "unique perspective" from which to make decisions concerning his teaching. Despite what Alex considered to be a fairly well established image of what he wanted to do in the classroom,
Alex admitted that, "Like most beginning teachers, my first units were based on the textbook."

Alex cited two experiences with textbooks which also helped shape his current SMS. The first was the opportunity early in his career to make a selection among the three versions of the BSCS text. According to Alex, this opportunity "made me think about what I wanted to emphasize at that time." His final selection, the BSCS Green version, also played a large role in Alex's current SMS. Alex explained:

I taught Green Version biology for a long time, and that probably really influenced me a lot about how I taught. But I found that if you use their approach...it took a lot of time. So I combined the units. I spent an enormous amount of time writing and rearranging things so that I could kill two birds with one stone and combine ideas. And then, of course from the very beginning, I was doing a lot of integration of process. I kept mixing and matching and I think this thing [the current SMS] has just developed over the years....So I had it pretty well mapped out in my mind by the time I left my second job to come here.

Alex described the final move to his current job as solidifying many of the conceptions included in his developing SMS of biology. For a second time in his career he had to verbalize and justify what it was that he wanted to do. Alex described the experience as follows:

When I first came here, about ten years ago, I sat down with the rest of the department and talked about the various units that we were going to do. And that was the basis for this [matrix]. Though I don't know if then I would have included all that I have here now.

At the time of the move to his current position, Alex felt that his answer to the SMS question "would have been very similar." However, Alex recognized one area where he may have changed slightly over the last ten years:

I don't think, however, that I would have been as convincing about this part [Teaching Themes]. I have seen enough of it [T] now, and different ways of doing it. I am far more convinced now that this [T] is the way to go. The idea that once you do that [Descriptive material] you have covered the book and the kids know biology, to me, is incomplete. It has got to have this [T] dimension to it or it is not complete.

Experience reconfirmed Alex's early conviction to teach toward process and integration. In addition, Alex admitted that his commitment to continue teaching in this manner was "influenced by how easily I can do some of this." Alex cited a number of workshops which he had attended which helped him refine his teaching of process through the content of the "descriptive material." These experiences helped solidify his personal philosophy and made him a keen observer of the students produced as a result of the various styles of teaching. Alex described the difference between students who just knew their content and those who knew both content and process in the following comment:
I have just seen so many examples [of where teaching for process has made a difference]. I guess I've had so much feedback where "A" students walk through my course and can do all this [Descriptive material], but if you ask them to think critically they can't.... I will tell you this, if I were hiring a science kid to do science for me, I am not sure I would hire a kid that has memorized the content but can't think. Kids that can do that are smart, but they're smart in a dull way.

Summary of Alex

The SMS which Alex held at the conclusion of this investigation can be described as a matrix consisting of integrating components positioned on the two axes: Content and Teaching Themes. The content, or Descriptive Material as Alex called it, consisted of the traditional content which constitutes most biology classes. Though the basic information contained in the content members of the matrix can be thought of as somewhat traditional, their organization within the structure of the curriculum was controlled by Alex through the generation of study guides as opposed to the sequence recommended by the text. Thus, in Alex's case, the textbook was used as a resource rather than the focus of the curriculum.

Alex felt that the organization of the content within the curriculum was relatively flexible as long as the teacher made a point of "building the background" needed for new units and providing the linking ideas necessary to establish connections from the new unit to those taught in the past. As Alex put it:

As a teacher, the sequence that you choose helps you describe the types of connections that you want to make and where to make them. I'm sure that the students don't know the difference [in sequence] as long as you're relating topics.

The content sequence that Alex preferred, though he recognized other sequences as being equally effective, was the sequence which he had taught in the past. This sequence was valued because the connections among content had already been established, process skills had been integrated, and care had been taken to ensure that major content themes such as photosynthesis had been incorporated into several different sections of the content. Changing from this represented a time commitment on Alex's part in order to rethink the structure of the course and concerns created about reestablishing the repetition and reinforcement of key ideas. According to Alex:

If you mix the whole thing up, it's almost like being a new teacher again. You have to rethink carefully about how you are going to articulate these ideas throughout the year.

In addition to the established pattern of course content, the content portion of Alex's matrix was influenced by his academic strengths and preferences, the interests of both Alex and his students, and the academic requirements of colleges. For instance, Alex tried
to rearrange the second semester content in order to ensure the adequate coverage of Ecology, one of his favorite topics and an academic strength. Alex also was willing to leave topics such as DNA/RNA to the end of the year without making a firm commitment to teach them. This lack of commitment came from his own limited background in the areas of DNA and biochemistry as well as a perceived negative student reaction to the topic. Despite these reasons to not teach DNA/RNA, Alex felt a certain obligation to eventually include it in the curriculum since it was part of the content which the colleges expected incoming students to have knowledge of. Student reactions not only influenced Alex's selection of content but also its timing within the semester. When students seemed to get bored or frustrated with the traditional content such as cell biology and chemistry, Alex often interspersed a nontraditional unit to rekindle student interest in science.

The more important members of Alex's matrix were represented by his teaching themes. These themes, which had been developed over the course of Alex's entire teaching career, represented personal philosophical orientations which he felt could and should be achieved through the biology content. These orientations came from Alex's personal understanding of science (i.e., the nature of science and science methods and process skills), the perceived needs of his students (i.e., study skills and critical thinking), and the need to make science useful to students in their everyday lives (i.e., STS issues, ethics, and critical thinking). Thus, the teaching themes did not represent separate content as much as a vehicle through which the content could be delivered, thus "killing two birds with one stone." Prevalent among Alex's teaching themes was the orientation toward inquiry and process skills in science. Alex felt that scientific process could tie together the content through its integration and repetition. If a focus on process was maintained, the sequence of the content became secondary.

Three major types of events seemed to have shaped Alex's ultimate conceptions of the SMS of biology: an introduction to and adoption of a philosophical orientation, reinforcement, and reflection. Each of these ideas, which will be discussed briefly, seem to be a function of Alex's 26 years employed in the teaching of biology.

Many of Alex's philosophical orientations seem to have been established in his early college days. Though Alex was unclear as to whether the orientations which he held toward the teaching of biology existed prior to entering the university, it is clear that the university was the first formal exposure which Alex had to many of the orientations which he still held during the study. In particular, it was at the university where Alex was first introduced to and adopted the ideals of a process orientation, the importance of the nature of science, and the manner in which these ideals could be implemented in the curriculum through the structure of the BSCS curricula.
These orientations, which Alex felt "matched" his own personal philosophies, were reinforced during his student teaching experience where he worked with a teacher who was in the process of incorporating many of the same ideas and teaching techniques. This orientation was further reinforced during Alex's second teaching job where he was allowed to create a biology curriculum using many of these principles with a group of faculty who held similar orientations and who "spoke the same lingo." Finally, these ideas were reinforced again through many workshops dealing with the translation of an inquiry and process orientation into classroom practice.

Though the above mentioned factors in the development of Alex's SMS certainly seem influential, the strongest influence may have been in the area of reflection. Alex found himself having to think through and justify his content and teaching approaches to himself for the first time during student teaching. This reflection was fostered by a cooperating teacher who felt that all labs should be rewritten in order to reflect the personal content goals and orientations of the teacher and to match the needs of the student population with which they would be used. Opportunities for reflection also occurred at the juncture of each new job which Alex accepted. In each situation, Alex was expected to rethink and sometimes verbally justify the mode of teaching which he was about to employ. The most significant of these experiences seemed to occur when Alex moved to his second job and was given the opportunity with his department to design the biology course of their choosing. This reification of philosophy was enhanced by the need to select a textbook for the course, a need which again forced a confrontation with the goals which Alex wanted to pursue.

In addition to the above opportunities for reflection, Alex mentioned that he felt that he had been put in a "unique position" because he had been able to observe both "good and bad" teachers during his career. Such observations and the careful analysis of the students' reactions to such teaching seemed to also influence and reinforce Alex's philosophical orientations. Interestingly, the political strife which Alex felt during the semester of observation may have also acted as a reinforcement for his SMS. Having to defend his manner of teaching against district scope and sequence mandates, state-wide science curriculum reforms, and poor teaching conditions (too many preps, too many students per class, and poor teaching facilities) may have acted to further commit Alex to his initial beliefs. Overall, it seems that the initial impetus for Alex's SMS was formed as a result of his university experiences and was further developed, through reinforcement and reflection, throughout his 26 year career with the bulk of the formation occurring within the first 16 years of his career.
All of the factors listed above may have contributed to the strong translation of Alex's SMS to classroom practice. The SMS created by Alex and the one created as a result of the analysis of the classroom observations are almost identical (with some minor variations in the vocabulary used to describe the various aspects of the SMS and the mode of representation). Such strong congruence may have been possible because of Alex's rejection of the scope and sequence recommended by the text and his option to construct his own scope and sequence through the use of study guides. In addition, such strong congruence would not have been possible without Alex's active reflection on the goals for the course and the purposeful translation of these goals into practice.

Despite the strong translation of Alex's SMS into classroom practice, three threats to this translation existed. The first two dealt with time. Time was a critical factor in Alex's ability to think and plan for the integration he valued. Since the themes which were of greatest importance for him were "not in the book," Alex needed time to be creative with this integration. As with the adoption of the state Common Curriculum Goals, Alex felt a reduction in the time to plan and integrate would ultimately undermine any change since the new teaching techniques would not have a chance to become "ingrained" in routine.

Time was also a factor in terms of teaching content. As Alex mentioned, teaching with a process orientation and teaching for the connection, repetition and integration of ideas was "more time consuming," but resulted in a higher quality of class. This time was being threatened by district mandates to include more content, increases in class sizes, increases in the number of preps per day, and decreases in student motivation to learn the introductory material so they could move on the "more interesting" problems which utilized this information and incorporated more of Alex's teaching themes.

The final threat to the translation of Alex's SMS to the classroom was the students themselves. As Alex stated, students make up a very "real variable" in the classroom. Activities had to be molded to the needs and reactions of individual classes. Some materials had to be avoided until the students felt comfortable with Alex and his "motives," others had to be carefully introduced in order to not "overwhelm" the students and turn them off to the class.

Of the teachers observed in this study, Alex had the most well developed SMS and the strongest translation of this SMS to classroom practice. The key variables which affected this seemed to be the early introduction to and adoption of a personal philosophy, opportunities which reinforced the selected philosophy, and time to reflect on this philosophy and the translation of these goals into classroom practice. Two of these three variables seem to be a function of his 26 years of experience in the teaching of biology.
Ben: Growing to Appreciate Biology

Academic and Professional Profile

Ben's involvement with the study began when he received the general letter of request for participation from his department chair. Friendly and enthusiastic, Ben called to ask to participate the spring before the study began. Ben's initial interview was conducted in his classroom the following fall approximately two weeks prior to the start of the school year. Following a classroom tour of the live animals (snakes, lizards, and assorted rodents), mounted animals (mammals, birds, and insects), skulls and skeletons, the interview convened and lasted approximately 75 minutes.

Ben graduated with a BA in Secondary Education and certification in biology from a small regional state college in Oregon and had completed one summer's worth of classes beyond his BA. Originally intending to be an English and Physical Education teacher, Ben became inspired by an anatomy and physiology class that he had taken, and changed his certification area to Biology. Ben's education coursework seemed to follow a fairly normal pattern with the traditional types of foundations, educational psychology, and methods courses. His science background included introductory sequences in chemistry, physics, health and geology as well as a wide variety of biology classes. The biology courses were classified into the following general categories: natural history, zoology, genetics, health, evolution, microbiology and biological illustration. When asked to describe his content emphasis or specialty within Biology, Ben replied:

Zoology, and I don't know why. I just enjoy that a lot more. To me, animals are a lot more interesting than plants. It's probably that I've been fairly active in the outdoors and things like that. And that [zoology] probably feeds my interest more than anything....I think it is just one of those things where some people like strawberry ice cream and other people can't stand it....I really tried to get interested in it [botany] but...I just get bored with it and I don't know why.

Ben's personal interest in outdoor activities was confirmed by frequent comments about his weekends spent hiking, birding, running, mountain biking or hunting. Ben also spent one weekend during the semester as a volunteer on a riparian habitat improvement project and another bungee jumping.

At the time of the investigation, Ben was starting his seventh year of teaching of which the last three were spent in his current school located in a rural community of approximately 5000 people. Ben's first teaching job was in a very small school where he was the entire science department. There he taught Biology, Environmental Studies,
Marine Biology, Forestry, General Science, Introduction to Physical Science, and a math course when it was necessary. Now one of four full time science teachers in a 9-12 high school, Ben's teaching responsibilities included three science preparations: two sophomore Biology classes, two freshman Physical Science classes, and two semester-long Zoology electives for juniors and seniors. The Zoology classes would be replaced one in Marine Science during the Spring semester. Ben was especially excited about the semester classes because they would allow him to teach the content he really enjoyed.

Reflecting on his college experiences, Ben felt that, in terms of the science content preparation necessary to teach:

There was no problem whatsoever. As a matter of fact, I had to cool it down.....Looking through the basic textbooks and all, I was well prepared...because the content was so much at a lower level.

Later in the semester, Ben was asked about the methods he used to keep his content background up to date. In general, he felt that updating was unnecessary and that his background, as provided through his college coursework, was sufficient. Though he subscribed to a current popular science magazine, he admitted to not reading it because:

The stuff that is taught in high school biology is the same stuff we have known for the last 30 years. Current science research is interesting but it's not really going to affect understanding at this level [high school] of information. Maybe it would affect it at the college level but not here.

Instead, Ben admitted to getting new content information from other high school science textbooks. Having recently gone through a textbook adoption, he was quite proud of the more than 30 textbooks which he had on his shelf though it was unclear how or if he actually used them.

Ben's opinion of his education coursework was not as positive as that of his content coursework. When asked about his educational training, Ben described most of it as "a total waste of time" in terms of preparing him to teach. He continued: "When I first came out, of course, I had no idea what I was getting myself into. College doesn't prepare you well for that kind of thing." Part of this dissatisfaction may have been based on the fact that Ben had never been provided with the opportunity to observe a biology class until he actually student taught. Though he found the biology methods course that he had taken in college very helpful, he did not feel that it was enough to adequately prepare him for the teaching experience. When asked about where he ultimately learned how to teach, he replied:

Here. You learn in the classroom. My first year at X High School was an exceptional experience. It was hard and it was confusing, and most of it was because a lot of things that go into teaching we don't cover in college. You don't cover dealing with administrators, handling paperwork, organizing your time in a sense that you have to have some kind of method
of correcting papers and things like that. All of those things just aren't covered in the classes that I took. So those are the things that you have to basically learn that first year.

In addition to teaching, Ben was involved in coaching. The lack of school funds had reduced the number of high school coaches to a skeleton crew, leaving Ben without a coaching position. Though disappointed and worried that this may later limit his professional opportunities, Ben viewed his freedom from coaching responsibilities as an opportunity to concentrate on his science classes. Later in the semester, several coaching positions opened up at the middle school level and Ben accepted positions coaching three sports.

Ben described the local community as white, conservative, and traditionally of farming or logging backgrounds. He felt that the students were "probably lower level than the average student somewhere else," but admitted to having limited knowledge about this since he had limited experience in other districts. Though Ben discussed adjusting the biology curriculum by attempting to "water it down as much as I possibly can," he felt that the majority of the students were "socially conditioned" to not do well in school. Ben explained:

[Biology] is a lot of work, so they [the students] are conditioned to back away from that. I think they are conditioned pretty badly by their parents. [In response to telling parents that] "Your kid is not doing well in science," the most common thing I hear is, "Well, when I was in high school I hated it." So you know they [the parents] are at home going, "Well, you know it's hard. Just get a C." That's hitting them from all sides. In this school, more than any other place I have ever been, it is not really very cool to be very smart. In fact it is pretty cool to not be very smart. I have a lot of kids that receive grades that are a lot less than what they can handle mostly because it is a social thing for them. They don't want to be labeled a "nerd," that's real important to them.

Ben illustrated the influence of this "conditioning" against working hard in Biology when he discussed the selection of the new textbook which would be used in the Fall:

Kids need diagrams, lots of them, that are simplistic and can tell a story without them reading it [the text]. Because my experience is that they won't read it. Ninety percent of them won't read an assignment that I assign to them. And so what they have to do is be able to thumb through, look at some pictures and get some information that way, and that book [the newly adopted Prentice Hall] is great that way.

In addition to poor student motivation fostered by the attitudes of parents, parental support of education was a concern for Ben in several additional areas. First, he felt that though the parents seemed supportive, few actually had the time to spend with their sons and daughters on homework. Parents were described as "busy... they are 4:30 in the morning to 6:30 in the evening types...[who] don't want a lot of homework and they don't
want to be bothered with it." Ben felt such attitudes contributed to an "overall feeling...that there is no point in getting out of [the community], that everything that you need out of life is right here," which potentially limited the students' motivation and interest in learning. Since economic situations in the Northwest limited future job opportunities in ranching and logging, Ben felt that such attitudes would create "a bit of a problem" for his students, both now and in the future, in terms of being academically prepared to explore other career options.

Second, the community had not been able to pass an education levy for three years. Consequently, lack of funding had forced cuts in athletic programs, transportation, and classroom funds. Of particular concern for Ben was the lack of funds for textbooks and field trips. The biology textbooks from the previous year were over ten years old. Provisions had been made to raise enough money to buy one classroom set of the new text which would need to be shared. This situation was recognized by Ben as awkward but superior to using the old texts. Field trips had virtually been cut from the budget unless the teachers were willing to do their own fund raising. Ben felt field trips were important because they helped generate and maintain student interest in science. As he stated in the interview:

Marine biology was a big draw [of student interest and enrollment] because we are going to go to the coast at the end of the year. We have to raise money to do it now. You have to get them in the classroom and pique their interest.

When asked about the specific advantages that field trips provided but classwork did not, Ben responded that field trips "give kids something that they can go outside and deal with." Ben felt that "whenever the weather was good," that the students should be involved in working "outside doing natural history stuff," and they "wouldn't be doing theoretical garbage. We don't really need to. But we're so clamped into it [the theoretical, that] we never get to go outside."

Though Ben was frustrated by the general lack of student motivation, parental support, and school finances, there were many things that he liked about his teaching situation. For instance:

We have a lot of freedom, it's really nice. We have freedom to create these new classes and total freedom to do whatever we want to make those classes. No one has asked to see what we are doing. They just want to see the name of the class and let us go, which has really been fun....It's a great atmosphere to work in.

In addition to enjoying the freedom in the selection of content, teaching styles, and classroom emphases, Ben made the following comment:

We are in a perfect situation [in this school] where we can relate so many things that are taught in the general biology class to major economic issues
and major ecological issues that are going on right now [the spotted owl, log exports, etc.]. I think we did a decent job of that last year and we are going to do a better job this year. I think you need to try to do that, you need to try and mold your program to where it fits with what is going on with the kids.

When asked during the initial interview about his general philosophy of biology education, its purpose in the curriculum, and the goals he had for his students, Ben did not hesitate with his answer:

I tell them at the beginning of the year: This is what we are doing here guys. We are going to learn a lot of things that are totally impractical for you to ever learn again and I know you will never use. I have two functions here: one is to teach, to try to wean a couple of kids for the field of biology and my second function is to teach problem solving skills. That's what I tell them. They are always asking me: "How come we have to learn this chemical formula of photosynthesis?" And the only reason, the only reason is number one: maybe two of you 60 or 70 kids are going to be biologists and it is going to be important that you know these things. And the rest of you are learning how to do difficult things. Part of learning and part of becoming a better learner is being able to memorize and work out some things that are not particularly pleasant to do but you have got to do them. And that will help you in every day life and every job that you are going to have, I don't care if it's pumping gas or building bombs.

Later in the semester, Ben admitted that his original personal goal was to inspire students to enter the field of biology but lamented that he had failed miserably. He could not think of any students that went on in the biological sciences but qualified this by stating that a few did enter the medical professions. Upon reflection on this failure, he changed his personal goal from inspiring biologists to providing students with a positive experience in biology, one in which they liked him and thought back kindly on the class. By the end of the semester of observation, Ben was adamant about the fact that his job was not to train biologists but to provide a positive experience in biology. The influence of beliefs such as those described above will be developed in future sections of this case study.

Overall, Ben was an enthusiastic and cooperative participant in the study. His sixth-hour Biology class was observed 15 times over the course of the Fall semester, or 17.9% of the days which Ben actually taught. Since this class was followed by his prep period, conversations about the class and his thoughts and beliefs about teaching often extended for 20 minutes after the classroom observation enhancing the information obtained about Ben. Ben's final interview, conducted four weeks after the last classroom observation, lasted approximately 75 minutes.
Course Specific Perceptions and Concerns

When asked about his plans for Biology and the types of activities and content which would be observed, Ben immediately cautioned:

One thing I think you need to know is that I take a pretty firm stand on being different from what I perceive and what kids perceive as being a standard biology/science teacher. I take a lot of pride in what I do. I like to keep it pretty light and I think that's pretty important. I don't sacrifice content to do it, I don't want to and I don't have to.

In the final interview, Ben was asked about this general philosophy of "keeping it light" and "being different." Where did this come from? Why had he selected to teach in this manner? He replied:

One of the reasons is because that is the way I was taught to [teach], I think. Another reason is it gives me the chance to just be me. I don't have to make up somebody else to be.... I think it is a combination of those two, really....

I think about the teachers I had in high school and the classes I enjoyed. Most of them had to do with the fact that they could keep my eyes open and on them [the teachers] most of the time. I would be off day dreaming about something else if it wasn't about half interesting.... There are some times when I don't really feel like it [being funny], but it is still the way it has to be....

And I am going to enjoy my life as much as I can and that makes it a lot more fun for me. That may be the number one reason, because I may want to get my own jollies before anybody else does.

With the tone set by the above statements, Ben described the units which he planned to teach and the rationale underlying the selected sequence.

Ben mentioned that he was prepared to structure his course in two different ways depending on when, and if, the new textbooks for the Biology class arrived. If Ben was limited to teaching from the old textbook, BSCS-Green Version, he would start with ecology and then reverse the order of presentation provided by the textbook to cover units on cell biology, genetics, protists, animals and plants. When asked about the rationale behind this reversal of order, Ben stated:

BSCS does everything backwards and they end the year with chemistry of cells and stuff. Last year we ended with photosynthesis and those kids were about dead. I'm going to end with plants. That's a little easier on them.

Ben said that he would follow his intended order regardless of text. If he had to work with the BSCS books for the year, he would just "start with chapter ten and work backwards" to achieve his preferred order. Unfortunately, this technique of achieving his desired course sequence posed some problems for Ben:
[The problem with using texts out of sequence is that] the textbook authors assume that you have hit every chapter...and they keep using all the terminology from before. That is one of the big things about this book [Prentice Hall] and I have seen it in almost every textbook is that they want to include lots of questions that will weave everything together and include that stuff and that is fine if you were to take all the chapters and study them in order. But no one has time to do that.

Ben elaborated on the advantages that he saw with following the order of the Prentice Hall textbook as well as his rationale behind its selection:

They [Prentice Hall] start from basics [the cell] and go to more complex [ecology]. In BSCS, the whole assumption was: "Let's do it backwards so we can be different so we can sell some textbooks." I really think that was it. They start with more complex [ecology] and go to the simpler stuff [the cell]. Like I said, we have got kids that are sitting there and you are only going to have them [with you] a certain percentage of the time. Why blow them completely out of the water at the beginning and then try and catch them at the end when you can snag them a little bit at a time as you go on? I just like that better.

When asked specifically about the new Prentice Hall textbook, Ben stated again that:

"It's a great book. I really like it. I like everything about it." He continued:

It has questions galore in it so I can assign some homework out of that thing. Mainly it was the illustrations that I used to pick that book. And the organization is really good. It is a general organization but it is really good as far as kind of taking a phylogenetic sequence to it and I love it.

By necessity, Ben was planning to start the year using the BSCS text and following the initial pattern of content organization it contained, which meant starting with ecology first. In terms of the influence of the immanent arrival of the new text, Ben said that he was "planned for it" and would continue to follow the same general sequence he had in mind for the use of the BSCS text. The units he intended to teach were mentioned in the following order from his course outline: environmental biology, basic biochemistry, cell biology, genetics, classification, evolution, protists, animals, and plants. This order generally followed that found in the Prentice Hall text with the exceptions that the ecology unit would be placed first rather than last and the order of the plant and animal units would be reversed. An analysis of the initial list of units which Ben proposed suggested that he had selected to teach some units found in the new text and not others. When asked how he selected the units that he would actually cover and their order of presentation, he replied: "I just sit down at the beginning of the year and say, "What are we going to do?" I pretty much do the same chapters I have done forever."

The two texts which Ben had the option of teaching from differed in their general organization. BSCS covered ecology first, Prentice Hall last. Whether or not the Prentice Hall text arrived in time for the first day of class, Ben had committed to covering ecology first. When asked about rationale behind this placement, Ben replied:
Well, I did that more because that's the sequence of the way it goes in that book [BSCS] and also it's a good time to do it. That's why I love doing the plants at the end of the year and I love doing the ecology [at the beginning]. Before, I did the ecology at the beginning of the year because that is how that book did it and it doesn't really matter. As long as you have weather. As long as you have some plants and some critters to look at... it doesn't matter how you do it [the sequence] as far as I am concerned.

An added advantage to teaching ecology first was that ecology "is easier for them [the students] and more interesting for them." This comment made by Ben is interesting in that he had previously stated that part of his dissatisfaction with the BSCS text was that it started with ecology first and that this content was "complex" in comparison to the more "simple" cell unit. It seems that Ben's definition of "simple" and "complex" had more to do with the relative size of the biological component which was being studied rather than with students' perceptions of which content was "easy" or "difficult" to learn.

Ben's plan was to follow the ecology unit with content on the cell, including the processes involved in cell energy use and transformation. Ben felt that teaching topics such as photosynthesis near the end of the year "nearly killed" his students and that the placement of this content earlier in the year may help. Regardless of placement, Ben had some reservations about spending too much time on the concepts of photosynthesis and respiration:

I am not sure if there is any really good reason to even teach photosynthesis other than that, to me, the basic concept is to understand that energy comes from the sun and that the energy you get also comes from the sun and that plants are important. Even if they just understand that plants produce oxygen, that gives plants, all of the sudden, some importance.

For Ben, the important content relating to photosynthesis had to do with its ecological role and the increased appreciation that the study of photosynthesis can provide for plants. However, Ben considered this content difficult for students to learn and thus maybe not worthy of extensive classroom coverage:

I can understand why misconceptions [surrounding photosynthesis and respiration] happen, you just don't have time to get into it. But, I will tell you one thing, when I do that one section on respiration, I want to give them that test as quickly as I can because that stuff is so tenuous, if I give them the weekend they forget it all... But in reality, with a little more time these guys would be able to do [learn] it. You can do as much as you want but it's how much you want to cover in the long run [that affects your decisions on the time spent on each topic].

The low priority placed on the content of cell energy was in contrast to Ben's concern that his students learn about DNA, RNA, and protein synthesis. This content gained much of its importance since "they will be going into genetics afterwards." Since Ben felt that
there were no deadlines constraining him, such as vacations or breaks in the school schedule, he planned on spending as much time on this unit as was required for his students to "really get this down well." Though Ben's intentions to teach this content to mastery sounded noble, these intentions were compromised by reality:

You can get that [base pairing in DNA replication] through their heads fairly easily, but messenger RNA, no way....I finally got to the point where I said to the heck with it, let's just take the test and get it over with.

Ben was frustrated by his students' poor grasp of the concepts which he tried to teach but rationalized this lack of success on student maturity which affected their appreciation for the content. Ben explained: "They certainly aren't at the age to appreciate it [DNA replication] but we have still got to do it. They just can't get it into their heads why we have to do it."

The DNA portion of the curriculum was a point of concern for Ben in other ways. Though he felt that the content was important, it seemed to take too much time to teach, time which may have been spent doing other content which was "more fun." Ben elaborated on this point of view during the final interview as follows:

[For next year] I am going to take a long look at the genetics part [of the curriculum]. It is just too long to do it thoroughly and there is no way to do it in any less time. And it takes up so much of the year that you don't get to do some of the fun things. I am thinking about just bagging it. Maybe not entirely, but maybe the DNA part....I hate doing that because DNA is important. Everybody has heard about it, but nobody knows what it is. But it's all a trade off because you have no way that you can cover even a third of what you want to cover.

When considering the topics Ben liked to teach the best, he noted a change in his preference over the course of his career. Though originally liking to teach the content in the ecology unit best, Ben now felt that he enjoyed the content in genetics and cell chemistry more. He explained:

I think partly because it is still a tiny bit of a challenge for me. I tend to like the things now that are different than what I liked when I was learning them because the real simple concepts like...ecology, which is very interesting, is also pretty easy once you learn it pretty well. Then it becomes a lot more monotonous [to teach] than the other material. Some of the other stuff, when you have to go back and look a few things up, becomes more interesting for me.

Ben described the community in which he worked as conservative. This perception affected the way in which he taught evolution. Ben described his teaching of this unit as follows:

BSCS doesn't cover it [evolution] very well and I don't believe in spending a lot of time on it either. I think it is a real important concept and I hit on it constantly, especially environmental [evolution]. But I don't see a lot of point in spending a lot of time on it. And usually it's right after genetics
and we have been through a three month long [abstractly-oriented unit] and then I hit it [evolution] for a week or two. If I skim through it I don't get any comments at all. If I was to really hit it hard I know there are some people who would complain, but not a majority.

Throughout the semester of observation Ben consistently described the zoology content of biology as his personal favorite. In fact, this interest and preference influenced his decision to offer a semester long course in zoology. When asked if this preference made a difference in his teaching, Ben replied:

Yes, I know it does because when we talk about plants, basically we sit down and do nitty gritty plant talk for about three weeks out of the year and that is all we are going to do. Any time you talk about relationships, especially about food relationships, you are going to have to bring it [plants] up but I think if I was a major plant guy we would spend six weeks on plant structures and planting plants and classification with plants....but we are going to whip through [plants] and we won't do that much. If I had my druthers we would spend nine weeks just doing the animals. As it is, we won't have enough time to do it [animals] now.

A notable absence in Ben's course sequence was a unit dealing with anatomy and physiology. When asked about this absence and the current role and/or placement of dissections in his class, he commented:

I don't dissect simply because I don't want to do a unit on anatomy because they cover it in health. That frees up a whole six weeks for me to do something else. I also think it's kind of a waste of time [to dissect] and I know it's a waste of animals....I just couldn't justify why it was important to do it, so I just finally said "no."

This attitude about dissections being a "waste of time" was mirrored in Ben's comments regarding laboratories in general. Ben claimed to be in conflict over the use of labs. Though he felt that labs were supposed to be in the curriculum, he felt that they were used primarily by the students for socialization and "playing" with the materials and generally a waste of time which could have otherwise been spent learning content. When he did use a lab, Ben claimed to carefully select labs which were motivating and would pique student interest.

Ben's conflict with the use of labs was interesting in light of the labs which were observed in Ben's classroom. The labs were generally poorly organized and the students poorly prepared for their roles during this infrequent endeavor. Ben's own inability to teach effectively in a laboratory situation may have fostered many of his attitudes. Comments about the actual use of labs in Ben's biology class will be discussed in his Classroom Profile.

Of equal interest, when asked during the final interview about the parts of his curriculum which he might change if he had no constraints, Ben mentioned that:
I would probably try to do more hands on stuff than we do even though I am not a crazy lab person, I'm really not. I think a lot of people waste more time than they have to [in lab] and you limit the amount of material you can get across by doing that. Again, I don't see myself as somebody that is training biologists. And I am also keeping a real open eye during lab situations and I see that they [the students] are probably less on task during lab activities than they are in non-lab activities. And from every thing people tell me it's supposed to be the other way around. It may be the way I do it, which could very well be. Regardless, I am not as excited about it [labs] as a lot of other people, but I would do more. There would be no doubt.

During the initial interview, Ben had quite proudly displayed his collection of 30 or more high school biology texts and curriculum guides. Ben claimed that these materials were his primary source of content information and new teaching materials. When asked how he selected materials from this vast resource, Ben explained:

It's just like picking a car. I like that shade of the color red. That is exactly what it is. I go through and think "which one of these things is going to [do what I need]." Number one, I look for illustrations. I look at the materials [list] probably the first thing because if we don't have any of that stuff we can't do it. And I look at which one has the most precise drawings and which ones are going to be the easiest for the kids because that is real important...Different labs can get the same exact concepts across but it's just not as hard.

Ben selected his sixth period biology class, the last class of the day, for observation. Though he originally described this class as "rowdy," he felt that they would be representative of his biology students. This timing also provided additional time to talk after class if so desired.

Though the class had 32 students on the roll there rarely seemed to be more than 27 students in attendance on any one day. Ben described his classroom population as "fluctuating" with daily differences caused by absences and long term differences though class section changes or school drop outs. Despite the changes in student clientele, the class seemed to maintain approximately the same number of male and female students throughout the semester.

Ben described this class as "pretty close to the middle" in terms of both academics and behavior. Having had most of the students previous years, he sometimes worried that they would "blow things out of proportion" at the beginning of the year, remembering that "Mr. B. was a fun guy and this is going to be a fun class." Ben felt that much of the first part of the year was spent "reeling them [student] in and yanking on their reins" until their behavior settled down to a acceptable level. Though frustrated by the size of the class, Ben commented that "if you can keep a decent amount of control with that many [students] you are doing all right." On a scale of one to ten, Ben rated this class as a seven in behavior.
When asked to describe his ideal biology student, Ben replied:

The best kid that I could have is a kid that does all of his homework and participates in class and adds what they know about life to what I am talking about. That opens it [the content] up a lot. It's hard for me to come up with examples while I'm teaching. For instance, if we're talking about relationships and I am trying to explain classification system... it's nice to have a kid that sits in the middle of the room and goes, "Yeah, what about a fox and a dog?" That's the ideal situation [and student] for me.

Keeping this description in mind, on an academic basis, Ben rated his sixth period class at "about a five, they are about average." When asked about how a group of "tens" would influence his teaching, Ben described such a class as "self motivated" and "having the intelligence to take it [the content] a step further." Ben elaborated on the difference such a class would make in the following manner:

Ben: It is kind of refreshing when somebody says, "Well what about this and what about that?" Usually that's the kid who's thinking and actually paying attention and letting the process go a little bit. That's more fun.

The thing that we don't have in that [sixth period] class is we never have, or I shouldn't say "never," but we don't very often have somebody ask a question that stretches what it is that we are talking about. They sit and take it real well and they write it down and memorize it and they go through the motions, but they're not really going crazy to learn more than they absolutely have to.

Researcher: So they're not doing any extended thinking at all?

Ben: Heck no! That burns calories.

Ben obviously valued a student who paid attention and provided him with examples which would enhance and extend the content as well as make the content relevant.

In light of the comment that Ben made above, it is interesting to note that Ben had earlier described one of the important aspects of Biology as being the teaching of problem solving. Despite the stating of this goal, Ben seemed to feel no personal responsibility toward "pushing" his students to think about the content or to "stretch" their thinking. This responsibility belonged to the student. When such thinking did occur, it was viewed as a "treat" for the teacher, to keep him and the rest of the class interested and motivated.

Three primary variables seemed to affect Ben's thinking about biology, the goals he established and the probability that these goals might be achieved. These variables were student interest, time in the classroom, and student "maturity" as it affected their learning of the biology content. The influence of each of these variables will be discussed separately. The interaction of these variables within the overall picture of Ben's class will be illustrated in the following section of this case study.
The importance of personal and student interest was discussed by Ben throughout the investigation. In some cases, personal and student interest seemed to be the prime motivation behind content selection and implementation. In other cases, interest was mixed in with the influence of traditional teaching as Ben had experienced it. When asked to describe the primary influences on his teaching, Ben stated:

What I like would be number one. And what I think they [the students] would like would be number two. And then probably what I have had in the past done for me. Again, I don't draw on that [my own experiences] that much consciously because I don't remember my biology class in high school. I remember my biology teacher real well and I am not very much like him. But I think in a lot of ways, in some ways the note taking part of my class and the lecture part, is really oriented after the way he did that.... I think those three things together would probably be it, definitely.

The idea that the content should be centered around the interests of Ben and his students had created a consistency problem between what Ben was doing and what he believed he should be doing. This lack of consistency concerned Ben. He explained:

I am at a point of major uproar and turmoil. I am going on my eighth year of teaching and again, I just did some big soul searching this year....I am really taking a hard look at what I want to do and it's like I'm at a crossroads right now where I am looking hard at it and asking myself, "Is what I am doing the right thing and do I want to change some things?" and I think I will.

When asked about the specific types of changes that he would like to implement, Ben replied:

I think that what I want to do is take a long look at the 40 chapters in that biology book and instead of saying "What were the 40 chapters that I learned in high school?" or, "What 40 chapters would my college professor probably like to see these kids have some background in?" I might say "We have a responsibility to the profession and we have a responsibility, to a certain extent, to the colleges but we also have a responsibility to the 60% of the kids who aren't going [on to college]."

To Ben, the enactment of this responsibility in terms of the classroom meant to use student interests as a primary factor in the selection of content. He discussed the impact of student interest as follows:

I am committed, and we made this commitment in our department and I have made it personally, to make it [biology] more interesting to the kids than it is. I can see how some of the stuff is dry and boring and not any fun.

I have continual flashbacks to when I was in high school and I just know perfectly well what is going to bore them and what is not going to. I am always tugging with my agenda versus what they might want to hear and my agenda usually wins out but I'm not sure that is such a good thing.
Let's do something that they might have fun with. Every year I've skipped the chapter on extinction of animals and paleontology and stuff because we don't have time to do that, but I think they would enjoy that. And I have avoided some of those things because I don't know much about them but those are things that I think they would like to do.

It is interesting to note that Ben felt able to predict his students' interests. This prediction may not be a reflection of how the students felt as much as it may have been a reflection of how Ben felt concerning his own personal interests in biology.

As many other quotes in this case study attest, the selection of class materials and their style of presentation were greatly influenced by the idea of interest. In some cases, the importance of interest threatened to undermine the importance of adequately teaching content, as the following incident illustrates. One day after class, Ben discussed the fact that one of his students had brought in a ferret. Since the ferret had never hunted before, he had decided to use it for classroom observations to help students determine if hunting was instinctual or learned behavior, a seemingly excellent idea. As part of this conversation, Ben mentioned how interesting he thought this activity would be, but how he felt guilty if he did not teach his students a little bit of "biological theory." To Ben, including theory meant having the students do worksheets on predator-prey relationships which he felt were boring. This instance was the second time that Ben brought up the idea that "theoretical biology" was associated with a boring presentation style (an earlier reference to this idea claimed that the theoretical components of the curriculum limited the opportunities to be involved in field trips). Additionally, Ben did not see any potential in using the ferret or other more interesting instructional styles as a means of teaching "theoretical biology." It is possible that this definition of teaching may also be a function of Ben's own school experiences or the lack of science education training and experience.

The format of and teaching style in Ben's class was also greatly influenced by concerns for time. During the interviews, Ben explained that he usually thought of a unit as lasting two weeks. When planning his units Ben outlined the general activities that he wanted to do, listed them in sequence, and then worked on his day-to-day planning as it was needed. Though he claimed to evaluate student progress and use this information to adjust the schedule and ultimate length of the units, Ben commented that "it always seems like there is a deadline somewhere." In a large majority of cases, the deadline seemed to be a break in the school calendar such as a three day weekend. Since most of Ben's units seemed to require more time than he had available between these breaks, he was often put in the position of having to adjust his schedule. Ben explained the effect of interruptions in the school schedule as follows:

They [breaks] kill you. They completely tie your hands....I like to end things up by three day weekends. Every two weeks there is a vacation of some
kind and I don’t like it. You have to take the test tomorrow, and you’re not ready. The kids aren’t ready. They could handle one more day but there is no way you are going to do it [take a test] after a three day weekend because you have to spend another two days to get them back to where they were and you just run out of time.

The concern Ben stated above has been echoed in other comments made in this case study. For instance, tests on respiration were given quickly because the understanding of the information was too “tenuous” to survive a weekend break. But Ben realized that adequate time on a topic was what was needed in order for his students to master the content as the following quote attests:

But in reality, with a little more time these guys would be able to do [learn] it. You can do as much as you want, but it’s how much you want to cover in the long run [that affects your decisions on the time spent on each topic].

When Ben felt no constraints by deadlines such as breaks in the school calendar, as he did with the DNA unit, he felt that students could learn the material and he was willing to take the time necessary to do this. (It is interesting to note that the semester ended midway through the genetics unit and Ben did not feel that this was a significant reason to cut the unit short.)

As a consequence of trying to fit many of the units into the framework provided by the school, Ben admitted to “watering down” the content in an effort to get it all in before a test or eliminating “unnecessary” elaborations as illustrated in a comment made by Ben to his students: “I was going to show you the way ions separate in solution but it doesn’t really make that big of a difference. I’m running out of time and that is a bigger problem.”

When asked about the fate of the original sequence of activities which had been established at the beginning of each unit, Ben replied: “I usually just throw something out, whatever was at the end of the unit.”

It is obvious from these comments that Ben felt a great pressure to squeeze units into the periods of time between interruptions in the school calendar. When time ran short, topics were arbitrarily cut from the curriculum or watered down. Thus, time rather than the nature of the content, the meeting of specific instructional objectives, or the teaching to student understanding dictated the length and ultimately the content of many of Ben’s units.

The final variable which affected Ben’s realization of the curriculum he claimed to want was the idea of student maturity in terms of learning the content. When asked to describe his ideal student, Ben characterized this person as one who paid attention, took initiative, and was an active participant in both the class and their own learning. This description strongly contrasts that usually provided by Ben about his students. In most cases, Ben felt that his students were poorly motivated, could not be relied upon to do their homework,
and needed pictures in the text because they refused to read. This contrast may suggest that Ben held generally low expectations for his students. Evidence of these low expectations can be found in a comment made by Ben asked to describe the knowledge which he felt his students would have as a result of completing the first semester of biology. Ben replied:

I think they know very little and I think that that is okay because again, you would have to hit them with the same thing three or four years in a row before they would know very much of anything. The nice part [about the biology class] is that it gives them some basics that they can build on. If they are put in a position where they need to know something, they have some background so they can handle it...

They could do simple things [like recall having heard vocabulary terms], no problem. What they would have a hard time doing is coming up with specific facts and figures which is okay... I think they can pick out some terminology, they can pick out some concepts. They can say, 'yes, we talked about that but I don't really know [what is was about].' and then you might even be able to ask them specific questions that they would come up with some things [in response to]. But it is impossible to teach kids to remember every little bit of what they did. And they remember different things, mostly having to do with experiences that they had, positive or negative.

The idea that a true understanding of biology takes years to develop was mentioned by Ben in the above comment and elsewhere. It is possible that this rationale was used by Ben to feel less responsible for the lack of success which he sometimes experienced with his students and may account for his acceptance of relatively low expectations for his students' learning and success. Ben's following comment illustrates how the understanding of some content took him many years to achieve. This comment began in response to an observation that Ben seemed to link student success with enjoyment:

You are going to have more success in the things you enjoy doing. I really believe it's kind of a "Skinner" type thing. You have to turn them on and they're not going to like it if you don't turn them on. It is hard to turn them on to genetics. Why, I'm not sure I can reason that out. [Maybe] because it's difficult for one thing and nobody likes a good challenge, or not very many of them do. Also, the whole thing [genetics, cell biology, DNA and protein synthesis, etc.] is such an interwoven situation that we get to that point [in genetics] where they barely have a hold of everything and it is hard for them to really get a good grip on it and put everything together to make some sense out of it. Because at the end of genetics, ideally, you should be able to say "wha-la", and everything [about biology up to that point] should be clear.

Really what it is, and I remember when I took evolution, I took genetics the first time and it was exactly the same thing. It was, "I have everything but it doesn't mesh very well." It takes a long time, I know. I took genetics twice in college. I took human genetics after I took regular genetics and the
human genetics was so much funner for me because then it started making sense because I had time to process it and make it come together.

I think they [the students] are in that position. They will remember some things but I know from asking questions in class, that they just can’t pull it together.

When asked about what it is that students need to pull all the content together, Ben replied simply: "Maturity." When asked if anything could be done to facilitate the making of these connections by students, Ben responded:

I don’t think it’s our function to do that, I really don’t. I think it’s our function to plant that little seed [that everything is connected] in the back of their minds and then, later on in life when it becomes important to them and they have enough basics they can go and read something, then, without ever realizing it, they will probably draw on some of that hidden knowledge that they had [this content] before and it will make some sense to them. I think in the limited course that we have - even the whole idea of biology in eighteen weeks is ridiculous - that it’s not going to happen. It takes years and years of study just to get a general concept of what it [life] is. I don’t have any pretenses or misconceptions about doing that. You always have a few that are going to come out in the end and understand everything and it’s going to make sense, but the average kid, I don’t think they really need to [put everything together].

Ben had other personal experiences which lead him to believe that only maturity would lead students to the ability to put all the content together for themselves. For instance, early in the year, Ben had mentioned how much he had hated mathematics as a student. But, by the time he had reached the age of 25, Ben found that he had grown to appreciate the subject. His experiences with biology, as illustrated above, were similar. In his own experience, much of his personal appreciation and understanding of biology came later in his college experience because he "had time to process it and make it come together." Since he assumed that the experience of his students would be the same, Ben saw little value in dealing with higher order conceptions because "they are not as mature as they are going to be eventually. If you had 25 to 30 year old people taking biology, they would enjoy it immensely compared to what they enjoyed as 15 year-olds." For Ben, there was little reason to deal with topics beyond memorization because his students didn’t have the maturity to deal with them. When students finally were able to pull the content together for themselves, then Ben felt that they would appreciate the content in a way which they could not before. It may be experiences such as these which inspired Ben to make comments such as: "They certainly aren’t at the age to appreciate it [DNA replication] but we have still got to do it. They just can’t get it into their heads why we have to do it." Ben’s students would simply have to wait and gain the maturity needed to develop an appreciation for and understanding of biology.
Classroom Profile

Despite being near the end of the school day, Ben’s students generally seemed excited about coming to class. Many of the students, especially the females, would enter the room, walk immediately over to Ben and start a conversation. Rarely did these conversations have anything to do with biology. The students just seemed to like Ben and enjoyed telling him their stories.

During these first few minutes prior to the start of class, the students would pick up their assigned copy of the textbook from the bookcase in the front of the room. When they returned to their seats they would talk quietly or finish up a past assignment out of the text. At the bell, Ben usually made some sort of announcement that class had begun and would then use the first 5-10 minutes of the class period to take attendance and to deal with class-related issues such as make-up work or missing textbooks. The students rarely changed their pre-class behavior during this time, nor did Ben seem to expect them to do so. For instance, the students were not expected to have their books open or to be working on a warm-up assignment.

Once roll was completed, Ben called the class to attention for the second time by asking them to open their notebooks and label them with the day’s date. On approximately 50% of the days (as determined by analysis of lesson plans), this class opening was followed by a lecture which lasted 20-25 minutes. On other occasions, students may be given the entire class period to work on an assignment from the text or a worksheet. Labs and activities were infrequent, occurring only 9.5% of the days during the first semester.

Lectures were usually accompanied by notes which Ben wrote on the board as he talked. Ben’s use of the board often had him standing in front of his writing and talking to the board. This poor board technique was compensated for by Ben’s booming voice which could still be easily heard by the students. The lectures were generally dominated by Ben. He often walked out into the room and addressed his students but rarely asked them questions which required much thought. When questions were asked, they were generally of a lower level nature and required only short, one or two word responses. As a result of this questioning style and Ben’s somewhat informal classroom atmosphere, most questions were answered through callouts. These questions seemed to be used to “keep students awake,” rather than assess student understanding of the lecture material.

During these lectures the students were expected to write down everything that Ben wrote on the board and to pay attention. In addition, students were expected to follow the content presentation along in the text and look at the pictures provided there. Ben explained:
It [the book] gives the kids a chance to look at some pictures while we are talking in front of the class....If they are going to space out and they are going to about 40% of the time, they might as well be spacing out at something that has to do with what we are doing. The kids have already gotten conditioned to going and getting it [the book] and turning to the right page because they know I am going to lecture out of the book. In fact, they will catch me every once in a while. I will say something stupid and they will say, "it says right here..." or, "you spell it like this..."

Despite seeming to follow the text closely, Ben generally did not cover the content of the text in much detail. In fact, the content was often delivered in a superficial manner and was admittedly "watered down" because Ben had run out of time or he felt that the level at which the content was presented in the text was higher than the students could handle.

Ben often seemed apologetic when his class involved lengthy periods following a "traditional" classroom format. For instance, Ben occasionally started his Biology class with comments similar to the following:

I will make apologies to start off with. Yesterday most of you weren't here, so we will have a lot of catching up today. It is going to be a pretty hard note-taking type day. One of my goals for the year was not to have very many days where we took notes the entire period because that is really boring. We haven't done that very often so far, but today we are going to end up doing that most of the period. We have to catch up from yesterday.

To keep the lectures light, a big priority for Ben, he often inserted stories about himself or used the students' names to create examples which might make the content more concrete. The following two excerpts illustrate this lecture style. In the first example, Ben is lecturing on valence electrons as part of the introduction to his biochemistry unit:

Ben: Four valence electrons, good. Randy, is that a strong atom or a weak atom?

Randy: Well, a little below average. (Another student has called out: "It shares.")

Ben: (laughing) It is right in the middle. Right on average. It is right in the middle. It's not strong enough to steal electrons and it's too strong to get electrons stolen from it. It's kind of like a regular guy. [It's as] if you have the toughest atom in the world, that would be me, and the weakest atom in the world, that would be Don, and somebody in the middle would be like Randy. (students laugh)

In the second example, Ben is talking about solutions. In providing examples of solutions, Ben brought up the possibility of dissolving mothballs in alcohol. Following this comment, a female student interrupted the lecture:

Female Student: Who wants to dissolve mothballs in alcohol?

Ben: Who wants to dissolve mothballs in alcohol? Hey, when you're single and 31 in [town name], you do a lot of crazy things on weekends. That's what I do. (Students laugh.)
To help his students understand the often heavy vocabulary load associated with biology content, Ben often found ways to try and relate concepts and vocabulary to the students' lives. For example, in one instance Ben had students form an analogy between the structures and functions of the cell and the parts of a factory. This activity was introduced with the comment: "One of the things that makes it easier for me to remember [concepts and terminology]...is that I relate them to something in my real life." Ben used similar logic later in the year when he described his technique of remembering which of the base pairs of DNA nucleotides matched:

You need to get something in your own life that you can kind of compare this to. For me it is real simple. Cytosine goes with Guanine. Those are my initials, C.G. G for G____, and C for Mister....Just like mitosis. If you can memorize how the first letter of those words go together, then the words themselves come later and it's real easy for you.

Following the lectures, Ben usually assigned some sort of an assignment out of the book or gave the students time to finish up a past assignment. This use of time was important since the students were not allowed to take the textbooks home. A typical assignment would be to construct a vocabulary list with definitions from the chapter or to answer the questions either in the text or at the back of the chapter. On some occasions, this time following the lecture was used to complete a worksheet or activity sheet which expanded on the concepts covered in the lecture.

Early in the semester, the students generally worked on these assignments in small groups. This group formation was usually done with a minimum amount of disturbance since the students had selected their own seats and were generally sitting next to their friends. Simply sliding desks together had been sufficient to create these groups.

Following the second test, Ben felt that these working groups were fostering more socialization than productive work. He changed the seating arrangement to break up groups of friends and required the students to complete their work on their own. He often commented during this time how "cooperative learning is a bunch of crap. It just doesn't work." From this comment and others made by Ben, it seemed that he defined cooperative learning as occurring whenever two or more students worked together. To him, this work arrangement generally meant that one student did all the work and the other student copied it, hence his dissatisfaction.

No specific system for students getting help while working at the end of class seemed to have been established. Students either got up and went to the front of the room where Ben was, or they raised their hands and waited for Ben to come help them at their seats. The technique used often depended on the location of the teacher. In most cases, Ben was out in the room working with students so raising one's hand was usually effective.
The students often complained about not knowing what to do or not knowing how to answer the questions included in their assignments. Ben usually complained that this confusion was due to student laziness and their desire to be told the answers to everything. Ben never seemed to associate these problems with his own level of content coverage, the degree of preparation he provided for students prior to the assignments, or the limited use of student feedback during the lectures to assess student understanding. Despite his complaints and assignment of blame, Ben was very supportive of his students when he worked with them, often kidding around, putting a hand on their shoulder when helping them, or patting them on the back in recognition of a job well done.

Ben rarely did anything to break away from a fairly traditional teaching format in his biology class. This observation is interesting when one considers how adamant Ben was in describing his classroom delivery as non-traditional. Ben obviously found lectures and worksheets boring, but did not seem to change based on this belief. It may be that Ben's use of classroom humor was what made him characterize himself as non-traditional. It is also possible that Ben's non-traditional style was more evident in other classes. For instance, it seemed that Ben felt more freedom when it came to the structuring of his Zoology class than he did with his Biology class. This may explain some of Ben's excitement about teaching the Zoology and Marine Biology courses in addition to his more traditional course load.

Labs and other activities were used in Ben's class only 9.5% of the time. This percentage was mostly composed of pencil and paper activities. As Ben had previously mentioned, he did not consider himself a "crazy lab person" and did not feel that labs were an effective means of teaching or reinforcing content. Some of the reasons behind these feelings may be found in the manner in which labs were actually conducted in Ben's class. The few labs which were observed in Ben's class were poorly organized and ineffectively conducted. The students were poorly prepared to engage in the unfamiliar lab activities and time use was very inefficient. For example, Ben provided his students with the opportunity to observe the stages of mitosis using microscopes and slides as part of his Cell Division unit. This instance was the first time that students had been allowed to use the microscopes the entire year so much of the lab time was spent teaching the students how to focus the microscopes. Rather than taking a few minutes to cover this skill in pre-lab, Ben attempted to cover this skill in conjunction with students trying to find the mitotic stages. This ultimate task was complicated by students not knowing what they were looking for and the use of two different types of slides: onion root tips and whitefish blastula. The result was an inability of students to find what they were looking for unless Ben was specifically helping them. Lab tables without Ben's assistance spent the time...
talking after they had reached their threshold of frustration. By the end of the class period, several of the lab group had not yet managed to get their microscopes focused on medium power so that they could attempt to look at the stages of mitosis. All in all, the lab was an inefficient use of time, as Ben had believed all along.

No special routine for the formal closure of the class period occurred. As the end of the period approached, the students individually turned their papers into a box located in the front of the room and returned their books to the book case. Since this class was the last of the day in the room, the students put their chairs up on their desks and waited by the door for the bell to ring. On several occasions Ben had to request that they remain in their seats until he told them to put up their chairs in order to prevent students from stopping work too early in the period.

As Ben stated earlier, a unit usually lasted approximately two weeks with tests often scheduled for the day before a three day weekend or school vacation. Since Ben did not feel that his students did well on the tests, he usually ran a study session in his classroom the night before the test. To encourage attendance at these sessions, Ben often offered to provide snacks for the students.

Ben's tests were usually about 50 questions long. The questions, which usually came from the test bank which was provided with the text, were short-answer, objective questions. These questions usually tested lower level understandings (83%). The few higher level questions (17%) included on the tests could typically be classified at the application level. Essay questions of any length were rare.

Semester tests were required by the school. Ben felt that these were "ridiculous" because high school students had too many classes to seriously spend any time studying for the exams. For this reason, Ben gave very little weight (in either emphasis or grade-wise) to the semester test scores, though he claimed to tell the students otherwise because "it's hard enough to get them to take these seriously as it is." Ben's semester exam was 120 questions long and also consisted of questions selected from the test bank. Many of the questions were the same as those found on the unit tests. Overall, the test seemed representative of the topics covered during the course of the semester.

**Classroom Subject Matter Structure**

Ben taught the following units in the sequence listed during the semester of observation: Introduction to Biology, Ecology, Understanding Life, Basic Chemistry, Cell Biology, Cell Energy, Cell Division, DNA/RNA, and Genetics. It was based on the data collected from these units that Ben's classroom SMS (Figure 5) was generated. Methods
for the derivation of this SMS can be found in Chapter IV, Textbook Subject Matter Structure: Methods. The reader is referred to this section if questions concerning methodology arise. In addition, the evidence used for the generation of the SMS can be found in Appendix H and cross referenced to Figure 17.

In general, Ben can be described as following the content sequence proposed by the text in use. The reader is reminded that Ben began the year using the BSCS-Green Version text. As a result of starting the year with this text, Ben provided his students with an introductory unit which focused on the use, construction and interpretation of graphs. According to Ben, this material was included because "BSCS has graphs all over the place and they [students] have a hard time reading them." This content was followed by basic science process skills, content which Ben seemed to have included by his own choice. It should be noted that the first chapter of the BSCS text moved directly to the Ecology content. Thus, an "Introduction to Biology" chapter was not included in the text and was of Ben's own design.

Ben moved to the exclusive use of the BSCS text in terms of selecting and sequencing content once he began his Ecology unit. Seven days into this unit, the Prentice Hall texts arrived. Ben immediately switched to the content in the new textbook and finished the unit selecting additional content from Chapters 36 and 37.

Ben followed the Ecology unit with the Understanding Life unit, Chapter 2 of the Prentice Hall text, and then systematically followed the content provided in the Prentice Hall text for the rest of the semester. The only other observed variation from the textbook sequence which occurred was in the division of the textbook's Cell Reproduction unit into two smaller units: Cell Division and DNA/RNA. It is assumed that this division was done for ease of content presentation and to decrease the amount of content covered on any one test.

Classroom observations were scheduled during all units taught by Ben. Ben had only started the introduction the Genetics unit during the last two days of the first semester. Thus, the lack of connections surrounding this unit may be a result of the limited number of observations made and the introductory nature of the lesson which was actually observed.

In looking at the SMS generated through the analysis of Ben's classroom transcripts and materials (Figure 5), two major components can be identified: introductory units with limited connections and the closely connected units which surround the cell biology content. Each of these components of Ben's SMS will described separately in the paragraphs which follow.

The units which occurred at the beginning of Ben's school year seem to lack the level of integration which can be seen in other components of his SMS. For instance, the
Figure 5. Ben's Classroom Subject Matter Structure.
Introduction to Biology unit, even though it seems to have been tailor-made by Ben, is only occasionally referred to during the remainder of the year. It is possible that an explanation for the limited use of this chapter in the future may be found in the move from the BSCS text to the Prentice Hall text. Since this introductory unit was designed specifically with the BSCS text in mind, Ben may have no longer felt that the content in this unit reflected the needs of the new text. However, this explanation seems weak when one considers the generic nature of the content presented in this unit. The content in this unit which received the most attention dealt with the use of scientific methods to develop theories, an issue that Ben spent relatively little time on (less than 20 minutes of a nine day unit). The primary connections radiating from the Introduction and Understanding Life units seem to be centered around examples of concepts which may be described in more detail in future units (i.e., Human Biology and Organisms). For this reason, these first two units may be thought of as introducing students to science, but not really teaching them any critical content.

The Ecology unit did not seem to be an integrative force in Ben’s SMS even though he selected to teach this unit first. This may be explained by Ben’s rationale (presented earlier in this case study) behind the selection of this unit to start of the year. The book sequenced it at the beginning, and the nice weather made this unit a logical choice. It is interesting to note that at no time during this unit did Ben take his students outside.

It is possible that the relatively unconnected nature of Ben’s first three units may be attributed to the change from one textbook to another. Since Ben seemed to follow the sequence and content of the text quite closely, the change from one text to another may account for the fragmented nature of the connections found among these units.

Additional units of only loose integration were Evolution, Human Biology and Organisms. Evolution was only implicitly referred to by Ben during the first semester. Classroom situations arose in which opportunities to discuss organism adaptations and changes over time but in such situations evolution was only alluded to and never directly discussed. In other cases the formation of connections to topics outside the realm of the current content was outright avoided. (Potential reasons for this avoidance will be discussed later in this section.) The following lesson segment illustrates this last point. This conversation occurred during a discussion of the cell theory. Ben was interrupted by a student with a question. Note how he brushes the question concerning the origins of life off and chooses not to discuss cell evolution even though it represented a perfectly appropriate point in the content to do so. This appropriateness becomes more apparent when one realizes that Ben’s next topic of conversation concerned prokaryotic and eukaryotic cells:
Ben: All cells come from other cells that were already there, right?

Female Student: How about the first cell? Where did it come from?

Ben: Well, the first cell, that's a little bit of controversy. We are not really sure. We have two kinds of cells, and that is what we need to talk about today...Prokaryotic means "before the nucleus" or "no nucleus." This type of cell (pointing to a drawing on the board) is called a eukaryotic cell. Eukaryotic meaning that the nucleus is present. So, we have two kinds of cells.

Human Biology and Organisms were used occasionally as sources of examples. In most cases, these examples were used to tie abstract concepts to concrete representations. In other cases they were used as a source of humor in the classroom. It should be noted, though, that the use of such examples decreased as the semester progressed.

In Ben's classroom SMS, many of the units taught in the middle of the year seemed to be much more closely interconnected. Many of these connections seemed to focus around the topic of Cell Biology or the basic structures and functions of the cell. The development of this topic relied on content concerning Basic Chemistry and Cell Energy which, themselves, were tightly interwoven through the concepts of energy transfer and the chemical structure of matter. Cell chemistry again became important in the discussion of DNA and the synthesis of cell components. Within all four units, both forward and back-reaching connections could be found, tying all the content together.

It is interesting to compare the integration of the cell biology units in Ben's classroom SMS to the rather loose relationships established by the textbook for the same units. Since Ben followed the content of the text quite closely it seems obvious that these connections resulted from Ben's own content understandings rather than from the presentation of content in the text. Thus, Ben's interconnections among topics can not be simply attributed to the use of a single textbook for the selection of classroom content.

It is a little less clear how the units of Cell Division and Genetics fit into the interconnected cell biology units discussed above. Connections could be found which linked these topics to those discussed earlier. In particular, Cell Division seemed to link the content developed in DNA/RNA and Genetics units. However, the strong cross referencing seen in the other units was not found. A contributing factor to such an observations may be the limited number of observations which took place in the Genetics unit.

Only weak evidence existed of the presence of themes in Ben's teaching. Topics involving the History of Science (HofS) were introduced at length in three of Ben's units. It is interesting to note that the discussion of the HofS closely followed the information introduced in the text in two of the units (Understanding Life and Genetics), but included
information not in the text in the DNA/RNA unit (a short description of the unraveling of the DNA code by Watson and Crick). Science-Technology-Society issues were only introduced briefly in the Ecology Unit. It may be that Ben was saving many of these topics for the end of the school year since he seemed to feel that they were controversial (as reported elsewhere in this case study) and would have less of a potential political affect on his career is placed at the end of the school year.

In many ways it was surprising to see such an integrated orientation arising through the analysis of Ben's classroom data. The impression imparted through the simple observation of Ben's classes was that content coverage was superficial and often purposely limited to a discussion of the concept at hand. Evidence existed which verified these impressions, but this same evidence can also be used in the interpretation of the SMS which was generated. The two factors which contributed to the impression of the limited interaction of the units were issues related to time and the oversimplification of the content. Both of these factors will be discussed in detail. In addition, two other factors which influence the general interpretation of Ben's classroom SMS will be discussed: Ben's incomplete content knowledge and the overwhelming influence of the textbook.

A consistent theme running through Ben's comments about the teaching of biology (as presented elsewhere in this case study) was the issue of time. This theme was also evident during the classroom observations. Time seemed to affect the quality of the content presented through Ben's inability to adequately cover content which he felt was important. The following comment taken from Ben's introduction to the Basic Chemistry unit illustrates this point:

"We are going to be spending a little bit of time, not a whole bunch but a little bit, on chemistry because much of what we are going to do throughout the rest of the winter is going to have to do with chemistry....Now, one of my pet peeves in science is that I want people to understand the difference between mass and weight. However, we don't have a whole bunch of time to go into little Miss Picky things like that. So for our purposes, they mean basically the same thing."

Note how, in the above quote, Ben commented on the importance of making the distinction between mass and weight but seemed unable (or unwilling) to justify the time that it would take to teach the content. A similar reduction of content coverage was found in Ben's presentation of organic molecules at the end of this same unit. Ben introduced the last day of content coverage on this unit in the following manner:

"I have some good news and some bad news. I already gave you the bad news and that is that the test is going to be Thursday. The good news is that we have a rather large amount of the chapter left to do and we are going to shrink it and take out all the hard stuff and give you the easy part of it. (Sarcastic groan from the class.)"
I knew you'd hate that. In reality, if I was going to cover this stuff with any kind of proficiency whatsoever we would spend at the very least a week doing this section. But it's not as important as getting through this chapter and giving you guys an opportunity to raise your grade one notch before [the end of the quarter when] your parents try and kill you [after they see your grades].

The lecture that proceeded was one which Ben described as his "twenty minute watered down version of all of organic chemistry," a time estimate which was quite accurate. For Ben, it seemed that getting through the content was more important than having the students actually learn the content in any depth of detail. Similar examples can be found throughout Ben's classroom transcripts. In many cases, the necessity to "rush" through content seemed to be stimulated by breaks in the classroom schedule, such as three day weekends and vacations. Having to cut units short bothered Ben, as can be noted in a comment that he made one day after class:

I am going to have to do so much of this kind of junk [covering material very quickly]. I hate doing this too because I would almost rather not even touch the stuff [content] than do it this way. But you should see our schedule for November!

Ben went on to list the large number of planned interruptions in the school calendar and to count the number of days left for "squeezing" in a unit. Such calculations were always based on the number of consecutive days uninterrupted by more than a two day break. Ben then scheduled his units into the available time slots, regardless of content. Labs and activities which would give students concrete experiences with the content were often cut using the lack of time as an excuse. Similar constraints imposed by the school calendar were evident later in the year. In this case, the calendar was working in Ben's favor:

I plan on spending a lot of time on the unit on DNA. It's real important to me that the students get this one down well since we'll be moving on to genetics next....The nice thing is that I can spend as long as I need to on this unit because I don't have any deadlines, like vacations, coming up to deal with.

Adjusting the presentation of content on the basis of the school calendar seemed to bother Ben but not enough to look for alternatives methods of scheduling his units. Instead, Ben sought ways to cover more content in a shorter period of time. Generally such coverage was implemented through simplifying the content though this created problems of its own. As Ben explained in an almost apologetic manner:

I love this little balancing act I get going where you try to simplify to the point where you are just almost as inaccurate as you can get. And I worry about not being right. But you could go as crazy [present as much detail] as you wanted to with this stuff....But I wanted to be done by Thursday because Friday a lot of kids will be gone.
Maintaining a balance between the simplification of material and the accuracy of the presentation seemed to pose a constant problem for Ben. In many cases, simplifications were needed to cover large amounts of content in a short period of time. Connections to other content areas were avoided because took too much time. For instance, in the lesson segment on cell types (provided earlier in this section), Ben may have purposely avoided making extended comments about evolution in order to save time and present the planned content. In other instances, simplifications may have been deemed necessary to keep the students focused on the content which Ben felt was important. For example, note how Ben introduced a worksheet on graphing during the first week of school:

First of all, the title of this [worksheet] is: Finding a Niche in a New Environment. What we will be trying to do here is make some graphs out of some data and for our purposes what "niche" means doesn't really matter. We are trying to take some information from a table and convert it into a graph.

In this lesson, Ben seemed to have purposely avoided introducing basic ecology content even though it was to be covered in the next unit. This teaching technique may have been purposely selected in order to focus student attention on the task of graph construction. Unfortunately, tactics such as this often confused students more than it helped them since they were trying to learn skills in isolation of content. Lesson segments such as this, and there were many, lead to the initial impression that Ben had made few connections in his classroom presentation of content.

Interestingly, it may have been Ben's desire to simplify the content so that it would fit into the school calendar which actually fostered many of Ben's connections during his classroom presentations. Having only 20 minutes to teach all of organic chemistry may have forced Ben to select examples and background content from outside the current unit since little detail had been presented within the unit. Teaching DNA/RNA without the detailed background coverage of meiosis may have forced Ben to tie these ideas to those covered previously: cell structures, cell enzymes, and the functions of proteins in the cell. Thus, Ben's superficial content coverage and avoidance of relating units together in some cases may have actually created the need to make connections in order to adequately teach the content in other cases.

As previously mentioned, the analysis of Ben's SMS must be tempered not only by his superficial coverage of content but also the adequacy of his own content knowledge. As may be expected with most teachers, Ben made several minor mistakes in his presentation of content. These were usually tangential to the main focus of the lesson and may not have been significant. But several instances occurred where misunderstandings on Ben's part may have significantly affected his students' understanding of content. Many of these
misunderstandings centered around topics in chemistry. For instance, the following lesson segment occurred in a lesson concerning the nature of matter:

Ben: This thing right here (pointing to a diagram on the board) is a covalent conglomeration of atoms. What do you call it?

Male Student: Bonding? Cluster?

Ben: The whole thing. Not a cluster! A cluster of atoms? What do you call it?


Ben: This is a molecule. This cluster of ions here (pointing to a second diagram on the board) is called what?

Male Student: A compound. (Ben writes on the board: Covalent bonds form molecules. Ionic bonds form compounds.)

Ben: So you've got compounds over there, you have got molecules over here. I probably won't give you an F if you get those two confused, it's not that important to me. Compounds and molecules. More than one atoms stuck together, then we've got compounds and molecules.

Though these definitions of compound and molecule are a bit unusual, in and of themselves and presented in isolation they are probably not dangerous. But, such misunderstandings seemed to indicate potential misunderstandings or an incomplete content knowledge on Ben's part. For instance, the definitions presented above seemed to be stable components of Ben's understanding of chemistry, as a comment made the following week attested:

Organic compounds. In a sense, it's almost a misnomer because we have said that compounds are formed by ionic bonding. And yet, most organic compounds are not ionically bonded but covalently bonded.

The above conversation, introducing organic compounds, shortly lead to the following statement:

People say organic farming. What is that? (No response from students.) They are growing things with carbon in them, right? Does that make sense? If you are an organic gardener then you are growing plants with carbon in them. The funny thing is, you can't grow plants without carbon in them. So, every farmer is an organic farmer.

Some of Ben's chemistry concepts seem to be incorrect, possibly fostered through the over-generalization of rules learned during his own content training. It is interesting to note that Ben did have a college level chemistry course in his background. It is possible that Ben lacked confidence in his own content understanding, thus potentially shedding light on his earlier comment: "You try to simplify to the point where you are just almost as inaccurate as you can get. And I worry about not being right." It may be that Ben
unintentionally put himself in a position where he had to simplify the content in order to avoid facing his own content knowledge deficiencies.

Some misrepresentations of content may have also been intentional. The following two lesson segments, the first taken from a lesson on the characteristics of living things and the second from a lesson introducing genetics, may illustrate just such situations.

Ben: Most organisms create a balance between tearing down and building up. That balance is called homeostasis. This is sort of like German class isn't it? All kinds of wonderful words every day in this class. Balance, it simply means a balance between the things that are going on in your body that are building things up and the things that are tearing things down. People like you who are still growing are not in the great state of homeostasis because your body is changing all the time. Weird things are happening to you, especially right around this region up here. (Ben points to his head. Students laugh.) When you get older, you get a lot more stable, like me. That's what happens to you.

Male Student: Then your hair starts changing color.

Ben: Yeah, your hair starts changing colors. You never do get completely balanced but...(laughs) you are in a state of constant change right now and so there is a bit of off-kilter to you and you are a little bit lacking in homeostasis.

Ben: To speed this up again, traits that I would have would be possibly not exceptionally tall, maybe a little chunky, kind of a little loud. Major intelligence, that's one. (Students laugh) Give me a break! (Ben looks jokingly indignant) Sense of humor. Maybe that's not a trait to pass on, I don't know. You get the point, right? The main thing to remember about this is to separate inheritable traits, which are things that you can pass on not things that your acquire during your life time, [from other non-inheritable traits].

Ben consistently stated (as presented elsewhere in this case study) that one of his personal goals was to make biology fun and to keep himself and his students entertained. It is possible that many of the 'mistakes' that Ben made (i.e., growth and homeostasis are opposite terms, being loud is an inherited trait) are made for the sake of classroom humor and liveliness rather than in an effort to better teach the content through concrete examples. Ben did seem to know the correct representations of these particular concepts (as exhibited later in the lesson). Unfortunately, it was not clear whether the students could separate the "comic license" from the actual content since both the definition of homeostasis and the distinction between traits which can be inherited from those which cannot seemed to cause students problems on the tests. This last statement was evidenced by a comment made by Ben following the review of a test: "Most of you don't know what homeostasis means because you didn't take the time to study and learn it, even
though we went over it about four or five times. It's not just balance. It's the balance between the process of building things up and tearing things down.*

Finally, the last factor which affects the interpretation of Ben's classroom SMS was the strong influence exerted by the textbook. It has already been noted that Ben was determined to follow the order of the textbook and did so even when he knew that he would be changing textbooks early in the year. Ben was also observed to adopt the language found in the textbook in his classroom presentations. For instance, while using the BSCS text, Ben often used the terms "thinking biologically" and forming "biological questions and observations." This language was specifically used in the BSCS text and was never used again once the conversion to the new textbook was complete.

In addition, the content that was to be covered was exclusively controlled by the textbook. When asked about upcoming units which would be taught during the first semester, Ben often looked uncomfortable and seemed unsure about what the next unit was. He often commented "I think _____ comes next in the book, but I don't really remember." This reliance on the textbook sequence may explain some of Ben's urgency to have his students working out of a single text. It may also explain his frustration with the school calendar. Since Ben used the school calendar rather than the content to set his pace of unit coverage, he often felt pressed for time. This perceived pressure sometimes forced him to squeeze units heavy in content into short periods of time and to stretch short units over longer periods of time. It is also interesting to note that Ben seemed to have a need to "get through" the biology content in a given period of time even though there were no curricular guides which forced him to do so. This need to cover material quickly is interesting when contrasted to Ben's casual method of content presentation in his Zoology class, where there was no textbook and the curriculum was set up according to Ben's own personal interests. Thus, it is interesting to speculate on the real role of the textbook on Ben's SMS. It is possible that, without a textbook, Ben's biology class (and resulting SMS) might look very different.

**Self-Described Subject Matter Structure**

The reader will be reminded that Ben was one of the two teachers randomly selected to answer the questionnaire concerning his SMS prior to the classroom observations. This task was assigned at the end of the initial interview and was to be completed prior to the first classroom observation. When asked for this SMS at the time of the first classroom observation, Ben admitted to not having had the time to complete it but did display a notebook in which he had several pages filled with what appeared to be diagrams similar
to concept maps. He stated that diagrams in the notebook represented an initial attempt to answer this question but he did not feel that the diagrams were yet complete. When told that the diagrams which he had were sufficient to answer the question, Ben requested another week in order to "perfect" the diagrams. When time precluded this perfection, Ben drew a diagram without the aid of his notes in order to provide his response in a timely manner.

The answer which Ben provided as the pretest of his SMS of biology can be seen in Figure 6. Biology was broken down into two major categories: Theoretical and Applied. Each of these branches was then further subdivided into content units with the greatest number of units falling under the Applied title. All topics listed were connected by arrows indicating a structure similar to a hierarchy. The diagram just described was not looked at by the researcher or described by Ben at the time of collection in order to prevent the possible bias of the subsequent classroom observations. It should be noted that later comparisons of Ben's pretest SMS and the SMS generated from his classroom data had no strong correspondence, implying that no instrumentation effect seemed to occur as a result of the pretest.

When asked to fill out the questionnaire on his SMS of biology as part of the final interview, Ben queried, "What if it's exactly the same?" When told that that was fine, Ben admitted, "I can't really remember what I did to tell you the truth." Ben spent about ten minutes constructing his SMS. Upon completion, he commented that "This might not be right either, but it's fairly good." It should be noted that Ben made several additions to his SMS as he explained it. The final SMS constructed, including all the additions, can be seen in Figure 7. Upon completion, Ben offered to explain his SMS. Initially this explanation wandered as he discovered portions of his SMS which were incomplete. The following description synthesizes several minutes of initial explanation:

What I tried to do is kind of take the whole deal [all of biology] and put it into two groups [theoretical and applied]. And then I thought about what we were talking about throughout the year. We will talk about anatomy and physiology and then classification somewhere in here. Really, all we end up getting to do with plants and animals is to classify them, put them into groups and explain why they are in those groups. In the process we can talk a little bit about function and structure [of plants and animals] in that way.

Ben continued in a similar fashion to list and superficially describe the rest of the contents of his SMS. It was obvious from this early explanation that Ben had mentally moved through the list of topics which he had included in his biology course and was then listing them on his paper. When asked about the source of the topics which he listed, Ben confirmed this observation:
Figure 6. Ben's Self-Described Subject Matter Structure (Pretest).
I just kind of went through [the biology curriculum] in step by step order. What we do, we start off with: life is this, life is that. Then we go to cells. Then we go to molecular cell structure. Then we go to cell function. Then we go to cell reproduction. Then we go to heredity and DNA and genetics and the whole works.

When asked about the meaning of the connecting lines, Ben seemed to imply that the lines were used for organizational purposes and really nothing more (i.e., no specific meanings in terms of relationships were implied by the lines).

Ben described the Applied side of the diagram as the topics which he most typically taught in his classroom during the school year. To Ben, the content under the Theoretical side represented controversial areas which were interesting to have students discuss at the end of the school year when the students "know enough about life" to be engaged in a discussion and when no one can "yell at him for bringing up these more controversial items.

When asked whether or not the SMS described affected his teaching in any way, Ben replied:

I think unconsciously that I do this [relate topics in the manner in which they are listed here], I really do. In the process of figuring out what I want to do, this [drawing a SMS] is what I do. And the nice thing about it is, if you actually show that to kids at the end of the year, it may help them connect everything and see that everything is interwoven. I don't know, subconsciously. I don't know of any other way you could do that [have the SMS affect teaching] than doing it just exactly like that.

Despite recognizing a potential way of using the SMS which he had derived to positively affect his students, Ben did not feel that that was something that he would do. "I don't know if it would make that big of a difference. Most of them are not really thinking by the end of the year anyway."

When shown his SMS from the pretest, Ben did not seem surprised that the two SMSs were as similar as they were. When asked to discuss any differences that he saw, Ben interpreted this question as asking for a comparison between the structures and what he did in the classroom. Using this interpretation, Ben noted that the structures were representative of "a problem that I have. I thought I was going to get a lot farther than I did. That's the biggest difference [between what these say and what I did in the classroom]." This comment, as well as the earlier comments made, seem to reflect the idea that Ben saw the SMS recorded as his scope and sequence for the year, his content overview for teaching. This interpretation was corroborated by Ben when he was asked if he had ever thought about the SMS of biology in a similar way before:

I have, like I said, subconsciously. I haven't diagrammed it out, but I do [think about the SMS] when I sit down at the beginning of the year and go, "what am I going to do?" Especially if I want to start something different.
Figure 7. Ben's Self-Described Subject Matter Structure (Posttest).
For my zoology class, that is pretty much what I did. When I created the Zoology class I sat down and just made a list of what I wanted to do and organized it in a way to do it. And then I made up subdivisions of each one of those things. It was more of a Roman numeral outline kind of thing, but it is really the same thing.

The idea that the SMS is a representation of Ben’s scope and sequence was reinforced again when Ben talked about the factors which influenced the construction of the SMS. In addition, Ben commented on the rationale behind a similar SMS which he had constructed for his zoology class:

Weather, that is the biggest thing. Maybe availability of resources to a certain extent, but mostly it is the weather. I pick the boring indoor stuff for the middle of the year and save the stuff that we might possibly be able to get outside and do for the ends of the year.... When I sat down and did the zoology thing [SMS], I did it with the thought that I was going to do the fun stuff that I liked to do. And hopefully they [the students] like it too, which they pretty much did.

It is interesting to note that, in terms of having a SMS, that Ben brings up the Zoology class which he designed for the current school year. For Ben, it may be that the creation of a course was much of the initial stimulus needed to explicitly state what was important in terms of content and then determining the best way to translate those ideas into classroom practice. In addition, the content included and emphasized on Ben’s SMS (at least for Zoology) seemed to be greatly influenced by whether or not he considered the content “fun.” This consideration was in opposition to considerations such as the content having a logical order or hierarchical structure which influenced the learning of the content.

Ben was specifically asked about whether there were any truly essential topics in his SMS or if all the topics were of equal magnitude. He replied:

Again, I am at that point [in my career] where I have to make that decision because I am not sure about some things. Four or five years ago I would have said, "Yes, this is the way I want to do it," and I really stuck to that. And I was pretty tenacious about it. But I'm starting to melt a little bit now and say 'maybe I was wrong.' It's probably a little bit of reality slapping me in the face and not having as much success at getting kids to love biology. Again, I don't think it [that kids liking biology] has one tenth as much to do with what I am doing [in class] as it does to the fact that they are not as mature as they are going to be eventually. If you had 25 to 30 year old people taking biology, they would enjoy it immensely compared to what they enjoyed as 15 year olds.

When asked if there was any additional information which Ben felt should be included in his SMS, he provided not only an answer to the initial question but also provided insight concerning the source of some aspects of his SMS:

Off the top of my head, no [nothing needs to be added to the SMS]. That [diagram] pretty much sums it up for what I like to do. Again, that shows you to a certain extent what my specialties are, and what my education has been.
For Ben, the development of his SMS has been similar to the development of someone's personality:

It's [the SMS] just an accumulation of everything I have done. That's really it. If my education was different than it was I think I would have come out a lot different as far as what I chose to teach. Had I had different professors, different classes in a different order from the way I took them, had I gone to college with being a biology teacher in mind and started out as a freshman, I would probably would have a different idea of what I want as a teacher right now. It's like everything together. It's like a personality. How do you turn out the way you turn out? You turn out because of all the other things that come together to make you. And I think it's exactly the same way with teaching. In choosing what I think is important has a lot to do with what has been presented to me in the way I was most receptive to it.

**Summary of Ben**

The SMSs constructed by Ben, for both the pretest and posttest questionnaire, were very similar in structure and nature. In both instances Ben divided the content of biology into two discrete categories: Theoretical Biology and Applied Biology. Ben usually described the Applied Biology topics as those which constituted the core of his biology course. The Theoretical Biology topics were more typically described in terms of controversial issues which were saved for discussions at the end of the year, or as "boring" content which Ben felt obligated to cover. Under each of these two broad categories Ben listed the specific content topics and the sub-categories which were included in his biology curriculum. The structuring of Ben's SMS can be described as a listing of discrete topics (as opposed to integrated topics) with a simple categorical organization. No specific meanings were associated with the lines which connected the topics to the original two categories. The lines of connections simply represented a convenient manner of organizing the topics listed.

When asked if he had ever thought about biology in this manner before, Ben admitted that a listing of topics was used as part of planning a new course or selecting content from a large text, though these lists typically used an outline format. Thus, for Ben, the SMS which he had diagrammed represented the scope (though not necessarily the sequence) of the course which he was going to teach. It should be noted that no themes, logical pattern of organization, or hierarchical structure (other than the groupings under the original two categories) were evident in Ben's SMS. In addition, no connections between individual content topics were included.

Ben felt that the use of the SMSs which he had created was "subconscious" and with its primarily benefit being the content organization for his class. Despite this described
use, Ben stated that the SMS, if shown to his students, "may help them connect everything and see that everything is interwoven." Thus, Ben did seem to view the content of biology as being interwoven but the specific manner in which this occurred was unclear from the information obtained.

It should be noted again that there was a strong consistency between the SMSs drawn by Ben both at the beginning and end of the study, suggesting that Ben's SMS was stable during the time of the investigation. Since Ben's SMS represented the list of topics which he taught in his biology course, this consistency was not unexpected. An analysis of the classroom data did not indicate that the SMS pretest had any influence on Ben's classroom performance. For instance, no greater consistency between Ben's SMS and the SMS derived from the classroom data existed as a result of filling out this questionnaire. In addition, since Ben felt that the SMS which he described was already in place at the time of the pretest, the SMS pretest did not seem to create a SMS where none had previously existed.

Ben described the formation of his SMS as being analogous to personality formation. For Ben, SMSs represented the sum total of a person's experiences. In particular, Ben cited his personal preferences, his content specialties and his education as affecting the specific items included in his SMS.

Ben's description of his SMS raises questions concerning the translation of this SMS into classroom practice. Since Ben's SMS consisted of primarily a discrete listing of content topics, a direct translation into practice would suggest content coverage which was self-contained within each unit with few connections made to other topics areas. The above description matches some portions of the SMS derived from the Ben's classroom data, particularly in the units taught early in the school year. However, fairly complex relationships were found in the units related to cell biology. As discussed elsewhere in this case study, these relationships may have been formed out of necessity. Superficial content coverage may have precluded connections to be made within units, thus fostering connections outside the unit of current coverage.

When interpreting the meaning of Ben's SMS in terms of its translation to classroom practice, it is difficult to forget the impression left as a result of the classroom observations. Few content connections were strongly emphasized in the classroom and there seemed to be an apparent desire to "get through" the biology content. This picture more closely matches the SMS generated by Ben and calls to attention a potential limitation of the methodology used to generate the SMSs classroom data: Since connections were sought and all connections identified were included in the SMSs, errors suggestive of a more integrated SMS than may actually be the case exists.
Many contradictions were found between what Ben said he believed and wanted in his classroom and Ben's classroom practice. Three assertions are proposed which may help explain the apparent lack of congruence which existed between Ben's words and actions. These assertions are as follows: lack of a clear philosophical focus, weak content knowledge, and an external locus of control. The evidence which supports each of these assertions and the factors in Ben's background which may account for or provide insight about the inconsistency between Ben's words and actions will be discussed.

Many of the contradictions which existed between what Ben purported to be important and his actual classroom practice centers around the assertion that Ben lacked a clear philosophical focus for what he wanted to achieve in his classroom and how he wanted to achieve it. For instance, Ben initially stated that he felt that problem solving was one of the primary reasons for the teaching of biology. However, in practice, essentially no instances of problem solving were observed. In fact, Ben provided few opportunities for his students to ponder the answers to questions beyond the level of simple recall, further calling his commitment to this goal into question.

Ben was also haunted by a dilemma concerning the appropriate target audience for his biology teaching. In some cases Ben felt that it was his responsibility to inspire potential biologists. In other cases it was to provide an adequate content background for the students who would go on to college. In still other cases, Ben felt that his biology class should modify its content in order to focus on the majority of students who would not go on to college. Central in this dilemma was the determination of the purpose of biology: Was the purpose of biology to teach for content understanding or to teach for positive attitudes toward biology created through a class which was fun, enjoyable and entertaining. Though at the time of the investigation Ben seemed to still be committed to "his agenda," the teaching of content, he was torn by the powerful prospect of teaching for personal and student interest and enjoyment. Thus, Ben often compromised his content coverage in order to make the class entertaining. This was done through the superficial coverage or "watering down" of content, and the misrepresentation of content in order to provide a humorous presentation. In addition, Ben was considering the elimination of content topics (i.e., DNA/RNA) which he felt were "boring," though important. This elimination would then create the time to teach other topics which both he and his students may enjoy more. Though it is contrary to the evidence presented in this case study, it should be noted that Ben did not feel that he was compromising the quality of content presentation for the sake of making his class "fun."

Other instances of philosophical conflict seemed to come to the forefront when Ben was deciding upon the format of his classroom instruction. Early in the year Ben
mentioned the importance of relating biology to the students' lives and the existence of a "perfect teaching situation" in which his students were living in the middle of economic and ecological issues which could be related to biology content. Despite this statement of curricular orientation, at no time during the semester of observation did Ben introduce such issues or make a point of relating content to the lives of his students. Ben also stated that, given total freedom, he would incorporate more labs into his biology program. Despite this statement, Ben rarely involved his students in laboratories. When labs were included, Ben felt that such sessions were an inefficient use of time as well as an ineffective manner of content presentation. Finally, Ben firmly believed that his class was run in a very "non-traditional" manner. However, the only potentially non-traditional aspect of Ben's class was his use of humor which, as stated earlier, may have compromised his presentation of content.

All of the instances stated above contribute to the impression that Ben did not have a clear philosophical position on what he wanted to achieve in his biology class or a firm understanding of how to achieve it. Several factors in Ben's background may provide insight into this lack of philosophical focus. First, Ben admitted to having limited experience in biology (or science) classrooms prior to his own student teaching. This lack of experience, combined with a generic teacher education program, may not have provided Ben with the opportunities necessary to form science-specific classroom philosophies or to reflect on the role of science in his students' lives. Such experiences may have provided Ben with more clearly formed philosophical goals at the time of the investigation. Second, Ben's apparent lack of focus on desired classroom outcomes may not have been as much of a problem as his inability to implement the teaching strategies needed to achieve these goals. More specifically, Ben may have had poor pedagogical knowledge and/or skills which limited his ability to effectively translate his stated goals into practice. Ben's lack of success in running laboratory experiences for his students lends credence to this assertion. Finally, Ben may be at a transition stage in his career. As Ben admitted in the interviews, he felt that he was at a "crossroads" in his career creating the need to evaluate past teaching practices. It is possible that Ben's first six years of teaching were too busy to allow him the time to reflect on his classroom goals and plan for their implementation. This assertion can be supported when one remembers that Ben was involved in teaching five different preps a day for the first three years of his career and, at the time of the investigation, was involved in teaching three preps a day. This heavy course commitment may have forced Ben into a "survival" mode in which the simple day-to-day logistics filled the time which he had available to think, limiting the time for the reflection on any one of the individual courses. However, it is possible that after six years
of biology teaching biology, Ben had finally become comfortable enough with the content and the day-to-day logistics of teaching that he was able to reflect on the results of his program and determine if the results were in congruence with his goals and expectations. Ben’s recent awareness that his students were not leaving his classroom to go on to become biologists may have stimulated the need to reassess his classroom goals and implementation plans. Ben may have been just beginning a stage in his career where he felt that he could make proactive rather than reactive decisions concerning the content and orientation of his classes.

The second assertion had to do with the adequacy of Ben’s content knowledge. One will recall that Ben felt that his college biology experiences had prepared him well for teaching. Ben also felt that keeping up with his content through popular science magazines was unnecessary since the content in the magazines was too advanced to be discussed at the high school level. Ben felt that all the additional content needed could be found in high school biology texts. But this confidence about his personal content understandings were in contradiction to obvious areas of incomplete content knowledge (i.e., chemistry) and Ben’s own concerns about inaccurately representing the content to his students. This subconscious concern for the adequacy of his content knowledge may have resulted in Ben’s selection to limit his content presentation to that provided in the textbook, deference to the order of content presented in the text, a willingness to “water down” the content for his students, and the casual manner in which topics were arbitrarily cut from the curriculum when time ran short. In addition, the fact that Ben lacked a recognition of themes in biology or could not articulate the nature of the interconnections which he believed to exist may further support the assertion that Ben’s content knowledge was inadequate in some respects.

It should be realized that some of these examples of potentially incomplete content understandings stated above may also relate to intentional decisions made by Ben. For instance, Ben selected the textbook of use, which may explain his deference to the content coverage and sequence used. In some cases, Ben may have “purposely” misrepresented his content in order to add humor to the classroom, or limited the use of content connections in order to maintain the pedagogical efficiency of content presentations. Thus, the strongest assertion which can safely be made is that Ben exhibited weaknesses in content knowledge (as supported by the misconceptions presented in class) and that the ultimate affects of this weakness on the content presentation is unclear.

The last assertion states that Ben seemed to have an external locus of control. Several observations can be used to support this contention. First, Ben was willing to allow the textbook to control the content and organization of the material which he presented in
class with the exception of two units, ecology and plants, which he purposely moved to the
either end of the year in order to have favorable weather for these units. Though it can be
argued that Ben selected the textbook because he favored the particular manner of content
presentation, this argument does not explain why Ben often seemed unaware of the next
topic of instruction, often vaguely stating that he would cover whatever was next in the text.
Second, Ben allowed the school calendar to control the length of his units rather than
making this decision based on the nature of the content or the feedback received from the
students. Ben's willingness to surrender such power to the school calendar was
confounded by his low student expectations in terms of their ability to remember the
content over a three day break. The combination of these two factors forced Ben to
terminate units before he felt comfortable with doing so, not seeing other options available
to him. Finally, Ben took only limited responsibility for his students' success in learning the
content of biology. Poor test performances were blamed on students' inappropriate study
skills or lack of motivation. Blame was never directed toward his own manner of content
coverage. In addition, Ben did not feel that he had the ability to influence students'
understanding of the connected nature of biology or developing appreciation of the
subject. True appreciation and understanding would only come through maturity. Beliefs
such as this may have contributed to Ben's low student expectations, his concentration on
lower level objectives in his teaching and tests, and his resistance to the possibility of
teaching the interconnected nature of biology was a part of his professional responsibility.
Carl: If Only I Had Better Students...

Academic and Professional Profile

Carl was contacted for participation in the study the spring prior to the initiation of the investigation. Recommended for inclusion in the study by a local teacher, Carl responded enthusiastically when first contacted and later reaffirmed his willingness to participate by returning the letter of confirmation during the summer.

Carl was a pleasant man of medium build and even temperament. His initial interview, which lasted approximately 90 minutes, was conducted in his classroom two days before the beginning of the school year. The close proximity of the interview to the first day of class was necessitated by Carl's participation in the State Fair and involvement with work on his ranch.

Carl recalled going to college with the goals of becoming a doctor or a biology teacher. After carefully considering the finances required to achieve these options, he selected a teaching career. This career choice was also influenced by past experiences working with children, especially in coaching situations, which he greatly enjoyed:

Carl spent his first two years attending a Regional State Community College and then transferred to a State University in the west to complete his BA in Science Education. His coursework included introductory sequences in many of the science areas (botany, zoology, chemistry and physics) and several math courses. His biology courses tended toward an emphasis in biochemistry and cellular biology, though he did have several classes in the areas of plants, microbiology, genetics and evolution.

When asked to describe his primary interests in biology and to characterize his science coursework, Carl stated:

My main interest lies in anatomy, physiology, structure and function. I was fascinated with that. How a certain organ's [structure] and its function, how it fit into the whole...I really enjoyed that. That was my favorite part of the biological part. And I had a lot of chemistry, so I looked not only at that [organism] level, but at the cellular level and how those things [biochemistry] control [the cell].

When asked about the adequacy of his science courses, Carl felt that he left the university well prepared in terms of content, but was a little disappointed with the quality of instruction which he found in his science courses. He explained:

I remember the college science courses, a lot of them, being taught exactly the way that I don't want to teach [primarily lecture]. The reason they were taught that way was because of the class size. Whenever you have limited
resources and time and space, you lecture. What else can you do? But,[overall],[overall,] science was pretty good.

Carl also took coursework in education. Since Carl's degree was in Science Education, his early coursework was generically offered through the School of Education and his later science specific coursework was offered through the Science Education Department. Carl later returned to the same institution to earn his Masters in Science Education. When asked about his educational coursework, Carl gave a far different answer than provided when reflecting on his content work:

A lot of my education classes were a waste of time. I would have much rather been somewhere else to be honest with you....I would have rather have taken content classes....I really had some unprepared teachers.... Thinking back, I can't imagine trying to fill the time taken up by those courses with the little amount of substance [content] that they had to teach.

The above statement referred specifically to the coursework taken from the School of Education. Carl felt that coursework taken which dealt with science specific topics was "pretty good," "enjoyable," and "worthwhile." When asked about his specific complaints toward the generic coursework, Carl quickly replied:

I think Schools of Education are not doing a good job of understanding that the kids that the teachers are getting are not the ideals. It is not, "if you motivate them, they will learn." It is not that way. You need to get some practical stuff [teaching techniques]....Teachers need to know what the real world is like. The idea that you will find a way to motivate every kid is a lie....You are not going to reach every kid. Because every teacher that has ever left [the university] thinks that they can be a savior, at least the ones that care about the profession. And you find out that you just are not going to do it....You get disillusioned. You walk out and sure, that first year you are just trying to stay ahead of the kids. And you are learning how to teach, and developing your own style. But there is a certain disillusionment when you find out that, "hey, I gave an assignment and not everybody did it!" And you have got this Joe Blow over here who could care less about your subject and he hates your guts and that is a very real thing. Another important thing is you are not going to be every kid's favorite teacher, and you can't let that bother you....You can't be every kid's friend. You just can't.

The above comments seem to stem from some of Carl's own frustrations with the task of teaching. He seemed to have felt let down that his university education did not prepare him for the reality which he faced throughout his career. Interestingly, when asked about his feelings upon leaving the university and approaching his first teaching job, none of the above concerns seemed to have existed:

I felt good about my knowledge of subject matter. I felt good about my ability to relate to people and I don't know if that was directly related to the University or not. I felt like, if I had problems, I had somebody I could call back there [at the university]. I don't know that I felt inadequate at all.
was ready to go. I was excited. I knew I would have problems, but I
guess I figured I could solve the problems [I would meet].

Carl's first teaching job was in a small school in Eastern Oregon where he taught math
and physical science. It was here that the experience of teaching introduced Carl to the
realities of the classroom. Teaching in a school with a large migrant farm population, Carl
taught classes of 40 students with only a few textbooks and not enough desks to
accommodate all the pupils. Carl vividly recalled the last bell of his first year teaching
where he remembered standing and thinking, "Thank God, they're gone!" Carl taught one
more year in that school and then moved to his current teaching position where he had
been teaching for nine years.

The initial teaching requirements of the position which Carl held at the time of the
study had been to in the areas of Biology and Physical Science. At the time of the study,
Carl had taught Biology for a total of nine years. Being one of four science teachers in the
building and one of two biology teachers, Carl had early hopes of eventually moving out of
the teaching of required science content courses and into the elective sciences in order to
obtain a better level of student. An opportunity arose when a teacher in the department
retired, making available the opportunity to teach the chemistry and physics courses.
Without enough credit hours in either area to be certified, Carl passed the National
Teacher's Exam and gained endorsements in both areas three years prior to the current
investigation. At the time of the study, Carl taught three sections of biology, two sections of
chemistry and one section of physical science.

The community in which Carl taught had a population of approximately 5000 and
supported a 9-12 high school with approximately 700 students. Carl described the
community as "primarily a ranching community where the kids learn to work hard
[physically]." Interestingly, Carl's school had the largest minority population in the state
with 37.4% of the population being Native American, 11% Hispanic, and 51% white. This
population composition seemed to impose some unique problems and concerns for Carl
and the rest of the community. Drop out rates among Native American students averaged
68%, almost double the state-wide average. When asked for possible explanations for this
phenomenon, Carl cited broken homes and the lack of parental interest in education as the
primary factors which lead to such high dropout rates. As Carl explained:

It seems to me that the home, no matter where you are at, is coming apart.
There are a lot of broken homes [for both white and Native American
students]. In the broken home situation, children are just wondering who
they are going to be with and who is going to feed them, so education is
kind of on the back doorstep. By in large, the white kids are in much better
shape. Their homes are in much better shape. In general they [the white
students] are a good group of kids to work with.
[But, the Native American students.] It is sad. Their home life is very poor. There are a few [parents] who are genuinely interested in their kids and their progress and their success and it shows. But, by in large, the majority is not that way. There is a high level of unemployment and low self-esteem and that is reflected in their children.

When asked about the effects of the lack of support for education on school related activities and relationships between the students of the various ethnic backgrounds, Carl stated:

A lot of the white kids see the Indians as non-motivated, the same way much of the staff sees them. However, there are the Indian kids who are [considered] equal. The ones who really try to excel in athletics and education are accepted. But they may be shunned by their own peers, which is the case a lot of the time.

Carl offered his enrollment patterns in Chemistry as evidence of the problems faced by having a large population of Native American students:

The class loads are up [in chemistry], considering our clientele. Half the kids [in the school] are Indian and if they were white kids from the same community, my enrollment numbers would double. I would teach chemistry/physics full time. But these [Native American] kids don’t see education as being important, in general. In four years of teaching chemistry and physics, I have [only] had probably 10 or 15 Indian students. And the ones I have had were good students.

In describing what Carl considered an "ideal" student, he used terms such as "well rounded," "self disciplined," "self motivated," and "self learners." Unfortunately, Carl did not feel that these terms were particularly representative of the students at his school. Carl described many of the students as wanting to be "spoon fed." He was particularly resentful of a situation which had occurred the previous year in which the administration had admonished the science and math departments for their high rates of student failure. Carl described the problem as being based on inconsistent expectations across the school, stating that "some departments will just pass them for sitting in class." Carl disagreed with this philosophy stating the following rationale:

I give very few A's in biology. I think excellence is excellence. I dropped my standards for B's and C's because, if I didn’t, these kids wouldn’t make it. But I refuse to pass kids just for showing up and that is what we are being pushed to do. I don’t think it is doing the kids a service. I think they need to suffer the consequences for the choices they make and if they make bad choices, they had better suffer bad consequences.

But, despite the negative sounding attitudes and situational constraints, Carl added: "I think this school system, even in spite of the problems we have community-wise, I think we do a pretty good job of raising kids and motivating them to succeed."

When asked about his favorite content to teach, Carl seemed to be influenced by the type of student which took the class. As Carl explained:
The chemistry and physics classes have become my favorites. I enjoy the subject matter of chemistry and physics also. And biology I still love, but I think if I had the caliber of kids with chemistry and physics, they would be more on equal basis....I honestly believe that if I had the caliber of kids [in biology] that I did in chemistry and physics, that things would be different.

For Carl, the caliber of student also affected the goals which he set for his courses. When asked about his goals for his science students during the initial interview, Carl replied:

First, the content. There is a certain amount of content and concepts that kids have got to be familiar with if they are going to be successful in their freshman level [college] science classes. So I see that as a primary importance, to see that they are at least exposed to that [content].

Second, the process is important. So at the beginning of the year I look at the concepts that I think are essential to them [the students] and along with teaching those concepts I try and probe them to learn the process of science and to learn to think and reason. Those are the two goals that I have in any science class, concepts and process. That is what I see as primary importance and that is what I base my goals on.

These goals seemed to be primarily stated in terms of the essential information and skills which were needed by Carl's chemistry and physics students. When asked specifically about his goals for his biology students, the previously stated goals were modified. The first modification was in terms of content. Carl described feeling that he was "changing at the moment as far as some of the concepts I see as important" in Biology. Central in these changes was the relative importance of certain ideas and topics in the biology curriculum as influenced by the level of his biology students. Carl was considering dropping some of the topics, particularly biochemistry, due to the lack of student interest, motivation, and poor achievement. Thus, the second modification of goals came in terms of how the students would use the content they had learned. Whereas college preparation was the ultimate goal for the chemistry/physics students, this changed for the biology students. Carl explained:

I still think that some chemistry is important, but what I want my biology kids to do when they walk out of the classroom is to recognize the five kingdoms. If they are wandering around on the Oregon coast in a tide pool, they can identify something by the five kingdoms. I can then consider the year a success and that is my main goal for this kind of kid that I have. If I had advanced kids, it would be a different story. I certainly would want more for my [advanced] students than that, but if they could at least have that. In some cases, I will dig and try and insure that they [students] have some in depth understanding [of a topic]. But [in which topics], I guess that depends on a biology teacher's interests.

During the final interview, Carl's goals for his biology students seemed to have changed again. At the time Carl stated:
The underlying goal is [understanding] that life is complex. Living things are so complicated and of course second semester ties that in more because it is more of a phylogenetic study. To just gain an appreciation of the beauty of life and how it works and that Biology is open ended and that we are still learning things about living things. I told them at the very beginning of the year, "I don't expect you all to be biologists," but one of the things I want them to do is to appreciate life. Second semester is nice because they can see examples of all the kinds of living things. So second semester, [during] the dissections..., the kids, I think, gain a real appreciation of how things fit together. It is a nice way to end the year.

That would be the main thing that I would hope. That they would look back and say, "life is really something. It is not something to be taken for granted."

It should be noted that Carl has made three sets of goal statements of science students in general and biology students in particular: content and process, recognition of the five kingdoms, and an appreciation of the complexity of living things. In both of the latter instances, the true "evidence" for the success of Carl's goal statements would only be able to be measured as a result of his second semester teaching. For this reason, it may be difficult to determine the influence of these goals on Carl's teaching. In addition, it is difficult to determine if changes in Carl's stated goals for his biology students was a result of a true change in philosophy, a rewording of his original philosophy, the result of reflecting on the goals of biology at a different point in time, or due to changes which occurred in Carl's personal life (to be discussed later in this section). A change in stated goals for students may also reflect the lack of clearly formulated goals for his biology students.

When asked about the consistency of his stated goals across the science department, Carl seemed to be unclear of the goals of other faculty members. Coordination within the department and within class offerings, such as biology, seemed to be limited to a general agreement as to the content which would be covered during the first semester. This agreement facilitated student schedule changes at that time. Carl felt that such a level of coordination was beneficial, as he explained: "We like to give each other the flexibility to do what we see fit with the kids... There is a lot of idea sharing, but we don't have to do the same stuff."

One change that Carl felt would eventually affect the nature of the current individuality in terms of what and how teachers taught had to do with the introduction of the state's Common Curriculum Goals which were being mandated for inclusion in the science curriculum by the district. Carl's reaction to this mandate was as follows:

We got told that if anything we were doing wasn't meeting the common curriculum goals we had better change it. Some of the things they talk about in the common curriculum goals are important. But for me,
especially with the chemistry/physics kids, what is important to me is to give them a basic background so that, when they go on to college, it isn't the first time they have been exposed to it [the content]. And where that doesn't meet the common curriculum goals, I am going to cover my butt and do whatever I want to do anyway, because I can see what is best for the kids. I feel that I have been in it [teaching] long enough to know what the kids need and I am going to do it.

Besides the level of student he was working with, the only other factor which Carl felt might be a major influence on his teaching was his coaching. At the time of the investigation Carl coached the football team. As he confided: "I used to coach three sports. But with the ranch and the family, something had to go, so two sports did. It was affecting the classroom, I didn't have time to prepare." Even though Carl felt that coaching was a large time commitment, he enjoyed this form of student interaction and involvement. But concerning the multiple time commitments imposed by teaching, Carl firmly stated: "My family and my church have priority, but I will do the best job that I can here [at school]."

Carl was observed ten times during the semester of the investigation. The discrepancy between the number of times Carl and the other teachers were observed was caused by a number of factors. First, Carl asked that his class not be observed until the third week of school. He rationalized this by stating that no "real" teaching would occur during the first week of class due to interruptions caused by student pictures and a football game. In addition, Carl wanted a week to get to know his students before the observations began. Carl was observed the third week of school, but then planned for once-a-week observation schedule was interrupted by teacher illness which resulted in Carl being out of school for eight days.

In addition, Carl's own schedule of being in class was disturbed by football games, scheduled about once a week for the first ten weeks of the semester, and a rotating schedule. In the rotating schedule, students were scheduled into seven classes but only six periods met each day. This meant that each class would only be seen six out of every seven days. According to Carl's calculations, this decreased the number of class meetings by 35 periods a year, though the amount of time each class met was adjusted for by increasing the length of each period.

The rotating schedule affected the ability to observe Carl on an unannounced basis (which was often possible for other teachers included in this study). When possible, specific days were scheduled for observation so as not to conflict with the many changes in the classroom schedule. In the end, Carl was observed ten times. This amounted to 17.2% of the total number of days which he taught, which closely approximated the average of 17.6% observations per teaching days for the other teachers in this investigation.
Due to a serious ranching accident, Carl was hospitalized for two months following the beginning of the second semester. As a result of the accident, Carl was paralyzed from the waist down and did not return to teaching second semester. The final interview was held in Carl's home approximately 12 weeks following the last classroom observation and lasted approximately two hours. At the time of the final interview, Carl had not regained the use of his legs but seemed hopeful that the paralysis may only be temporary due to swelling and trauma to the spinal column. Carl was determined to regain the use of his legs and had made the commitment to return to teaching the following year.

Course Specific Perceptions and Concerns

Carl's biology class closely followed the sequence of topics recommended by the textbook: introduction to biology, characteristics of living things, basic and organic chemistry, cell structure and function, cellular energy, cell division, DNA and protein synthesis, and genetics. Carl's intentions were to use evolution to bridge the gap between the first and second semester and then to continue to follow the book sequence: classification, the five kingdoms, and ecology. The only planned interruption to this schedule was "Nature Week," a week scheduled sometime prior to the Christmas break in which the students watched films on nature and related topics.

When asked about the strong correlation between the sequence of the textbook and that found in his class, Carl replied that the correspondence was intentional. He discussed the reasons for the selection of the current textbook as follows:

The order of approach [in the Prentice Hall text] was a little different [than in the previously used Scott Foresman text]. In fact, that's one of the reasons why I liked the text, I liked the way they approached the subject. The order of approach was more logical to me and I liked it. With the Scott Foresman text I had to do some skipping around, going back and forth. So I did it the way I wanted to anyway. But this one [the Prentice Hall text] was arranged the way I thought it should be taught. That's one of the reasons we chose it.

When asked about the perceived advantages or disadvantages that the sequence of content made for his students, Carl replied: "I don't think it makes a hill of beans difference to the kids." He felt that the primary advantage related to sequence was more from his point of view:

You develop that [logical sequence of a topic] in college and the first couple of years teaching. Even in college you [already] may not agree with the sequence of things that you were taught and would have liked to had it done differently. Sometimes you just put things together the way you think and sometimes that is not always best for the kids.
Carl felt that there were some general advantages to the sequence which he felt comfortable with and the text emulated. He commented:

The advantage [of the sequence] is, if a kid is really going to follow through with it, he can see that the key to life is on the cellular level and then you build on [that, increase the] complexity. The disadvantage [of the sequence] is that you can lose kids early because of those difficult topics. They can say, "this is a bore," and then you have lost them. Some of them [the students] don’t even want to give you a chance to try and bring them back in [to the content]. Some of the kids are so turned off by the second semester that, when they [finally] get a chance to do a lot of hands on stuff with all the specimens, they are already lost and they don’t care.

Though the disadvantages posed by starting with the cell first may be eliminated by starting with ecology and then progressing back to the cell and chemistry, Carl saw problems with this sequencing. When teaching ecology first, which Carl had done when using the BSCS text (prior to the Scott Foresman text), he would involve students early in the year in "ecological projects" and problems:

[Teaching ecology first] tended to get kids involved early. And ecology lends itself to a lot of class discussion because there are a lot of opinions, a lot of strong feelings. [Working with the ecology projects] they would start asking questions about, "well how does this fit in?" and "what is the problem with this?" But then your explanation delves into the molecular level and they don’t have a clue [about what you are talking about].

Despite the inability to explain concepts in terms of the cell, Carl preferred his current approach. However, the seeming success of the aforementioned sequence was qualified with the comment, "but that was when we were tracking kids, and I had the advanced kids." Since his classes were now more heterogenous, Carl did not feel that his earlier success with an "ecology first" sequence would translate to his current group of students.

Similar concerns about the ability and motivation level of his students also affected other aspects of Carl’s classroom sequence. As alluded to in an earlier comment, Carl was rethinking his level of coverage on the topic of biochemistry. Carl cited the following advantages and disadvantages to decreasing coverage of the topic:

The one reason I don’t want give up the biochemistry section is because it’s an interest of mine. But I may have to....I used to think that cell chemistry and the idea of cell replication [DNA and protein synthesis] were absolutely vital to understanding the overall concept of heredity. But I’m not so sure about that anymore because of my students. I still think it’s important, but I am wondering if I can bypass it....To the average kid, it is Latin to them, Greek. It just doesn’t make any sense.

Despite trying a variety of learning approaches and ways to make the content interesting, Carl felt that the biochemistry unit was the "least successful" in his curriculum. His rationale was again based on the response of his students:

I just almost think that those concepts might be kind of stiff for a sophomore. Not a sophomore that is average, that will read and spend
some time with it [the content], but the sophomore that doesn't give a hill of beans about biology. You might as well be teaching them Latin.

In response to the problems that his students have with this content, Carl was thinking about making the following compromise for the next school year:

I am still considering dropping the biochemistry, or I might just hit it lightly. [Just teach] some key ideas, [keeping it] simple. [I realize that] the basis for life is on the chemical level, but [don't get into that], just talk about things like enzymes and catalysts, how they relate to a living system and not really get into the chemistry of it and just go on from there.

Carl admitted to liking the units on heredity, DNA and genetics the best. He also enjoyed teaching the unit on evolution, even though his Christian fundamentalist beliefs did not permit him to "hold all of Darwin's ideas to be true. But some of them I think are pretty insightful and I agree with them." Overall though, Carl's favorite topic to teach was genetics. Carl also felt that genetics was one of the favorite topics of his students. When asked why he favored genetics, Carl replied: "Maybe it's because the kids like it so well. I don't know though, genetics was one of my favorites in college, so I don't think it [that it's just because the kids like it]. The section on heredity is my favorite."

When asked to speculate on why his students seemed to enjoy the unit so much, Carl answered:

Because the kids could relate it to themselves. They thought, "well gee, this is interesting". They can apply it to themselves more. We were going over hitchhikers thumb and all those kinds of things and they enjoyed that. During the genetics unit I also had the most interaction from the kids and they were the most successful.

Since Carl made several statements that alluded to the fact that a student may be more successful at something he/she was interested in, Carl was asked directly about this connection. He replied:

I think the more that a student enjoys a topic, the more it enhances his chance to be successful. At least, I know that is the case with myself. The more you enjoy something, the more you are going to get wrapped up in it. Think about the things you do in your spare time. Those are the things you are really interested in and you tend to be good at them.

Finally, on the issue of course scope and sequence, Carl was asked how he prioritized the topics he would teach. He answered the question in terms of his advice to a new teacher:

If I were talking to a new teacher, I would say, "select what you deem important. This is your first year, and your ideas are going to change. Undoubtedly, you will develop and it [what you want teach and how] doesn't develop over night. It doesn't develop in one year." In fact, I find myself [still] struggling with the same things I thought about five years ago. I would say, "select what you think is important....What do you think is essential? Your views are going to differ from mine, but that's okay."
Because if the kids learn something, they are better off than they were when the came in."

Carl described three primary constraints which he felt were detrimental to his teaching effectiveness: money, time, and his students. Carl commented that the biology department had a limited budget which prevented him from having as many live and preserved specimens as he would like. Time was primarily an issue created by the rotating schedule. As Carl calculated: "one out of every seven days you lose, so you miss each class approximately 35 times. You get your clock hours in but 35 times is a lot of times to miss."

But for Carl, the most important factor that affected his teaching was the level of his students. Carl explained:

Some of the things I would like to do [in class] I simply don't dare. I would end up doing the stuff for them because they won't [do it]. And if you really get into the real work of biology you find out that there's a lot of quantitative stuff and that's some of the stuff that I would like to do. But even some of the kids that are in Geometry and Algebra II, their concept of math and just doing simple kinds of calculations, it [the skill] just isn't there.

Without the constraints mentioned, Carl said that he would buy more materials, such as models, which would "enhance instruction." And if the group was small enough, Carl might even consider conducting field trips. But the major change that Carl hoped for was an increase in the quality of his biology students so that he could increase the level of instruction. Carl elaborated on the influence of this ideal situation on his classroom instruction wistfully:

The first thing I would do is ask more out of my kids. I would expect more. I would attempt more. I would attempt more higher level kinds of things. I would do more quantitative lab stuff...I would do a lot of comparative anatomy...because that was one of the fascinating things [content] for me....Simply, the class level of instruction would take a step up. I wouldn't necessarily change the topics, but I would be much more in depth and expect more. That's the main thing I would do different. The level of instruction would go up. I would be more challenged because those kinds of kids [better students], they ask questions that make you think. It's like with physics.... If I could take six classes with the kind of kids I had in physics and chemistry, teaching [biology] would be a joy.

There can be little doubt that Carl is dissatisfied with the general level of student which he had in his biology classes. Carl's seventh hour class, the one which was observed in this investigation, seemed to follow the cultural characteristics of the school. Of the 15 students in regular attendance, just over half of the students were Native American or Hispanic. In describing his seventh period students, Carl stated:

I would consider that a middle of the road group. There were some good kids there, but there were some bottom end kids too... But that was an enjoyable group of kids. It really was....Of the classes that I had, they were the ones that I could have the most fun with. And that's ironic, being seventh period, because seventh period can be a real nightmare or a drag.
I found out that, by the end of the day, I get the same way [tired] that they do. So by the end of the day I figure I am just going to try and have a good time. And it [having fun] helps seventh period [students] out because they are tired too.

Despite characterizing the seventh period students as fun, Carl also noted that the students had the same problems reflected in the larger population. In summarizing these characteristics, Carl noted: "My overall impression of that group is that, for a lot of them, their socioeconomic and home problems get in the way of their education." In way of evidence, Carl stated that the county in which the school was located led the state in teen pregnancies. Such pregnancies seemed to occur equally in white and ethnic populations. Carl also saw alcohol abuse as a big problem, especially on the reservation. These problems, coupled with poor parental support of education, created problems for his students in school, especially the Native American student. It was noted that Carl seemed to pay special attention to some of these students in class by "riding them" to do their work or by repeatedly offering them opportunities to participate in class. When asked about one of these "special cases," Carl described the situation as follows:

That's a typical reservation kind of a kid. They have ability, looks, could really have a lot going for them, but the reservation is a crutch that they go back to. I think [for many of the students] there is no motivation to do it [school work] and then they eventually make a conscious decision [to drop out] because they see no value in school. The unemployment rate on the reservation is high, yet people still make it. They get their bonus check, see that dollar coming in and think, 'why should I bother learning because I am just going to go out onto the reservation anyway and I will be taken care of.' They never see the other end of life. It's a shame...[he is an example of] another kid that could make it off the reservation. Who could really be successful.

But there are some [Native American students] with above average intelligence. And with some skill and with a little bit of motivation, they could make it....There are always two or three in each class that you would like to try and bring out.

Based on the type of student that Carl had in class, he was asked about the special considerations that he made when selecting classroom materials and activities. He replied:

The first thing I look at is the ability level of the kids.... if you've got a classroom of kids that don't have those [certain] abilities then I'm going to limit some of the things I am going to teach and pick and choose that way. With a real good group of kids I like to include the idea of the ethics, like the ethics of genetics. Do we have a right to, in essence, play God? And that stimulates some good thought....So with a brighter group, you do more involved things....If we tracked kids then you could pretty much [do these activities all the time]. But, when you get them in a melting pot, you tend not to try some things with them because it gets so frustrating.
When discussing the topics which Carl felt were most important, he stated that he chose to include "topics which simply give them the key ideas." Carl feared that "trying to cram all the content in" would only lose students. He continued:

When you are short of time you kind of panic because there are so many things that you feel are essential, which maybe really aren't because they are your interests. So I would pick and choose things that would just sample the topic to give them an idea. I would limit the advanced topics to some degree and more or less take an overview [approach] rather than concentrate on any one area. I would certainly make sure that they understand the key ideas and principles.

But Carl quickly added to the above statement that when time was not short he would "try to include more of the fun things." The idea of having fun in his biology class was important to Carl and did not limit itself to what Carl considered fun activities, but also extended to the presentation of content. As Carl explained: "I enjoy clowning around. I try and use humor as much as I can to get their attention. It seems to me these days that kids are in tune to being entertained." Carl remembered initially coming up with the idea of presenting content material in a humorous way after dealing with a particularly unresponsive group of students. After strong initial success, Carl began adding to his repertoire of entertaining activities and presentation styles. For example, Carl mentioned talking in different accents, teaching dehydration synthesis in the guise of "Samurai Enzyme" (chopping a water balloon in two with a meat cleaver in order to demonstrate the necessity of removing hydrogen and hydroxide from bonding sites), playing Jeopardy when reviewing units, and doing fruit dissections in which the students were allowed to eat the specimens. As Carl explained:

Carl: Some of those kids you can reach that way,...wherever I see a situation where I can put humor in to the content, I try. I think it's important because it gets the kids involved. And I guess in the last five years I've decided that, if I am going to stay in this business long, I need to make it really enjoyable for myself too. It's kind of fun just clowning around.

Researcher: Do you think the students get more out of the content because of the use of humor?

Carl: Yes, I do. They still know that I expect something of them,...I expect them to know something [content-wise]....But most importantly, it gets the kids attention. And it lets them know that you are human too. I just found out after four or five years that the real structured lecturers don't last. The kids just don't relate to that....You can still teach your content and have a good time. It makes it more enjoyable for me. And so if I enjoy it more, surely it is going to help them enjoy it more. At least that's my philosophy.

When considering the other teaching techniques which Carl seemed to feel were important, a few key methods surfaced: reading the text, lectures, labs, and films. When evaluating the textbook as far as an instructional tool, Carl stated once more that he liked
the current Prentice Hall text. The Scott Foresman text was considered "too simple and too Mickey Mouse. It insulted me the way it read." Carl's opinion of the Prentice Hall text differed: "The depth is there and the reading level is challenging, about eleventh grade, but that's okay too." This requirement for a textbook with a higher reading level is interesting in light of Carl's earlier dissatisfaction with the low academic level of many of his students. Carl explained this discrepancy as follows:

"I have had a lot of kids come back and say, "I really thank you for pushing me to read in chemistry because it made a difference." I will do that because I think kids, at some point in time, need to be able to read a textbook to get something from it and go from there....And I don't know how you teach biology without asking them to read. You can't give a lot of homework, because they won't do it. Whenever I can I give them a period to read and ask them to make a vocabulary list because the vocabulary is tough."

The comments about reading naturally led Carl to talk about his other most prominent teaching technique: the lecture. Carl justified the use of this technique as follows:

"There are so many different learning styles that kids have. But whenever you are teaching a subject like this, I don't think there is any way you can get around a lecture. You have got to have some of that. I try and not make them 50 minute lecture periods, maybe 20-25 minutes at a time and after that have some kind of hands-on activity or something to do that makes them think. But there has to be some giving of knowledge [through a lecture]. The kids at that age are not going to get it out of a book, though some kids will at least get a smattering of knowledge from reading."

It is interesting to note that, though Carl had just finished discussing the importance of "pushing" students to read and finding information from the text, that he did not feel that this was an effective means of transmitting knowledge to students. This raises questions as to Carl's intended purpose for reading the text. Is it for students to gain knowledge, or to teach them how to find information in a textbook as stimulated through vocabulary words and questions from the reading? This apparent contradiction was not explored in the interviews.

When asked about other teaching techniques which were effective, Carl noted that his "ideal" in terms of good classroom teaching had "changed considerably," but that he strongly agreed with using hands-on materials as much as possible. Limits to using this teaching technique were stated to be money, availability of labs that matched the content and the number of students in the class. When asked about his purpose for including labs in the curriculum, Carl replied:

"A lot of teachers will teach a unit and then the lab is more like a confirmation of what you learned in lecture. And some teachers use the approach that the lab [will introduce] brand new content and then the lab leads into the lecture. I think [that the model that you use] depends on your kids. With physics, a lot of times I will lead with a lab. They will learn
the principle and dig it out and it is much more meaningful. It sticks with
them because they had to figure it out. But I think it just depends on your
kids. I’m not sure that that [inductive technique] would work with the
biology kids.

The complications raised by having students of a lower level ability seemed to have
affected Carl’s frequency of labs and the manner in which they were used. He continued:

I wish we could do more labs [with the biology students]. But what I found
is that many of the labs designed for biology are just so far above the kids.
The kids have difficulty reading and following directions. And their math
skills are so poor. You ask them to do something quantitative and you can
just forget it. It comes to the point where you answer the same questions
so many times that you say, “why bother?” And you can see that what you
say goes in one ear and out the other and they didn’t have the concept. It
makes me want to tear my hair out, but I refuse to do it [the lab] for them.

Finally, Carl mentioned the use of films as an “important part of the curriculum.” Carl
saw this mode of delivery as particularly effective because: “films just show some of the
stuff [we’re talking about]. And I think that’s an important thing too because I can’t bring
those things [shown in the film] into the classroom!” Maybe of the greater importance to
Carl was the fact that films seemed to “hold the kid’s attention.” This seemed to be
important from both a learning and retention point of view. Carl elaborated:

If you get a film, a really good film, I noticed that it holds the kids attention.
And that’s the thing about it. Some things [that students see] stick and
they will never lose that. They remember things from [films] that I could
have never have taught them because Walt Disney did such a great job
teaching it. He put a lot of humor in it.

Carl also found that films could make connections between content for students that
might not be made otherwise and could connect science topics back to students’ own
lives. When asked if students might not make these connections without the films, he said
“maybe,” but then continued:

Too often the students tend to detach science from real life. I try and make
them understand that, “hey, the thing you crawled into the parking lot with,
where do you think that came from?” That is reality and I think it is
important but in their minds science is detached from reality. Sometimes
the films help them make that connection.

Classroom Profile

Carl seemed to genuinely like his students and they seemed to like him. His seventh
period class generally seemed to get to the classroom as quickly as possible from their
previous class. Many of the students used the minutes before class to talk to their friends
or finish up a homework assignment, but several of the students spent the time before
class talking to Carl. Usually such discussions had little or nothing to do with school.
Typically this time was spent telling stories about other people or classes or asking Carl's opinion on some current event. Carl seemed to enjoy these interchanges, which were often lively and sometimes carried over into the first few minutes of class.

After the bell and when all the students were seated, Carl took a few minutes to take attendance. There was no formal warm-up or expectations for the students during this period of time. Most of the students continued with their earlier activities: talking quietly or finishing up homework assignments.

On 31% of all classroom days (as determined through analysis of lesson plans), Carl had scheduled some sort of classroom presentation. Carl's presentation of material was usually fast paced and dynamically delivered. The verbal presentations were often accompanied by an outline of the lecture notes, either recorded on the board as the lecture progressed, or pre-written on an overhead transparency. In addition, many lectures were enhanced with visual materials such as commercially produced transparencies or a demonstration of some type.

Though Carl provided his students with outlined information for notes, the students did not always comply and record this information without repeated requests and reminders. This frustrated Carl, though he did not often walk out into the classroom to check student compliance with his expectation to take notes. Instead, if he noticed a student who was not taking notes, he would stop the lecture in mid stream and deliver a general admonishment to the entire class. The following example of such a reprimand occurred while delivering a lecture on diffusion. Lecture notes had been provided and the students were writing down what was on the transparencies but they were not taking the initiative to record any of the verbal information which Carl was providing. Carl responded to this in the following way:

Folks, because I don't write it [a term and definition] down doesn't mean that it might not be something that you want to write. Remember, lecture notes are to remind you of what we talked about in class. That is what they are for and the reason why some of you have trouble on tests is because when you go back to study for a test the only thing that you absolutely remember is what you read and wrote on your lecture notes. It doesn't remind you of any conversation that we had but that is what they [the lecture notes] are for. This is the way that you listen to lectures: You go piece by piece. As soon as there is something to write down, you write it down, disengage brain, eyes are somewhere else, you doodle, look up, oh, there is something else to write down. And so all you remember is what you have written down, not what you heard. That is the function of notes. So you might try that. See if it doesn't improve what you are doing.

Such "preaching" to his students was quite common in Carl's class. The content of such conversations usually dealt with basic study skills such as note taking, reading the text, looking at "enhancement" information in the text such as margin notes and diagrams,
following through on homework assignments such as vocabulary lists, using class time effectively, etc. In other cases, such comments focused on poor attitudes toward school, the lack of math skills, the dangers of smoking, or the problems that the current lack of skills and good work habits may cause in the future. Though these comments were generally made in a level tone and often within the context of the lecture, there was always a hint of exasperation in Carl's voice. Maybe this was his attempt to encourage his students into being the higher quality of student that he really wanted, or maybe this was a way for Carl to vent his frustrations at his students under the guise of being supportive. Regardless of his motives, Carl's students seemed to be generally unaffected by such comments. Though they often listened politely to what Carl had to say, few students changed their behaviors in response to the suggestions.

Throughout the lectures, Carl seemed to dominate a large portion of the conversation. Students were involved in the lecture through questioning, but many of these questions related to information which Carl had not yet delivered. It is difficult to know if Carl was trying to assess information which the students should have learned by reading the text, or if he did not understand that the students were not adequately prepared to answer the questions. Nevertheless, the students usually did not volunteer to answer Carl's questions. To get responses to inquires, Carl usually had to call on specific students. Since the first several students usually responded to his questions with silence or "I don't know," several students had to be given the opportunity to answer the questions before someone responded with an answer. Once answers were provided, Carl rarely asked the students to expand on their answers, explain their logic, or provide insight into their thought processes. If elaboration was needed, Carl usually did this task for his students. The general unresponsiveness of the students may have contributed to what became the less and less frequent use of questions during the lecture. Questioning may have become too much of a struggle to continue and Carl, consciously or unconsciously, may have made the decision to limit the use of questioning.

Though lectures seemed to be the dominant medium to introduce material, it was by no means the only way. Carl seemed to work hard to find alternative ways to represent the key ideas of the content to his students in a concrete manner. For example, Carl used ball and stick models in conjunction with a series of demonstrations to help students understand the ideas of chemical reaction and bonding, used a "random movement box" with balls of different sizes to help students understand the concept of diffusion across a membrane and the effect of molecule size versus pore size in the membrane, and used a ball of clay to help students understand the importance of surface area to volume ratios in cell division with an additional demonstration on how "pinching" occurs in animal cell
division. In addition to the aforementioned "traditional" means of presenting material, many of the approaches Carl used were quite creative. For example, dehydration synthesis was demonstrated in the guise of "Samurai Enzyme," modeled from a John Belushi character. Dressed in a "samurai" outfit and speaking with an oriental accent, Carl would come out and try to chop a water balloon in half with a meat cleaver to demonstrate the necessity of removing water before joining two molecules in a chemical bond. Carl also designed a "skit" to demonstrate the process of protein synthesis. Each student wore a card around his/her neck identifying the students as a codon of DNA, mRNA, tRNA, or an amino acid. Using these props, Carl would have the students walk through the entire process of protein synthesis.

Humor in the classroom was also introduced during the more "traditional" classroom presentations of material. Carl would often adopt a "hillbilly" or "Australian" accent in order to deliver his lecture. Though the students generally found this amusing, they often tired of the accent before the period was over.

When in a playful mood, Carl would also engage in friendly banter with his students. The students seemed to enjoy this. Such banter kept the mood light and increased the students' willingness to participate. The following conversation, conducted in a "hillbilly" accent, occurred as Carl was dismissing his students to begin work on a lab exercise:

Carl: If you have questions come talk to me and I will tell you that you are ugly or something.

Male Student: Am I ugly?

Carl: You are ugly!

Female Student: You are ugly too!

Carl: That's right, and I will say I am ugly too so we can all go to an ugly farm.

Carl usually limited his lectures to 20-30 minutes. Having 55 minute periods, this left a large portion of time for further activities. On 25% of the total class days, Carl allotted the remaining portion of the class for some sort of review or reinforcement activity. In many cases, students were requested to read a section of material from the book, define vocabulary terms from the chapter, or answer questions from the text. Assignments such as these were written on a side board in the room. In other cases, Carl assigned a worksheet which coincided with the material which was being presented in lecture. In most cases, these worksheets, usually from the supplemental activities included by the textbook publisher, provided the students with practice on lower level concepts such as vocabulary. On a few occasions, the materials provided connections of the currently studied content to
past or future content, though such connections seemed to be a secondary focus of the
activity.

The students usually worked on these assignments begrudgingly. Many talked quietly
with nearby students while they worked, others read magazines or stared off into space.
Carl rarely came out into the room to monitor the students' activities at this time. He
traditionally sat at his desk and read or graded papers. When students had questions,
they would usually approach him at the desk.

Since the student level of concentration in completing the various tasks was usually
low, small incidents seemed to be enough to encourage the students to stop working. For
instance, if a student started a conversation with Carl, most of the class would stop working
to listen. This encouraged other students to join the conversation which usually continued
until the end of the period. In other instances, early finishers would become involved in
playing "football," a desk game using a folded piece of paper as the ball. Once this game
started, most of the students watched the game rather than work. Though Carl often
scolded the students for wasting the time that he provided for them in class, he usually
took little action to insure that the students worked until the end of the period.

On other days, Carl involved his students in lab exercises, group work, or movies.
Labs usually occurred about once a unit, or 7.5% of all class days. These labs, typically
from the text, were used to provide students with hands-on experiences with the materials
which were being discussed in class. The labs were usually used to confirm information
taught elsewhere and lasted one or two lab periods. Carl usually did a satisfactory job of
preparing his students for the lab exercises. Once the labs started, Carl was often busy
moving from one group to the next at the students' request for help. With only 15 students
in the class, there were often enough materials for each student to work alone, including
when using the microscopes. In an attempt to keep the students engaged in the lab
exercise, Carl often followed the unit with a lab practical, assessing the students' learning
or skill as gained through the lab exercise.

Cooperative group work was used on one occasion. When introducing the cell's
structures and functions, Carl assigned students to groups with each individual responsible
for teaching the other members of his/her group an assigned number of organelles.
Despite elaborate preparations by Carl, the unit was not very successful. Many students
were frustrated by the assignment, not knowing how to define terms whose definition
depended on understanding other terms. This frustration may have been partially Carl's
responsibility since he failed to recognize the reliance of the textbook definitions of the
organelles on the definitions previously developed in the chapter. In the end, five students
did not show up on the day of their scheduled presentation, negating the potential effectiveness of the activity.

Movies were shown on 12.5% of the days. Next to lectures and worksheets, this was the most prevalent instructional activity in Carl's class. Many of these films were shown as part of "Nature Week," a seven day classroom segment devoted to showing films related to plants, animals and ecology. Due to the timing of "Nature Week" versus the formal presentation of these topics, it is not known how or if the films were later tied back to the formal content.

In general, Carl covered the units in the text fairly quickly. Each unit usually lasted a little less than two weeks and was followed by a unit test. Unit tests were taken from the textbook's test bank and consisted of approximately 30 multiple choice questions. In some cases, a short answer essay question was included. Of the questions analyzed, 83% assessed lower level objectives, and 17% upper level objectives, usually at the application level. Carl had mentioned during an interview that the was particularly pleased with the test bank since it provided questions which tested high level objectives. Writing such questions did not seem to be a skill with which Carl was comfortable.

For most units, Carl also gave the students a quiz. These quizzes, usually about 12 questions long, were often similar to the tests and typically focused on vocabulary.

The learning which occurred over the entire semester was assessed through a semester exam. Using many of the questions found on earlier tests, this exam consisted of 100 multiple choice questions. Carl did not assign semester projects.

**Classroom Subject Matter Structure**

Carl taught the following units in the sequence listed during the semester of observation: Studying Life, Understanding Life, Basic Chemistry, Cell Biology, Cell Energy, Cell Division, DNA/RNA, Nature Week, and Genetics. It was based on the data collected from these units that Carl's classroom SMS (Figure 8) was generated. Methods for the derivation of this SMS can be found in Chapter IV, Textbook Subject Matter Structure: Methods. The reader is referred to this section if questions concerning methodology arise. In addition, the evidence used for the generation of the SMS can be found in Appendix I and cross referenced to Figure 18.

Carl's general sequencing of content followed the model provided in the text. The only significant variations in sequence had to do with the addition of units of instruction. Carl divided the unit on Cell Reproduction into two units: Cell Division and DNA/RNA. It is assumed that this division was established to decrease the amount of content that the
students would need to master for a single test. Carl also added a unit called Nature Week. This unit, lasting seven days and surrounding the Winter Break, consisted of a series of nature films which, according to Carl, "did not fit in anywhere else in the curriculum, but are really good." Carl considered the timing of Nature Week optimum since the students attention spans seemed to be limited during this time.

Due to Carl's initial request that observations not be conducted during the first two weeks of the school year, his early absences due to illness, and the nature of the content presented during Nature Week (it was earlier determined that observing movies would not contribute greatly to the understanding of a teacher's SMS, especially since the films were selected by departmental choice and admittedly not tied to the curriculum), several of the units presented first semester were not observed. Specifically, no classroom observations were made during the following units: Studying Life, Understanding Life (taught by a substitute teacher) and Nature Week. The reader is reminded that information concerning the content of these units was obtained through lesson plans, classroom materials, and tests.

There seem to be three major components to Carl's SMS: the structural foundations of living things, genetic continuity, and linking concepts. No evidence of content related themes were found. Each of the three major components will be discussed separately.

The structural components of living things, as evidenced from Carl's SMS, can be identified by the basic principles of chemistry and how these principles relate to cell structure, function and energy systems. These three units seemed to be tied together for Carl, with latter concepts directly tied back to concepts taught earlier in the sequence. On the classroom SMS, such connections are represented by a multitude of back reaching references and strong interactions between the chemistry related topics. Within these three units, Carl seems to draw on examples from Human Biology and, less frequently, the plant and animal kingdoms. These references seem to be provided in order to establish relevancy of the content to the student's lives through the medium of their own bodies.

Carl also used the content of these units to make comments of the role of models in science and the use of science process skills in order to collect and make sense of data. Unfortunately, it is unclear if these concepts were directly tied back to content in the introductory units since these units were not observed. However, analysis of the materials from the introductory units do not indicate any direct relationship.

The second component of Carl's classroom SMS was in the area of genetic continuity. The topics of cell division and genetics were closely related to each other through the concepts of meiosis, fertilization, independent assortment, and the transmission of
Figure 8. Carl's Classroom Subject Matter Structure.
hereditary traits. References occurred in both directions, reinforcing the interconnectedness of these two units.

Finally, the above two components seemed to be linked together by several other ideas. The primary bridge between these components was the DNA/RNA unit. The information in this unit related many of the concepts developed in the units on cellular structures and processes, through the chemistry of DNA and protein synthesis, to the content presented on genetic continuity or variations. In addition, forward reaching connections alluded to the eventual importance of such information in terms of evolution. The last bridge occurred in the use of the meanings of word roots, prefixes and suffixes to help determine the meaning of words. Comments concerning word meaning can be traced back to a single worksheet introduced in the first unit. This final connection back to the introductory units, which was not directly stated, may be "accidental" rather than "planned."

Inspection of the evidence provided through analysis of classroom materials revealed the repetition and reinforcement of connections made during classroom presentations. However, many of the connections existed as single questions on a worksheet or test and may have been fostered as much by the inclusion of such references in the text-provided materials as through the purposeful inclusion of these references by Carl.

Three factors which may or may not show up on Carl's SMS but which influence its interpretation include issues of relevancy, math avoidance, and incomplete content knowledge. Each of these factors will now be addressed and, when appropriate, supported with evidence derived through the analysis of the classroom transcripts.

In listening to Carl's classroom presentations, it was obvious that issues of relevancy were important to him. Carl seemed to use relevant examples in two different ways: scientific examples which related the content to the students' own lives, especially their bodies, and common experience examples which provided students with concrete representations of otherwise abstract ideas. In both instances, an emphasis seemed to be placed on using these examples in a humorous and/or interesting way. Each of these types of uses will be described and illustrated.

When appropriate, Carl often extended the biology content that he was teaching in such a way as to relate the content to the students' personal experiences. One such example occurred early in the year during a discussion of basic chemical reactions. Carl related this topic to students in the following manner:

Inside your body right now, you may not feel like it, some of you may feel like going to sleep, some of you feel like going out running, whatever. But inside your body right now there are thousands upon thousands upon thousands of chemical reactions going on in your body which is making you function.
This example was then followed by a simple explanation of what happened chemically when an organism dies and stated that such topics would be covered in more detail in the future. A second example occurred during a discussion of meiosis and the restoration of the chromosome number at fertilization. In this case, Carl used an example from his own life to illustrate the importance of correct meiotic divisions:

I think you all know well enough about reproduction, when sperm cell meets egg cell. The chromosomes that dad gives and the chromosomes that mom gives have got to total 46. My wife and I lost a baby a couple of months ago and of course the doctors tell you that they really can’t know why. How come it was a miscarriage? The best explanation they give you is that there was something genetically wrong. What you find out is this: One in three pregnancies will end in a miscarriage. You have a very complex situation going on and sometimes the chromosome numbers aren’t right.

A result of such uses of student related illustrations of the content often increased student attention, a benefit which usually continued for several minutes beyond the actual use of the example.

The second use of relevant examples involved equating abstract biological concepts with concrete experiences from the students’ lives which did not have a scientific slant. The following two examples illustrate this point. The first occurred during the introduction to cellular transport, the second in a discussion of endocytosis:

Our topic today is cellular transport. I don’t know if any of you have watched any of the Star Trek movies, but Scottie beams Captain Kirk, Mr. Spock and various other parties of the Star Trek Enterprise everywhere in the galaxy. So whenever he was beaming them around, he was having them change positions relative to one another. And that is what cellular transport is, except in cellular transport objects or molecules or atoms change position relative to a cell membrane.

Remember pac-man? I used to love to play that game. I think of these guys (cells undergoing endocytosis) as pac-man. They just gobble up things. Inside your body this happens all the time. Your white blood cells are responsible for getting rid of all kinds of bacteria, infection, etc., and that is what they do. They basically kind of swim around in the blood stream and when they see something in there that is not any good that they don’t recognize, they just engulf it and eat it up.

As in the previous examples, such use of relevance seemed to increase student attention, though it is unclear as to whether it actually helped them learn the content involved. Such examples also portrayed a "human" side to Carl which the students seemed to appreciate and enjoy.

A second factor which influences the interpretation of Carl’s classroom SMS is the avoidance of some content, in particular, math related topics. As Carl previously mentioned, he did not feel that his students possessed enough math content background
to adequately handle many of the concepts which he felt were important in biology. In response to this concern, Carl often avoided all math related issues (field of view under a microscope, surface area to volume ratios as they affect cell division, etc.) by eliminating that section of a lab or avoiding questions on worksheets. Carl seemed to feel that the avoidance approach to math was more important than the content understanding which may have been gained through the teaching of the math content. The following quote illustrates that decision. Carl made the following statement to his students during the pre-lab portion of a lab which involved viewing cells under the microscope:

We are going to skip page 31 and the last part of page 32 completely. We are not going to deal with any measurements. Some of you guys’ math skills are so poor that I am not going to fight with it and waste my time. So we are just going to skip it. I used to (assign the measurements sections). I could deal with those kinds of things. But positive ten is like speaking Greek to some of you, so we won’t bother with it for the moment.

Finally, the last factor which may influence the interpretation of Carl’s SMS had to do with incomplete content knowledge. In several instances, all related peripherally to genetics and heredity, Carl made statements which led one to believe that his content knowledge in that area was inadequate. Two examples of incomplete content knowledge occurred during the discussion of the stages of meiosis. Carl defined synapsis and crossing-over as different names for the same process. Later in the same lesson, Carl could not recall the genetic basis for Down’s Syndrome in response to a student inquiry. Though neither of these mistakes seem critical in and of themselves and may actually be considered trivial and/or a slip of the tongue, they seem to allude to greater misunderstandings. For instance, when working simple genetics problems with his students, Carl had a tendency to name the dominant allele "normal," regardless of the trait. So the alleles for straight and curly hair would be designated "normal" and "curly." Such a representation of the alleles involved may lead to later confusion and misconceptions by the students, particularly in terms of confusing the ideas of dominance (a genetic characteristic of an allele) and normal (an attribute of the frequency of a genotype in a population).

Perhaps more telling of Carl’s insufficient knowledge of genetics can be found in the following lesson segment. Carl was in the process of working out genetics problems with his students on the board. He has just defined the alleles in the problem as "N = normal" and "n = curly." The genotypes of the parents were listed as Nn and nn. Based on this information, Carl was asking his students for the information needed to set up the Punnett square:

Carl: Brian, what possible gametes can that parent produce? (No response.) Sex cells, also genes? Gary, how else can you phrase that?
Male Student: You mean like what is inside the box? (Obviously the students are unclear about what Carl is looking for.)

Carl: You have got to understand the term. What is a gamete? Let's go back and review what we have done. The sex cell. What happens in meiosis to the number of chromosomes in a cell?

Female Student: They make exact copies of themselves.

Carl: No, meiosis.

Male Student: They decrease....by half.

Carl: Decreased by half. In other words, if this guy is going to produce sperm, what two possible sperms can he produce?

Female Student: Big N or little n?

Carl: Big N or little n. So when I say gamete, I mean that.

Notice how Carl has confused the terms "gametes" and "alleles," even though he provided a correct definition for gamete earlier in the unit, which was the source of the students' confusion. Now that Carl has stated the above definition, he used it consistently throughout the rest of the unit.

It is interesting that Carl's greatest weakness, in terms of content knowledge, occurred in the area of Genetics. According to Carl's science course listing, he had a college course specifically in Genetics as well as introductory sequences in both Botany and Zoology where there is a high probability that genetics was covered. Despite this incomplete knowledge, Carl does an admirable job of appropriately tying the concepts introduced in Genetics to other portions of the curriculum. Finally, this incomplete knowledge of genetics is particularly interesting since Carl described the genetics unit as one of his favorite topics to teach and one in which his students typically do well.

In comparing Carl's SMS to that produced from the textbook, both similarities and differences can be found. Carl adopted the basic sequence presented in the textbook but then varied this by dividing the Cell Reproduction unit and adding Nature Week. In addition, Carl seemed to do a better job of integrating the content presented in the first nine chapters of the text than the text by itself was able to do (see Figure 1). His connections drew more directly on content previously learned (back-reaching references), as opposed to the text which typically alluded to how current content would be used in the future (forward-reaching references).

Carl also used the DNA/RNA segment of the text to relate the chemistry and heredity unit where the text did not. It is interesting to note the important role that the DNA/RNA unit
plays in Carl's SMS, especially since this is the one unit which he is considering dropping, or at least simplifying, in the future.

Carl's use of examples tended to gravitate toward human biology and/or non-science experiences that students have. This is in contrast to the examples used in the text which more typically related content to plants, animals and less frequently, the protists.

Finally, Carl's SMS should be viewed in terms of his stated goals for his Biology class. From the information presented during the first semester, little evidence can be found of Carl achieving his intended goal of making the students "aware of the five kingdoms." However, it may be inferred that Carl was building up the knowledge base necessary for his students to appreciate the complexity of living things which relates to the second goal which was stated by Carl for his students.

**Self-described Subject Matter Structure**

Carl was asked to answer the questionnaire concerning his SMS of Biology for the first time as part of the final interview. Since this interview occurred after Carl's accident and several months since he had last taught in the classroom, the question came as a bit of a surprise. As Carl put it, "I'm not used to having to think like this." Despite the fact that Carl found the thought process which he had to undergo to develop his SMS uncharacteristic of his thinking for the last several months, he seemed willing to complete the task. It is unclear what affect there may have been having Carl answer this question while being out of the classroom for an extended period of time or having it follow his accident.

The SMS which Carl created as part of his final interview is shown in Figure 9. Carl included four major components of biology, Cells, Botany, Zoology and Ecology. These components were joined in a somewhat linear fashion by arrows. Carl described his diagram as follows:

Well, the starting spot is the cell, as far as I can see, cell structure and function. And I broke it [heredity] down into meiosis and mitosis for heredity, which is how ideas are transmitted. The cell relates to both plants and animals which is the key idea. This, to me, is the key idea: That is that living things are complex. Then both of these tie into Ecology. You tie them together with how they fit in the big picture. That is the way I see it.

Carl described the connections between the boxes of content which he had created as representing a sort of hierarchy, a sequence of topics which should be followed. Carl described his connecting lines as follows:

They [the connections] show how the cell relates to both [plants and animals]. It [the cell] is the basis for both plants and animals. Then plants and animals then tie in, they relate to one another in the ecological picture. Like through photosynthesis and respiration, that idea.
Figure 9. Carl's Self-Described Subject Matter Structure.
Carl believed that the four components of biology which he identified were equal in value to each other but, in practice, some of the components were given more time within the curriculum. Increases in time were a direct result of more labs, specifically in the zoology and botany units whose labs took more time to complete. Carl was careful not to equate the time used to teach a unit to the time that students needed to conceptualize the content:

It's not necessarily that conceptually it's [zoology and botany] more important. But it's the amount of time that it takes to get through it if you plan to do labs with kids. It's the amount of time it takes to get through dissections and so on and so forth.

It is interesting to note that though Carl felt that the botany and zoology aspects of his curriculum were the most time consuming, the content in the cell "unit" which he included in his SMS took almost the entire first semester to complete. It is also interesting to note that Carl did not include evolution in his SMS even though he had previously discussed its importance in tying the content of the first and second semester together and had admitted to enjoying the teaching of the content in this unit.

For Carl, the most important aspect of his conception of biology wasn't really represented clearly in the SMS which he diagrammed. Carl felt that this philosophy, stated below, should permeate the SMS drawn. Carl explained:

The overall idea is that, and it really isn't included here, is that by their study of biology students should gain an appreciation of life. And then, there is some value with being able to put a name on something because what is a common question you get from kids? "What is that? What is this?" Like, if you went walking on the coast and you got in a tide pool. You should have some clue of what those [organisms] are. That's an idea that I think is important. To appreciate the study of life, it's a part of your world.

When asked where the various components of his SMS came from, Carl replied in a rather surprised fashion, "That's just the key things in biology. They're the same ones [topics] you see in every textbook and the main courses that you have to take in college."

However, when asked if he had always thought about these four components and the relationships between them, Carl admitted that much of this thinking had developed after he entered the teaching profession:

When you're in college you really don't have to think about how everything fits together. You just take the courses and concentrate on learning the material. But after I started teaching and seeing all the content in one place, I started to appreciate how everything fit together and I really started to appreciate the complexity of even the simplest things.

So, did the relationships between the four components of biology influence what Carl did in the classroom? Carl replied:
Like, do you mean, do I sit and draw this picture each day before I go into class? No, I just go in and teach my classes. But I know it all relates together and I think sometimes that comes out. And the appreciation part, sometimes I try to show how it all fits together. But if I do too much of that, it just confuses the kids.

A logical question, based on Carl's emphasis on the topics of biology working together in order to foster an appreciation for life was whether or not Carl felt that his students came away from his class with an understanding of the relationships which he had expressed. To this question Carl replied, "Oh man, that's a tough question." Carl continued:

Carl: I don't know that they would put that [SMS] together. Even asking my students to make an outline of something is like pulling teeth. And to go from a broad structure [such as that represented in class] to narrow something down [as in the SMS], that's a level of thinking that very few sophomores that I can see have. You know what they would do? They would go back and say, "First we studied the cell, then we studied this," basically like a table of contents.

Researcher: Do you think that it's important that students have more than a table of contents in their heads?

Carl: I do. I think you see an emphasis today, you see it on TV, you see it everywhere, on earth day. Hey, our planet. How long do we want our generations to live here? I think the kids are starting to see the importance of it, how everything connects together in nature.

Following this statement, Carl was reminded of an earlier discussion in which he stated that many environmental issues tied back to concepts in chemistry and genetics. Did he feel that his students could also see the connections of these content topics?

I think the majority of the kids, no. Some of the kids, yes. The kids that are on a higher level of thinking, that are really with you, I think they can make the connection. But the average kid, I would say no. I don't think they make that connection.

Carl seemed to take a fairly strong philosophical stance that the content of biology was interrelated through the complexity of living things and that it was important for his students to appreciate this complexity. However, it did not seem that Carl acted on this belief in his classroom in order to foster this appreciation in his students. For Carl, teaching them the standard content of biology and eventually teaching students the names of the organisms that they would see in the surrounding environments seemed to be enough. Other connections, for instance, understanding the complexity of such things as environmental issues, would come from some other undisclosed source such as the news.
Summary of Carl

Carl described his SMS as having four components of equal value: cells, botany, zoology, and ecology. These topics were listed in a roughly linear manner with cells being listed as the first and most fundamental element. For Carl, cells and the biochemical reactions which controlled cellular activity constituted the most basic and essential content in biology. This content could then be used to understand both plants and animals. A greater understanding of plants and animals could be obtained by looking at the relationships which these organisms have with each other and the environment in the content area of ecology. According to Carl, these four components were permeated by the goals of having students appreciate the complexity of life and to be able to recognize organisms to the extent that they could be classified within the five kingdoms.

Carl described the four components listed in his SMS as being the key topics in biology. These topics were distilled through Carl’s own experiences in college content courses and the textbooks provided for the teaching of biology. The relationships between these components became evident to Carl as a function of teaching biology and “seeing all the content in one place.” Such relationships were not recognized as a result of his college experiences since much of the time in college was spent simply “learning” the material.

For Carl, a logical order existed for the teaching of the biology components listed and the sub-components which made up each area. This order, starting with chemistry and the cell and building through the organisms to ecology, had been recognized by Carl during his college content courses and may have existed prior to that time since Carl recalled having opinions about the logical order of content presentation even as a college student. This logical order was further developed by Carl during the early years of his biology teaching career.

The selection of Carl’s current biology textbook was based on its match to the logical order of biology topics which Carl perceived. This selection explains the high correlation between the organization of the text and the sequencing of material presented in Carl’s classroom. When Carl taught from a text which did not match his perceived order, he changed the text sequence, confirming the presence of an inherent logical order as reified by Carl as opposed to the adoption of an order found in the text. As Carl stated, the order of the content was not necessarily as important for the student as it was for the teacher. In fact, Carl felt that it was possible that his organization may not be the best for his students, though he did not seem anxious to explore this possibility.

When selecting the content which would be included in his biology course, Carl noted that the topics which should be included were those which the teacher personally felt were
important and which interested them. Carl qualified this statement commenting that such opinions would change as a function of teaching experience, but that such a developmental change was acceptable and should be expected.

Carl did not seem to recognize any themes which existed across the content of biology. What he did envision as integrating forces were his two stated goals for his biology students: an appreciation of the complexity of life and a recognition of organisms classified according to the five kingdoms. The goals which Carl set seemed to be a function of his own personal experiences in biology. For instance, Carl recognized that one of the most powerful things which he had learned as a college undergraduate was the integrative nature of the structure and function of living things. It seemed that this experience was key in Carl stating a similar goal for his students. Carl's second goal seemed to be tied to his experiences with students. Carl noted the ubiquitous nature of questions dealing with the names of objects in the natural world. It seems that the prevalence of such questions acted as the impetus behind Carl's second goal.

It should be noted that Carl's goals for his students were also based on his perception of their academic ability. In several instances Carl qualified his goals and expectations for students in terms of appropriateness "for this level of student," or wistfully "if I had better students." Early concerns based on the consistency of Carl's goals were fostered by this observation.

The most obvious case of student level affecting Carl's goals seemed to be represented by the dichotomy between the biology and chemistry/physics students. The chemistry/physics students were expected to master the content needed for freshman college science courses. The content goals for the biology students, as listed above, were much less rigorous. It was also important for the chemistry/physics students to understand the processes of science. Such a goal was not mentioned in terms of the biology students though, during one classroom observation, an emphasis on science process skills did occur.

It is interesting to speculate why Carl did not feel the same conviction for teaching his biology students process skills as he did for his chemistry/physics students. A possible answer may be derived from statements which Carl directed toward lab work. Carl had explained that labs could be used in an inductive or deductive manner. Inductive labs would allow students more opportunities to be involved in process skills. Deductive labs, which Carl seemed to feel were more appropriate for lower level students, would not necessarily emphasize process skills as much as allow students to verify the content which had already been presented. It may be inferred that Carl felt that the level of students in biology classes were such that only deductive labs, minus the process orientation, would
be effective. This would explain the limited exposure of the biology students to process skills and the de-emphasis of this goal for the biology classes.

In comparing the SMS generated by Carl and that derived from his classroom practice, fairly high levels of consistency can be found. Both SMSs emphasized content and the relationships within and between content topics. Neither SMS had themes. Both SMSs showed a close relationship existing between the content included early in the school year: chemistry, cell structure and function, cellular processes, cell division, and genetics. A problem exists when comparing the two SMSs beyond this point. The majority of Carl's SMS was based on second semester content. Since second semester classes were not observed, the relationship between Carl's SMS and the manner in which would be taught cannot be evaluated. It is also difficult to determine the translation of Carl's goals into classroom practice since many of these goals would not be directly attended to until the second semester (by Carl's own admission). What can be claimed is that the SMS derived from Carl's classroom teaching was not inconsistent with that which he described. The only noted discrepancies between Carl's SMS and classroom practice existed in terms of a richer SMS being evidenced in his classroom teaching. For instance, Carl did not include the content items of evolution or DNA/RNA in his SMS though this content was included in his classroom content sequence. It is interesting to note that the content contained in both of these noted discrepancies were also content items which were of concern for Carl: DNA/RNA because of poor student response despite Carl's own recognition of the importance of the topic, and evolution because he did not agree with all the ideas contained in the evolutionary theory.

The most influential factor on Carl's ability to directly translate his SMS into classroom practice seemed to be his students. Through positive and negative feedback, Carl's students seemed to be in the process of controlling both what was taught in the biology classroom as well as how it was taught. For instance, positive student feedback, typically in the form of increased attention in class, had encouraged Carl to use and expand his use of relevant examples and humor. In addition, Carl continued to emphasize the reading of the text even though the level was admittedly above the capabilities of many of the students because a few students had returned to thank him for encouraging them to read the text. The use of negative feedback, primarily in the form of reduced attention or cooperation, had encouraged Carl to consider dropping content which the students did not like but that he valued for personal interests and its "vital" role in the content (the DNA unit), to decrease content from an in depth coverage to an overview, to reduce the number of labs or problems which involved math skills, to reduce the number of questions asked in class, to reduce the level of content from a higher level to a lower level, and to discourage
the emphasis on students being capable of synthesizing the content of biology beyond a "table of contents" level. It is interesting to note the power of the students in the translation of Carl's SMS into practice, especially when one notes the level of personal commitment which Carl seemed to place on the DNA unit, labs in the classroom, quantification in science, and the relationships (i.e., complexity) among living things. Carl's nine years of teaching in his present school system and the two years of teaching in a school of similar ethnic composition may have acted to shape Carl's classroom practice, though the influence of the students on Carl's personal SMS is unclear. It may be that Carl's "flight" from the required content courses to the elective science course was in an attempt to preserve his personal SMSs by dealing with a group of students to whom he could comfortably teach his SMS without compromise.

There are several limitations to the data collected from Carl and the generalizations which can be made from this data. First, Carl's SMS was primarily based in his second semester content. For that reason, the evaluation of the degree of translation of his SMS into classroom practice will be limited. Second, there is no way of truly understanding the impact of Carl's accident on the information which he provided during the final interview. The accident may have significantly affected the answers provided at this time. However, all data sources seemed to be relatively consistent. Thus, the accident may not have seriously affected the quality of the data collected during the final interview, though the possibly of such an influence cannot be ignored.
Don was contacted in the spring prior to the study to determine his interest in participating. At the time, Don said that he did not think he would have time to be involved because he coached volleyball in the Fall, but welcomed additional information that might be sent to him. Based on this initial response, it was surprising to receive a positive notice of confirmation of participation from Don during the summer. When called to question this change of heart, Don stated that he had been offered the Department Chair position for math and science which he "exchanged" for his coaching role. With this change in responsibilities Don felt that he now had the time to participate in the study and was willing to do so.

Don was a soft spoken man of medium build. The initial interview was conducted in the Fall in his classroom and lasted approximately 60 minutes. Since Don had originally been hesitant about participating in the study, his willingness to participate was checked again. Don reconfirmed his interest in participating in the study and acknowledged that he understood the expectations which were anticipated as a result of his participation.

During the initial interview, Don described his early career aspirations as leaning toward the fields of wildlife biology or oceanography. Don attended a branch campus of a state university in the West where he pursued his interests, graduating with a BA degree in Environmental Biology. His coursework produced a strong environmental perspective with an organism level emphasis in plants and aquatic systems. In fact, almost all of Don's coursework related to ecology, plants or aquatic ecosystems. As Don commented: "I took a lot of plant and animal courses. I was interested in plants and animals and how they fit in with the environment." In addition to the ecology and natural history courses central to his major, Don also completed coursework in genetics, geology, geography, chemistry and physics. When asked about his content preparation in terms of teaching, Don described it as "fine, more than adequate for what I was teaching."

Upon graduation, Don found the job market more competitive than he had originally imagined. He returned to a different state college in the West and obtained a teaching credential. Don considered the selection of a teaching career "natural" since both of his parents were teachers.

Don's educational training seemed to contain the usual courses in foundations, educational psychology, methods and student teaching. When asked about how this
coursework prepared him for the classroom, he replied: "Education classes? I learned more just student teaching. And I worked as an aid in lots of schools. I learned a lot more doing that. Education classes don't really prepare you much to deal with kids."

Don's statements about learning to teach through the process of teaching were consistently stated during the semester. In a discussion about a new teacher with discipline problems, Don commented: "You learn discipline methods as you teach and you become better at dealing with them in time." This comment is interesting in light of Don's own ineffective methods of classroom management and discipline, which will be discussed in his Classroom Profile.

Following his teaching certification, Don taught for one year in an alternative high school program in California where he taught all of the science courses. This job seemed to be an extension of his student teaching experience where he taught both middle school and high school aged students.

Don moved to his current location 12 years ago, about the same time that the school in which he was employed opened. The school was the third high school to be opened within a larger district and was located 30 miles from the center of the district. Don's school served a growing rural population of approximately 5000 people with approximately 450 students in grades 7-12. The majority of these students lived 10 to 20 miles from the school and depended upon school transportation which sometimes limited student attendance on heavy snow days.

When asked to describe the community in which he worked, Don replied:

It is not a real high academic group. Generally, the people in [the town] are people that either don't want to live in a city or can't afford to live in a city. So it is basically a lower economic group and we send maybe 10% on to college. It is not a real high academic bunch. [The parents] work in the resorts or work in [a neighboring city] or are loggers or are on welfare. We have a real high number of free lunches, probably 60%. We also have tons of kids moving in and out. If I have a class of 20, probably five or six kids will move out and five or six will move in every semester. A lot of them are children of retired people too, so they go south in the winter and come back in the spring.

Don described this population as being "generally disinterested in education," an opinion he supported with low attendance at parent teacher conferences, claiming participation by only five or six parents in a class of 25 students.

Don was one of three science teachers in the school. The school offered a Life Science class to seventh graders, Earth Science to eighth graders and Physical Science to ninth graders. All students, in addition to the courses mentioned, had to have an additional year of biological science. Sixty percent of the students fulfilled this requirement by taking Biology. The remaining 40% selected a combination of semester courses offered in
Environmental Science, Oceanography, or Forestry. Upperclassmen who elected to continue in science had the choice of courses in Physics, Chemistry, Advanced Biology, or Technological Systems. Some of these upper division courses were offered on an every other year basis.

Don's teaching load consisted of three preparations: three sections of Biology, one section of Life Science, and 2 sections of Computers. One of the other science teachers taught the remaining Life Science courses and biological science electives. Though Don had taught biology for 10 of his 13 years of teaching, he enjoyed his computer courses the most. Don found computers and computer work personally interesting, thus he found them stimulating and fun to teach.

When asked about his goals for the teaching of science in general and the teaching of biology specifically, Don commented:

As far as facts, memorizing facts aren't nearly as important as knowing how to take a problem and figuring out how to solve it. I don't throw them [the students] long lists of memorization to put into their heads. If I give them a question, I really want them to be able to find out the answer to that question. [Learning how to find the answer] is one of the hardest things to teach because, whose ever fault it is (and it is never anybody's fault), they [students] have learned the major thing is to get the right answer. But how you get the right answer isn't important [to them]. As far as I am concerned, how you get that answer is far more important than what the answer is. You forget the answers but you don't forget how you find them. That is the major thing and that's the most difficult thing to do.

Since Don taught a variety of grade levels, he was asked about his favorite age group to teach. He easily replied: "High school, just because they are easier to deal with in certain ways." When describing his "ideal student," Don said:

There is no such thing (laughs). [They should] listen and follow instructions, be able to read well, and basically have an interest in things other than themselves and their immediate group of friends. In [this town] a lot of students just don't seem to care what is going on outside of their own particular area.

Don's comments seemed to indicate rather low expectations for his students. When asked to describe the basic characteristics of the students who were traditionally successful in his biology classes and the classroom techniques which they preferred, Don described his students and their reactions to the teaching situation in the following manner:

They don't do much homework. Things that they can be easily successful at motivate them more than anything else. [For instance,] they like doing the regular hands-on activities and they like working out of the book. So I try and do as much hands-on activities as I can. Also as many labs as I can do, and that [labs] is probably the best, it works better than anything else.
Despite Don's verbal commitment to his involvement in the study, he was relatively uncooperative. This difficulty often manifested itself around Don's reluctance to commit himself to a teaching agenda for the week. Generally, Don only planned what he was going to teach the following day. Little occurred in the way of advance planning, which often made the scheduling of observation days difficult. In addition, Don often seemed reluctant to return weekend calls concerning the weekly schedule. This reluctance was probably a result of not having concrete plans to report.

Don had requested that classroom observations not be conducted until the third week of school, allowing him a period of time get to know his students and to allow for student adjustment to the class. Despite this initial delay and Don's reluctance to provide an accurate schedule of the week's activities, his third hour biology class was observed 14 times over the course of the semester resulting in the observation of 16.9% of the total days that Don taught. Worksheets, labs, activity sheets, and tests which Don generated for use in his class were collected on a weekly basis. Don's final interview was conducted three weeks after the last classroom observation, and lasted approximately 75 minutes.

**Course Specific Perceptions and Concerns**

The organization and sequencing of Don's biology class closely followed that represented in the text with the exception of teaching ecology at the beginning of the year rather than at the end. Specifically, Don taught the following major topics in the following order: introduction to biology, ecology, basic and organic chemistry, cell biology, cellular energy, and cell division.

Don's plans were to finish the year with units on genetics, evolution, and a survey of protists, fungi, plants and animals. Human biology was not taught and comparative anatomy and physiology was only covered very briefly. Don described the end of the year as typically falling somewhere in the middle of his survey of the animal kingdom. No special provisions were made to teach the key points of the content. The classes just simply stopped. Though Don praised the new text book because it had a phylogenic, rather than a systematic, approach to the kingdoms, he felt this change in organization would not affect his teaching. As Don explained: "I rarely have time to cover the animal kingdom and if I do it's very superficial...I haven't done any dissections in the last couple of years just because they are too time consuming."

When asked about the rationale behind moving ecology to the front of the biology sequence, Don provided the following explanation:
I think the main advantage is it [ecology] catches their interest earlier. It makes biology seem more accessible. As far as the content, I don't think it would make much difference. You will get different arguments from different people. I don't see any real advantage to doing it either way [ecology first or last]. I used to do it the other way around. I used to end up with ecology. But I found that I was losing large chunks and I didn't want to do that. I wanted to cover it thoroughly so I just put it at the beginning of the year.

Don obviously valued the content that was taught in the ecology unit and, as he later admitted, it was his favorite unit to teach. When asked about the source of this preference and student enjoyment and success, Don replied:

[Ecology] is my basic background and is something that I am most interested in....And it's easy for the kids to relate to. It's something they can see happening. And I don't think the level of difficulty is as high [in ecology] as some of the other stuff....They always have trouble with cell chemistry and things like that. Protein synthesis and genetics, they always have trouble with that.

The idea that students enjoyed and did well on this unit may have as much to do with the level of difficulty of the material as it did with Don's comfort level and interest in ecology. When asked about the specific influences of his preference for, and background in, ecology on his teaching, Don stated:

I have probably spent more time covering that area [ecology]. In fact, I know I do, more than other teachers who don't have that [ecology] background. I probably give more examples from ecology to other things.... I probably bring most of the extra stuff in on that one [ecology unit] than the other ones [units].

In addition to the above comments, Don agreed with the statement that ecology was potentially an overriding theme in his biology course and was central to many of his units.

Interestingly, when asked about his goals for his students concerning what their understandings as a result of the first semester of biology, Don's previously stated goal concerning problem solving seemed to disappear and a greater concentration on topical familiarity became evident. Goals were described more in terms of having a "basic grasp" of the content covered in the various units. Despite stating such content goals, Don seemed unsure if they could be achieved, possibly due to his perception of poor student motivation (as previously discussed). Don described his goals for student learning, as a result of first semester, as follows:

[My goal for biology students is that they have] just a basic grasp of the concepts [that] I try to go over. As far as what they probably remember, I wouldn't be too optimistic.... I would hope that students have] a general grasp of what ecology is all about. What the main cell structures are, what they do, how they work together. What DNA does and how it does it. How to make different types of organic chemicals, and what they do in compounds, what their functions were and how they were made.
A general reliance on the coverage of topics as dictated by the textbook and personal interest and expertise, seemed to influence much of the sequence and coverage of topics in Don's class. Though a district-wide science curriculum committee (of which Don was a member) had established some rough guidelines concerning the units to be covered, the order of coverage, and the number of days to be spent on each unit (see Appendix F), Don did not feel any pressure to adhere to these recommendations. When specifically asked about how he used the guidelines and how he determined the length of a unit, Don replied:

Basically, [a unit lasts] however long it is going to take them [the students] to understand what we are doing. I don't really pay that close of attention to it [the guidelines]. Generally I just set up my year....The stuff with the units, if I have to cut that off [at the end of the year because I run out of time], then, that's the way it happens. I haven't really covered vertebrate animals well in a long time because we just don't get to it. Some things [units] I cover fast and other things I take longer on. I took probably two weeks longer on ecology than everybody else would. Other people put that at the end of the year and they don't cover it at all. A lot of it is your own personal preference. Some people spend a lot of time on vertebrate anatomy and I don't spend any time on that. That is not my basic background.

As with the other teachers in this study, Don was using a new textbook during the semester of observation. When asked about the impact of the new text, Don described it as "a year of learning" as he became familiar with the new format. Though during the initial interview Don commented that the content of his course would not change as a result of the new text, statements made during the final interview contradicted this view. Don seemed to be closely tied to the order of presentation in the text and sensitive to the emphasis placed on certain topics, even though the text may contradict his personal preferences or traditional content coverage. In addition, Don seemed unwilling to teach any material which was not in the text. These ideas were manifested in the following comparison Don made between the current and previously used text:

Don: [The text is] the same thing [as the other text]. Some of the terminology is different. Some of the vocabulary is different. The amount of time they spend on each type of thing is a little bit different. I was surprised once. I looked something up and expected it to be there, and it wasn't there. They put it in a whole different order and I hadn't picked that up when I skimmed through it the first time. I was just noticing this. When they were going over fossils, they spend probably a half a paragraph on radioactive dating and the other book spent two pages on it and had some worksheets and assignments.

Researcher: Did you include the radioactive dating materials from the other text?

Don: I didn't because the background material isn't in there [in the text].
The above statements, the contradictions in the stated goals for students, the reluctance to plan more than one day at a time, and the reliance on the textbook to provide content coverage, raises questions concerning whether Don really had any clearly defined goals, global or content specific, for his students. His comments seemed to indicate that the content of his course was as much a matter of "personal preference" influenced by an established sequence of topics suggested by the textbook and/or district guidelines (until they had to be "cut off" due to the end of the year) as it was of the implementation of a well conceived content outline or plan which included the coverage of specific goals or objectives. The significance of this observation and how it relates to other data collected in this study will be discussed in the Summary section of this case study.

Don's selection of teaching techniques seemed to be based on two primary factors: student motivation and interest, and preparation time. Each of these variables will be discussed and supported within the following general discussion of the teaching techniques which Don employed and his rationale for their selection.

Don's third period class had 24 students on the role, though the actual number in class each day varied considerably. Most class sessions had 18-20 students in attendance. For those commonly in attendance, there were slightly more male than female students. Don described his third period class as the "brighter one" of his biology classes, "probably the better of the three in terms of scores and things." This observation was supported by Don several times during the semester when he stated that the third period class had four to five A's on a particular test, as compared to only one or two in the other classes. Despite the better overall performance by this class, test scores still seemed to average between 60-65%.

In terms of behavior, Don described all of his classes as being "pretty much the same." Don felt that his other classes may be "a little bit noisier....A lower level group," but he generally felt that these academic and behavioral differences did not affect his teaching in a significant way. Still, Don commented on the additional struggle imposed by poorly motivated students:

Researcher: Do you feel that the differences in student performance and behavior affect the teaching of the different periods?

Don: I try not to, but their motivation is a lot less. That's the kind of kids they are.... [You] try to get them interested at all. You wonder why they take it [biology] because they don't have to take it. You wonder why they are there at all.

The above description is interesting when one realizes that Don also described his biology students (as opposed to those students who chose electives for their second year of science) as the "cream of the crop" in terms of the sophomore class. Don's explanation
for the variation in student level among his own classes was directed toward the master schedule of classes. In a small school, Don felt that the students got "kind of tracked" by certain classes offered elsewhere in the system. In this case, Don felt that an Advanced English course had influenced the specific students assigned to each of his class sections.

Based on Don's generally low opinion of his students' potential and motivation, he was questioned concerning the key influences which affected how he taught biology (Why do you teach the way you teach?). He replied:

How do I teach? (Laughter, and then in a more serious tone:) I would say it is a combination of the time I have available to prepare for the classes, materials I have available and my background in biology. Probably those three things dictate why I teach the way I teach. I know that ideally I would like to have more hands on stuff but it is not possible [because of the lack of time and materials].

In describing his classroom practice, Don discussed beginning with the focusing of student attention on the text and then reinforcing this information with classroom lectures and worksheets. Don described his basic classroom sequence as follows:

Generally, the first thing I assign is to read the chapter. Then I will start talking about it as we go.... Lectures [are] just to get out general information about the subject you are teaching. I know that the kids don't read anything, so in the lecture I try and outline what is important in the chapter.

When asked about the sources and format of the information which he included in his lectures, Don admitted that they come "generally from the textbook." He saw several advantages to this methodology:

The main advantage I found, (pause), sometimes I don't do that [follow the textbook]. And when I don't do that I use different vocabulary. And I will structure some ideas differently than they do in the text. And I have found it is really confusing. It really helps to stay with the way the text shows it otherwise they [the students] will read it and answer questions and it won't be put together the same way.

Don then stated that he often followed his lecture with worksheets which were meant to: "Review what I have talked about and review what they should have read in the chapter. By doing those things I'm trying to get them to look at the book or at their notes or listen to me." These teaching techniques are again inconsistent with the earlier stated goal concerning problem solving but in accordance with his content goals for students, offering them enough material so that they can obtain a "basic grasp" of the content.

When looking for materials to use in his teaching, Don described looking through a variety of textbooks (at least three or four) and their supplemental materials and then selecting the materials that "work best." Though Don felt that worksheets from other texts were typically too text specific to use, this was not necessarily true for labs. Don then explained that he "put units together that I think the kids would understand." This
description, provided during the final interview, was interesting in light of the fact that it was generally very difficult to pin down the specific activities Don was planning on doing throughout the week as a result of his reluctance to plan. It may be possible that Don did collect materials prior to each unit but did not make the decision concerning when and if to use them until the day before their use.

As previously stated, Don did not seem concerned about the amount of time it would take to cover a specific topic. In addition, Don felt that experience was the best teacher when it came to learning how to teach. Both of these patterns are reinforced once more in the following quote concerning how Don selected labs and worksheets for use in his class.

Researcher: So how do you decide which worksheets and labs to use?

Don: Just experience of what I think works best.

Researcher: What if you found 12 days worth of great materials but only had six days to cover the topic? How do you decide which materials to use?

Don: I have never had that problem! (laughs) I don’t know. I just have to look and make a decision which [materials] are best to use. If I have 12 days worth of materials, I might just spend more time doing that [unit] if it looks like the material is going to work well. I am not really stuck on a time line.

In addition to worksheets, Don advocated the use of labs in his classroom. Each of these teaching techniques allow for “group work,” which seems to be defined by Don as any situation in which students are allowed to work together. Don saw this “group work” as important because “if they work in small groups, they actually exchange ideas and they actually come up with some extra things they wouldn’t have thought of before.” Despite this hope for collaboration, Don admitted that some students profited from this opportunity while others wasted it in socialization about topics outside those covered in the classroom.

The reader is reminded that Don originally stated that he felt that hands-on activities and labs were potentially the most successful in terms of student motivation and interest and that he would like to increase the number of hands-on activities used in his classroom. When asked specifically about the benefits of labs and their function in the classroom, Don replied that he used labs to allow students to “apply what they have learned,... to put together the concepts that fit what they have learned.” Don stated that he felt that labs would increase student interest, learning and attention. Despite this desired response, Don felt that many of the students did not benefit from the labs as much as they could. Don explained:

Don: I would say that probably 30 or 40% [of the students] are able to actually come up with a decent concept based on the data they have
collected. A lot of them, it seems to me, that you show them this and this and this and say, "what does that mean?," and they have no idea.

Researcher: Why is this the case?

Don: One, they haven't done a lot of it [labs]. Two, maybe they have not gotten to that cognitive state. They should be by now and maybe they have by now. Also, it's [a lab] a difficult thing to do and a lot of them just don't want to make the effort. They actually have to sit down and think about it. It's not something they can look in the book and look at line five and write the answer down.... [Some students] get more into the labs because they are giving more, putting an effort into trying. Other ones, they are just copying someone else's data and they are not going to learn.

On several occasions, Don commented that the labs provided with the textbook were organized in a manner which was "hard and confusing" for students to use. This encouraged Don to seek labs from other sources, typically from the lab books provided with other texts. Don elaborated on his dissatisfaction with the provided labs:

We did a couple of labs out of that book and they had instructions in one spot and a data sheet somewhere else. So you have to read the instructions and look and find the data sheet where the questions is [located], and that is really confusing.... Maybe if I used those labs constantly they [the students] might figure it [the organization] out. But the kids tend to look at the question sheet and wonder what they are supposed to do to get that answer. Then they have to get back over to the instructions again to figure out what they did and wonder where the answer goes and then they have to go back again...

As in other instances, this is an interesting statement since it contradicts Don's goal of problem solving. In addition, this statement may provide further insight into a source of concern for Don: time to prepare classroom materials. This lack of time may be responsible for Don's use of labs from other texts (ones with a format with which he was familiar), rather than spending the time to learn and teach his students a new format. As Don explained:

I think the key factor [in determining how I teach] is just time available to get things ready. The less time I have, the more I am going to just use things right out of the book. The number of [classroom] preps too. When you have three preps, a 40 minute prep hour doesn't go very far!

It should be noted that the type of time constraint described above is distinct from that of finishing units in such a manner that all of the biology content would be covered during the course of the year, a concern which Don does not have. Don felt a time pressure when preparing for class. This caused an over-reliance on the text as a source of lecture organization. In addition, Don uses the materials from the text as the primary source of worksheets and test questions, as the following statement reveals:

All textbooks are pretty much the same but they [the Prentice Hall text] gives you a lot of extra material. And I just don't have the time to plan for that many different classes. Maybe if I had just one biology class, I would
have more time for that [planning]. Plus, it [the text] comes with a computerized test program/bank, which I like.

Just as time may have been a factor in Don feeling comfortable with the format of the new lab book, time may also have reduced the effectiveness of some of the worksheets which he used in the classroom. In particular, Don admitted to not always having time to thoroughly preview the materials which he intended to use in class. In some cases this resulted in the assignment of worksheets which did not complement the lecture material. Such situations often prevented students from being able to complete the worksheets due to insufficient classroom coverage of key concepts and/or vocabulary. As Don commented following one of these instances:

There are a lot of different ways to do this [teach this concept], but I haven't tried this particular way [worksheet] yet...I looked at the worksheet and I thought, "well, maybe." I've never used it before but I thought it might be okay.

Don gave the impression of being a very busy teacher, so busy in fact that he did not have adequate time to prepare for his classes. To remedy this situation, he used the text and the text based materials as the primary source of information delivered in his classroom. Units were modified and rearranged based on his content background, personal preference, and student interest. Overriding goals and objectives seemed to be absent since the presentation of specific information during the course of the year did not seem to be an important consideration for Don.

Since Don described his student population as poorly motivated and of somewhat low academic ability, he assigned lessons which he thought would foster feelings of success: textbook work, worksheets, and hands-on activities. Most of these activities allowed students to work together in an attempt to have students "exchange ideas."

Classroom activities were selected without a lot of thought as to how they fit the flow of the chapter and were used in a random manner. Decisions concerning materials to be used were made on a day to day basis, rather than on a unit basis. In addition, these short term decisions may have also prevented Don from achieving the long terms goal of problem solving, which he once stated for his students.

Classroom Profile

Don's third hour Biology course was observed for the purposes of this investigation. This class followed an eight minute "snack break," which allowed both the students and the teachers a short "breather" in the middle of the morning classes. Don usually used this time to make the transition from his second to third period class. Typical activities included
erasing the board, setting out materials and papers which would be used in the upcoming class period, checking on audio-visual equipment and picking up handouts which had been copied earlier that day.

Prior to this time, Don had outlined the daily activities which were planned for the Biology class on the board. This list included the topics which would be discussed, new assignments which would be started and assignments that were due that day. Though this list was faithfully prepared each day, little reference was made to it during the course of the class period.

The students filtered into the classroom throughout the break, taking seats of their choosing throughout the room. Though the students seemed to have established a traditional seating pattern, there did not seem to be an assigned seating arrangement. Don's classroom was furnished with 12 tables, each of which provided comfortable space for two students and tight, but sufficient, seating for three students. Most of the students sat at "single gender" tables, with typically three students per table. The tables of choice seemed to be located at the back of the room, leaving the front two rows of tables nearly empty.

The time prior to the bell was usually filled with socializing among the students and classroom preparations or errands by Don. Don did not attempt to socialize with the students during this time, nor was there any attempt to do so by the students.

One of the few established classroom routines included a daily warm-up. About five minutes prior to the start of class, Don would turn on the overhead projector. On the screen would appear the warm-up instructions. Usually this consisted of a chapter and page number with instructions to define one of the key terms which would be discussed that day. Though this information was available, few students attempted to complete this assignment prior to the bell. It was necessary for Don to announce that the class had started and that the students should begin the daily warm-up before attempts at the task were made. Don used the time while the students worked to take attendance.

The classroom atmosphere was generally relaxed as the class started, but perhaps too relaxed. Many of the students talked to their neighbors while completing the warm up assignment. The rest of the students just talked. Comments concerning such off-task behaviors were rarely made.

Upon completion of attendance, Don typically moved to the overhead and used the warm up definition as a means of introducing the concepts which would be the focus of the day's lecture. As determined through an analysis of Don's lesson plans, lectures occurred on 31% of all class days, or approximately 1-2 times a week. These lectures were short, 15-20 minutes in length, and typically followed the textbook without deviation. Don later
confided that he purposely kept his lectures short because his students only had an 
attention span of about 15-20 minutes.

Generally, Don would ask for the definition of the warm up term to start the lecture. 
As students would read the definition, word for word from the text, Don would use this 
response to paraphrase a definition which would be written on the overhead. The lecture 
would continue with Don asking various questions related to the general topic which had 
been introduced. Most of these questions could be answered with a single word. The 
students were "trained" to look for the next word which appeared in bold print in their text 
(the texts were open to the correct page as a result of doing the warm up exercise) and 
respond with the next term in the text as the answer to the next question. In the majority of 
cases, the next term was called out in chorus by the three or four students who were 
actively following the lecture, though these students did not necessarily listen to the 
question before calling out the answer. This response was usually correct. Don would 
then write down the term and its definition, read verbatim by the students from the text. 
Questions which required thought or that might elicit multiple answers from the students 
were rarely asked. Questions were rarely directed to specific students.

The lecture, as described, was usually delivered from the front of the room so that 
Don could have access to the overhead projector. Only on rare occasions did Don leave 
this position during the lecture portion of the class. Students' comments, elicited by his 
questions, resulted in an "outline" of the concepts (or more accurately, the chapter section) 
on the overhead. The students were expected to record this outline into their notes for 
future reference, though compliance with this request was rarely reinforced by direct 
teacher observation.

Audiovisual aids, such as transparencies or diagrams, were rarely used. When Don 
felt the need for visual support, he typically referred the students to a picture or diagram in 
their text. An exception to this generalization occurred when graphs were used. Graphs 
were often used within the context of lectures and in assignments. As Don stated to his 
students:

Again we are going to be graphing. You might have noticed by now that to 
study this part of biology and ecology there can be a lot of graphing. 
Graphing is a different way to see the changes that take place. You can't 
really go out and look at them but we can see them by looking at graphs.

Despite this admission of the important role of graphs in "seeing changes," Don did not 
seem to discuss the construction or interpretation of graphs with his students. Students 
were rarely able to construct graphs for assignments without teacher assistance and rarely 
were they given the opportunity in class or in assignments to interpret graphs for 
themselves. Don always did this task for them.
Questions from students occurred infrequently, but when they did occur they often were directed at applications of the current topic to relevant issues in their own lives, social issues, or related "stories." Don used these opportunities to expound upon the current topic and develop it more fully. Rarely were these opportunities used to turn the questions back to the students in order to gain insights into their thinking or understanding of the issue. As a matter of fact, few if any questions were ever asked by Don which assessed student understanding of any aspect of the content or assignments covered in his class.

Classroom lectures were invariably followed by some sort of student assignment. As Don mentioned, his first assignment with each chapter was to read the text and answer the questions at the end of the chapter. Worksheets were used to "reinforce ideas taught in lecture and to allow students an opportunity for practice," though the selected worksheets did not always seem to compliment what was being taught and often resulted in a disjointed flow of content coverage. The initial assignment in the text was usually followed by a teacher designed, computer generated crossword puzzle of the key terms in the chapter. New worksheets, including those just mentioned, were given on 44% of the class days and labs on 14% of the days (as determined through analysis of Don's lesson plans). Other days were often used to finish up previous assignments. Since no assignment was due until seven days after it was assigned, there was usually a backlog of several assignments which needed to be completed. Homework was not specifically assigned, but work not completed in class was considered as homework.

New assignments, typically questions from the text or worksheets, were given with little or no explanation. This lack of explanation was equally true of labs, which included both paper and pencil activities (usually 3-4 per chapter) and less regularly, hands on activities (usually 1-2 per chapter). The absence of "pre-lab" explanations, coupled with the fact that Don rarely walked out into the room to monitor the start of an activity or its progress, may have greatly diminished the positive gains in students' learning which could have been achieved through these assignments. In addition, the students often expressed confusion about the purpose of the assignment. For example, one student was overheard saying to his partner: "This assignment is stupid! It's useless! When are we ever going to use this stuff anyway? I'd rather get a F than do this junk!" Comments of frustration such as this were common in Don's classroom.

While the students worked on their assignments, Don usually sat at the front desk and worked. Students with questions typically went to the front of the room for assistance. If the students became especially noisy and/or were obviously not working, Don would move out into the room and walk between the desks, though it cannot be said that he actually monitored the students' progress since he rarely asked direct questions of the students or
looked at their papers. While Don moved between the desks, he often answered student generated questions and sometimes made comments regarding a student's behavior.

Student behavior during class time was rarely on task. Though many students were open about not paying attention to the lectures which were delivered, they were generally quiet and respectful. Much of the off task behavior during the lectures consisted of quiet talking with neighboring students or using the lecture time to complete written assignments or write notes to friends.

This relatively low level of student cooperation and interest escalated during the 40 minutes of work time at the end of the period. Problems with loud talking, physical contact, copying assignments, roaming around the room, rude comments, and general off task behavior were common. The most typical problem related to the completion of classwork. Since assignments were not due for seven days after they were assigned, students rarely used the class time to complete the current assignment but used it to catch up on past assignments, many which were due that day. To complete an assignment, many students copied the work of neighboring students, or took a completed assignment from the "in" basket and copied it.

Talking and general off task behavior were serious problems which potentially limited the number of students who were able to complete assignments in a timely manner. Since Don did not actively monitor students' progress during the class period, many students spent the entire period talking uninterrupted. This was particularly a problem for tables with three students. A classroom atmosphere conducive to work was not maintained so few students seemed to feel any obligation to work.

Don did seem to notice off task student behavior, but was apparently unwilling to deal with it. He generally worked at his desk, but appeared sensitive to the presence of the researcher in terms of student behavior. In many cases, Don would look up in order to see who the researcher was looking at. If someone was misbehaving, the researcher's attention to it often stimulated Don to walk out into the class and quietly say something to the student. Had the researcher not been present, it is difficult to determine if the same action would have been taken. When specifically asked during the final interview about the influence of the researcher's presence, Don commented: "I really didn't think about it. It really didn't make that big of a difference."

Repeated infractions and "inappropriate" behavior resulted in a student's name being placed on the board. This action indicated that the student was to stay after class and be talked to by the teacher. Unfortunately, inconsistent application of the "rules," (assuming that rules existed) and a proliferation of threats by Don which were rarely carried through, soon made a mockery of such a punishment. Rather than stopping misbehavior, student's
whose names were placed on the board often called out loudly, "What did I do?," and further disrupted the flow of the class.

The opportunity to talk unhindered, general lack of consequences for misbehavior and the fortification of inappropriate behavior through peer pressure often resulted in more serious problems. Students openly and loudly treated Don with disrespect. For instance, on at least three occasions students refused to come to the front of the room when requested by the teacher or refused to stay after class despite repeated reminders and calls to return to the classroom.

Don never seemed to take any personal responsibility for the students’ misbehavior. Students were allowed to continue to sit in seats and groups of their choice (except in two occasions when Don moved consistently talkative students for a week after threatening to move them for ten weeks), and were allowed to talk throughout the lecture and work portion of the lesson. Don did not seem to notice student frustration due to lack of adequate coverage of assignments or the inconsistent application of classroom rules. It is possible that Don’s inability to control his classroom influenced the manner in which he taught, though he did not indicate that his was the case. This may account for Don’s infrequent use of problems solving or “open” classroom situations. Such situations may invite too many opportunities for student misbehavior. Perhaps, Don felt unable to manage the classroom situations which he felt were important and thus eliminated them in practice, though he remained loyal to them philosophically.

Generally, the students were expected to work until the bell at which time Don dismissed them. In some instances, Don would have students read the answers to the current assignment on which they were working. Answers were taken from volunteers, so the student who had talked for the entire period were never “put on the spot.” Since few students actually completed their work during the period, this was used as an opportunity to copy down the answers and turn in the assignment.

Two to four students were usually asked to remain after class for disciplinary reasons each day. When talking to the students after class, Don usually complained about the student’s behavior, asked it to stop, and described the consequences of what would happen if the behavior did not stop. Since Don rarely followed through with these consequences, the students did not take these admonishments seriously, and often smirked in response. Don did not overtly react to this disrespect and dismissed the students for the next class while he shook his head in disgust.

Though Don had few established daily routines, he did have several patterns which were followed for each unit. Unit assignments always began with the reading of the chapter, the answering of the questions in the back of the chapter and the completion of a
vocabulary crossword puzzle. The length of the units seemed to be somewhat arbitrary (since Don never seemed to have a firm time line of activities in mind), though tests often seemed to occur before school calendar breaks.

Before each chapter test, Don would spend a day in class outlining the key points of the chapter for the students. The students were expected to copy this outline into their notebooks. This outline was then available for their use on the test.

Don's tests were usually short (15-20 questions) and typically consisted of multiple choice questions from the textbook. If specific objectives for content knowledge did exist, they were assessed by only one or two questions. Despite the lack of problem solving opportunities in the class, a relatively high proportion of Don's questions assessed higher level objectives (25%) when compared to the other teachers in this study. These questions typically assessed the students' ability to apply the knowledge learned in the current chapter to a new situation. Semester tests given as the final assessment of student content mastery. Students were prepared for the semester exam in a manner similar to the chapter tests.

Classroom Subject Matter Structure

Don taught the following units in the sequence listed during the semester of observation: Introduction to Biology, The Environment (Basic Ecology), Ecological Changes (Populations and Succession), Biomes, Your Environment (Pollution), Basic Chemistry, Cell Biology, Cell Energy, Cell Division. It was based on the data collected from these units that Don's classroom SMS (Figure 10) was generated. Methods for the derivation of this SMS can be found in Chapter IV, Textbook Subject Matter Structure: Methods. The reader is referred to this section if questions concerning methodology arise. In addition, the evidence used for the generation of the SMS can be found in Appendix J and cross referenced to Figure 19.

Observations were made in all the units listed above with the exception of the Introduction to Biology unit. Don had specifically requested that classroom observations not begin until the third week of the semester. By the time the first classroom observation was conducted, Don had completed this unit and had begun the first unit in the Ecology sequence. For this reason, the connections formed from the Introduction to Biology unit were generated exclusively from the classroom materials used within this unit.

Don generally followed the content and format of units suggested by the textbook. However, there are several exceptions to this basic generalization. First, Don combined the first two chapters from the textbook into a single unit. Second, Don moved from this
introductory unit into a sequence of units covering ecology which were sequenced near the end of the textbook. Though the placement of the ecology units were contrary to that in the text, the chapters in this unit were taught in the sequence recommended by the text. When the ecology units were completed, Don returned to the front of the text and followed the sequence established by the text for the remaining units.

There were two other slight variations to the content and format established by the text. First, Don ended the semester with the text unit on Cell Reproduction. Due to the observation schedule, the only lesson in this unit observed was one pertaining to mitosis. Though Don had implied that he was going to separate the content dealing with DNA/RNA from the unit on Cell Division, it is not clear where the content concerning meiosis was taught. Second, Don added content covering Cycles to his unit on Ecology Basics. This complemented and expanded the content covered in the text. The addition of this unit was fostered by a directive by Don’s school district. As discussed elsewhere in this Chapter (i.e., Alex’s case study), Don was part of a district wide meeting of biology teachers. One of the goals of this group was to establish units meeting Oregon’s Common Curriculum Goals. The cycle unit had been designed, with Don’s input, to introduce the concept of cycles in tandem with the content taught in Ecology. With eagerness, Don included this sub-unit within the context of the first chapter in the ecology sequence.

There seem to be two primary components to Don’s SMS as exhibited in his classroom presentations (Figure 10): the Ecology sequence and all other units. In addition, evidence for a theme related to science, technology, and society interactions (STS) seems to be quite strong. Each of these components will be discussed in detail.

The integration of content within Don’s ecology sequence was very strong. In a manner similar to that found in the textbook (Figure 1), the early chapters in this unit were used as foundational content knowledge on which the remaining units built and expanded. References within this sequence were both forward and back-reaching, establishing strong relationships among all the content. However, contrary to the pattern established by the text, the unit on pollution (Your Environment) was not was firmly tied to the previous content. In addition, the evolution theme obvious in the text was missing from Don’s SMS with the exception of a single inferred connection. The lack of Don’s integration of the evolution theme may be based on the fact that this content was not taught prior to the introduction to this unit as had been the case with the text.

Rather than establishing continuity in his ecology unit surrounding the concepts central to evolution, Don used the theme of STS. In most cases the STS theme exhibited itself as references to environmental issues with which students could personally get involved and make a difference or as local environmental concerns which were examples
Figure 10. Don's Classroom Subject Matter Structure.
of the concepts Don was teaching in class. The following lesson segment illustrates this second form of STS integration. In this lesson, Don had established the idea that niches are created by the intersection of a number of abiotic factors. A change in any one factor outside a fairly narrow range of tolerances can cause the mortality of a species:

It is not easy to balance all three factors out is it? That's how difficult it is and why animals aren't found everywhere. Certain animals are found in certain parts [of the environment]. That is why, as you read things about the spotted owl controversy, people fail to realize why an animals is in only one kind of habitat. That is an old growth forest. Every forest has its specific group or set of factors and they all interact together to get animals to live there.

It should be noted that no STS related topics occurred in the Biomes unit. In addition, a lack of STS related issues in the rest of the content outside of the ecology sequence (with one exception) was noted.

As described elsewhere in this case study, Don enjoyed teaching the ecology sequence more than any other content area, and also felt that this was his strongest area of content expertise as well as an area of personal interest. This interest and content expertise may have contributed to the relatively large number of connections within this unit and Don’s ability to relate the topics presented in this unit effectively to STS issues. It should be noted that a straight presentation from the text would have also produced a SMS within the ecology unit which was similar to the one generated for Don. However, a comparison of the connections formed, especially in the area of STS, will reinforce the idea that many of the connections made were fostered by Don’s own content knowledge rather than the simple parroting of materials produced in the text.

Two other factors influence the interpretation of Don’s ecology unit. First, Don spent nearly half of the first semester on the ecology unit sequence (48.2% of all teaching days were focused on ecology units). This provided Don with more time to establish connections as well as lends support to the influence of Don’s personal interest and the prioritization of this topic over others found in the biology curriculum. (The time Don spent on his ecology sequence can be compared to the other teachers in this study who taught ecology at the beginning of the year. These teachers spent 17.8% and 22.6% of the teaching days first semester to teach ecologically related content.) Second, and less tangible, Don’s lesson presentations during his ecology unit were much more lively and animated than lessons presented on other content. For instance, Don brought in more concrete examples and was more willing to discuss tangential topics brought up by student questions during the ecology sequence more so than during the other units.

Interestingly, the conceptually-integrated and relevancy-oriented picture developed for Don in the ecology sequence stands in stark contrast to that derived for the rest of the
units taught during the first semester. There were few connections made between units outside of the ecology sequence. In addition, very few examples which related the content to human biology or other organisms were provided.

Almost half of the connections which were established outside the area of ecology in Don's classroom SMS were formed though the use of classroom materials. However, it is difficult to determine if the connections from materials were purposeful or not. In most instances, materials seemed to be selected primarily for the purpose of keeping students busy and quiet rather than for the enhancement of the current content. Many connections made through materials were limited to a single item on a test or a single question on a worksheet. In addition, Don rarely held his students responsible for the content covered in worksheets or labs (in any form, verbally or on tests) nor were these connections reinforced through classroom dialogue. Considering this evidence, it is unlikely that connections made through Don's selection of materials were purposeful.

In contrast to the ecology unit where connections to other content were frequent and the value of learning material made fairly obvious, evidence of "non-directional" connections occurred in other units. Students were expected to learn material for some future but undisclosed purpose as the following comment to students at the beginning of the Cell Biology unit illustrates:

We are starting the chapter on cell biology. It's a long chapter and there's a lot of information. And there's a lot of information in these chapters that you have to memorize, like cell parts, structures and functions, because you need to know those in the chapters to come.

Such a lack of purpose for learning the content in the other units was common. This attitude seemed to embody many of the subtle changes which occurred in Don's presentation style as he moved from the ecology sequence to the remaining content. Presentations became shorter, offered fewer examples or elaborations and covered the content in a quick and superficial manner. Many of the lectures were based exclusively on the content in the text. For instance, the following lesson segment was taken from a lesson in which Don was introducing the organic compounds important in a cell (carbohydrates, lipids, proteins and nucleic acids). This entire presentation lasted about 15 minutes. During this presentation, Don cued the students to look for the next term in bold or italicized print in the text in order to answer his questions. These answers were then used to fill out a chart outlining the key information about each organic compound:

Don: Let's turn to page 51. What is the next one?

Male Student: Lipids.

Don: What is another word for lipid?
Male Student: Organic compound?

Don: No, you think of lipids as [made up as] what?

Students: Fats, fatty acids.

Don: Fat. What kinds of things are found in lipids?

Various students respond, primarily with oxygen, hydrogen, and carbon.

Don: How about carbon? What are the basic building blocks of a lipid?

Male Student: Glycerol?

Don: That would be one. What’s the other part?

Male Student: Carboxyl?

Don: Carboxyl group is part of the other group [of organic molecules].

Male Student: Carbohydrates?

Don: No, it is right above there. Second paragraph, right below the heading 'Lipids.'

Female Student: Fatty acids.

Note that the terms above were never defined, but only stated in order to fill out the worksheet. No other coverage of this content occurred and there was no elaboration on the meanings of terms such as carboxyl, lipid, fatty acid, carbohydrate or glycerol. Such limited content coverage and lack of elaboration may have contributed to the relative absence of connections found outside the ecology sequence. In addition, Don rarely asked questions to assess his students' level of understanding of the content. Thus, he may not have been aware of students poor understanding of the content as a result of his style of content presentation.

Such teaching episodes may also be indicative of poor pedagogical knowledge on Don's part. From Don's actions in the classroom, he seemed to have felt that the simple statement of the key terms by the students in class was sufficient for student learning and understanding. Following the above presentation, Don gave his students a second worksheet on similar content to complete. When students came to him with questions, Don's typical responses were: "You should know the answer from the lecture. You took notes on it," or, "Look in your book under how to form proteins," or, "If you take notes you can look at those to help you answer the questions. It doesn't help to just sit around."

Don obviously was not interested in teaching the material in any more depth on an individual student basis than he had already done in class. It is also possible that he felt
that the first presentation provided sufficient content coverage, if only the students would have paid attention and taken notes. Alternatively, it may be that Don purposely did not want to do a more elaborate job of teaching than he had already done. This may be due to his inability to control student behavior, a lack of his own understanding of the content, or a lack of caring about the content and his students ultimate understanding of that content.

It is possible that the lack of connections outside the ecology sequence are symptomatic of poor content knowledge on Don's part. This could also be the rationale behind relying very heavily on the text for the format of the lectures, though this method of classroom presentation was also used in lessons within the ecology sequence. A second analysis of Don's list of college content courses does show a limited number of courses in the content areas of biochemistry and cell biology, though this attribution of cause is speculative at best.

**Self-Described Subject Matter Structure**

The reader is reminded that Don was one of the two subjects who was asked to complete the questionnaire concerning his SMS of biology both as a pretest and as a posttest. The initial request that Don complete this form occurred at the end of the pre-observation interview. At that time, Don asked several interesting questions concerning the task itself. He seemed to have no questions concerning what was meant by the term "topics," but seemed unclear as to the format that the diagram should take. His initial response was to ask if a flowchart was being asked for. When told that the format could take any form which he chose, he seemed to be satisfied. A second question which he asked was, "Do you want me to diagram biology as a science, or how I teach it?" At the time he was told that he could do which ever he felt the most comfortable with. Upon later questioning, he admitted that he was not sure that one diagram would have varied from the other.

Though Don was asked to return this questionnaire during the first classroom observation, he forgot to complete the task. After several weeks of reminders, Don volunteered to complete the questionnaire following a classroom observation. At the time, Don admitted to being unsure as to how he wanted to fill out the questionnaire concerning SMS. When, once again, he was reassured that there were no right or wrong answers, he completed the task in about five minutes.

The SMS which Don diagrammed as a result of the pretest can be seen in Figure 11. To draw this diagram, Don listed five components of biology and then placed them in a
diagram which showed a strong integration among the topics of Ecology, Cells, Genetics, and Evolution. In addition, Don showed a linear relationship between the topics of Ecology, Evolution, and Taxonomy. (The reader is reminded that at the time of the pretest, Don was not asked to describe his diagram, nor was it shown to the researcher, in order to reduce the potential bias which may be created during the classroom observations.) In response to the written question, "Have you ever thought about biology in this manner before? If yes, please explain," Don replied: "No. I have thought that all parts of Biology are interrelated, but I have never tried to diagram it before."

Don was asked to complete this questionnaire for the second time as part of the post-observation interview. During this interview, Don had a cold and complained of not being able to think clearly. Comments such as the following were stated by Don as he attempted to construct the posttest diagram of his SMS: "What did I do the first time?...Oh, I hate this. You are making me think too hard. My brain isn't working very well today." These comments can be interpreted as being illustrative of Don's hesitation to complete the questionnaire. Some of this hesitation may have been because of his cold but some of it may have been a result of his not having a clear conception as to what he wanted to record on his diagram. As in the SMS produced for the pretest, Don asked if he should put the diagram in the form of a flowchart. Though he was told that it could answer using any format he chose, he decided not to use a flowchart pattern and, with the response, "My mind is a total blank. Diagram. Okay, I will do something interesting here, do something different entirely," he completed the SMS in about four minutes.

It is interesting to note that in both the pre and posttests, Don seemed hesitant to complete the task. In the pretest, he avoided answering the question until specifically requested to do so. In the posttest, he stated that he could not think. In both cases, he asked if a flowchart would be an appropriate way of representing his answer. Though he did not choose this format in either case, Don's interest and teaching experience in computer programming may have influenced the proposing of this question.

Don's SMS as recorded for the posttest can be seen in Figure 12. When asked to describe what he had written down, Don replied "I have to explain it?" This question is representative of the rather unwilling manner in which Don answered the questions which related to both this and the answer recorded for the pretest. The answers to questions were generally short, to the point and resistant to probing.

Don described the diagram which he recorded during the post-observation interview in the following manner:

Well, I guess the boxes show the different content areas. The foundation is the cell, and then everything moves out from that. Cell structures are at the base since everything is made up of cells. The cells do something in
Figure 11. Don's Self-Described Subject Matter Structure (Pretest).
particular, like the particular functions they might perform. And they have some form of communication with other cells, at least the other cells in that particular organism. The cells that make up an organism are controlled by heredity. And then those cells are then classified into organisms which can be looked at and studied. Then entire organisms interact with each other in a variety of different ways.

When asked about where this SMS came from or the stimuli used to select the particular terms which Don used, Don replied: "Those are just what came to mind." Don did not claim to recognize any particular source of this knowledge such as college courses or the text, but claimed that the diagram was "kind of the way I see things work." When asked if his diagram followed the curriculum which he used in his current biology classes, Don replied, "I suppose it does. I kind of jump in and out [of the curriculum in my diagram]."

When asked if there were any other topics or themes important to biology which had not been included on the diagram, Don noted that he had forgotten to include Evolution. To add this to the diagram, Don felt that he would put arrows in and across all the different areas.

As Don had previously stated, he could not remember what he had recorded for a SMS as part of his pretest, thus, he did not think that filling out the SMS in the pretest had made any difference in what and how he had taught. Comparisons of Don's teaching before and after the filling out of this SMS support his contention that no changes in his teaching were evident as a result of the pretest. For instance, no greater integration among the topics included in the pretest SMS seemed to occur after the drawing of the pretest diagram.

When provided with the SMS which he had recorded for the pretest, Don noted no major differences in the meanings which the two diagrams conveyed. According to Don, "I just used different terms, but basically it's the same thing."

Don did not seem to be able to pinpoint the source of the SMS which he drew, nor could he think of any instances in his career which helped him clarify his thinking along this line. As far as he could remember, he had thought about biology in this manner since high school, though he could not think of ever making these thoughts explicit. As Don admitted, "It's just hard to put your thoughts in a diagram. I just kind of do it." For Don, "doing it" in the classroom meant trying to "constantly recall things we have talked about before that are related to what we are studying now." Though Don felt that he did this, he was hesitant to believe that his students could use such back-reaching references to put together a similar SMS for themselves. When specifically asked if he felt that his students would have similar conceptions to his own, a questions which seemed relevant since Don felt that his own
Figure 12. Don's Self-Described Subject Matter Structure (Posttest).
SMS had been formed in high school, he replied, "I don't know. I would hope so, but I wouldn't bet on it."

In general, it could be stated that Don was fairly consistent in the belief that the various aspects of biology are related, but had a difficult time explicitly stating what the components of his SMS are or how the components specifically interrelate. To portray the interconnected nature of biology to his students he tried to reinforce concepts taught earlier by attaching them to new content, but Don did not feel that this technique alone was sufficient to provide a SMS for his own students. Finally, in both the pre and posttest requests for his SMS, Don seemed reluctant to draw or discuss his SMS. It may be that he felt uncomfortable with this task because he was afraid of being "wrong," or it may be that Don had no firmly formed framework on which he based his knowledge or the teaching of biology.

Summary of Don

Don's SMS seems to be composed of five primary components (as synthesized from his pre and posttests): cells, genetics, classification of organisms, the interaction of organisms in ecological systems, and evolution. For Don, these components were highly interrelated. In particular, he saw the content presented in one unit as the foundational knowledge for the unit which followed. It should be noted that Don's SMS was primarily content oriented and contained no teaching orientations (such as an inquiry orientation) but seemed to have a loosely defined evolution theme described by Don as the content which integrated the others. When comparing his pre and posttest SMSs, Don saw no essential differences between the two and did not feel that the filling out of the pretest questionnaire affected his classroom practice. This evaluation of the influence of the pretest was supported by an analysis of Don's classroom data which showed no greater consistency resulting from the recording of his SMS early in the year.

Don felt his SMS was formed as a result of his high school biology experiences, though he did not have any distinct memories of its formation or recall the factors which had influenced its formation. Don admitted that his conceptions of SMS did not exist in the form of a diagram, though no statements alluding to his perceived format were provided. It may be inferred that Don conceptions of biology consisted of a set of biology topics which he believed to be interrelated in some implicit manner.

Despite his own vague identification of the source of his SMS being his high school experiences, Don could not state with confidence that his own students would have a
conceptions similar to his or one which was uniquely held. This belief was based on the generally low expectations Don held for his students.

Though Don did not feel that his SMS played a major role in his presentation of content, he did feel that his purposeful use of references back to content which had already been taught may be a translation of this SMS into practice. Don used such references to build on the foundational content of some topics and to provide for the interconnections which existed among the various content topics. Evidence of such a use of back-reaching references were found in an analysis of Don’s teaching of ecology, but not in the other areas of content presentation. Thus, Don’s SMS and that derived from classroom practice corresponded for the ecology units but not for the other units which he taught first semester. Three possible reasons are proposed for the inconsistent relationship of Don’s SMS to classroom practice: limited content knowledge, limited pedagogical knowledge or preparation time, and the lack of clearly defined goals.

Don described the ecology unit as being his personal favorite. This was the content area in which Don felt he had the greatest expertise. Don acknowledged that his personal interests and background knowledge allowed him to spend more time on the content and to provide more examples. Classroom evidence supported Don’s assumptions about the role of his content knowledge on classroom practice. In addition, Don was more animated in his lectures in the ecology units, was more willing to let students ask tangential questions and spent relatively more time on this unit than any other unit in his program. All of the above factors (more examples, more content, dealing with tangential topics, more time) contributed to the greater number of connections found in this unit than any other. In addition, the above factors also allowed for the development of an STS theme across these units. Don did not recognize this theme in his own SMS and evidence for the presence of this theme in other units was scarce.

The other units in Don’s course were not covered in the manner described for the ecology unit. Content coverage was superficial and strongly based on the text. Fewer examples were provided, students were not encouraged to ask questions, fewer questions were asked of the students, and less time was spent on the units. This contrast in teaching style may be directly attributed to differential levels of content understanding. This assertion can be supported through an analysis of Don’s transcripts (with a somewhat limited background in topics other than ecology) as well as through Don’s own testimony. The result of Don’s limited content knowledge was a decrease in the connections made outside of Don’s area of content expertise: ecology. The influence of content knowledge was also evident in the SMS derived from classroom practice which provided evidence for fewer connections existing outside of the ecology sequence.
The role of the textbook in Don's SMS should be noted. Don's classroom SMS and that derived from the text are quite similar in that both SMSs provide an integration of content in the ecology units and more discrete relationships among the introductory units. However, a comparison of the specific connections made by the text and by Don will show that the content of these connections are different. Don's ecology connections were of his own creation. But, the provision of connections among content items in the early chapters of the text were nonexistent. Thus, if Don was to integrate this content he would have to do so from his own content understanding. Don was either unable to do this or did not feel that such connections were important to make.

It was also noted that Don generally did not utilize questioning as a source of information concerning his students' level of understanding, lectured out of the text, felt compelled to outline the key points before each test for his students, had poor classroom discipline, and rarely provided a "pre-lab" his students before an activity. There are two potential explanations for such teaching behaviors. The first has to do with pedagogical knowledge. It is possible that Don simply did not know how to effectively teach his content. It is also possible that Don did not feel that he had the time to adequately prepare in order to effectively teach each day. Several comments made by Don support this second assertion, though it seems unusual that ten years of experience in the teaching of biology would not have remedied some of these concerns. It is possible that many years of multiple classroom preps had decreased the time which Don had available for planning any one of his classes adequately. In either case, these assertions, a lack of pedagogical knowledge or classroom preparation time, may provide an explanation for the lack of content connections made in the classroom or for the inconsistency which exists between Don's stated SMS and that derived from classroom practice.

Finally, it is possible that Don had no clearly defined goals at any point in this study. This possibility can be supported by Don's hesitation to complete the SMS questionnaires and his resistance to describing the diagrams which he constructed. A lack of consistency between what Don said and his classroom practice may also support such a contention. In particular, it is interesting to note that Don discussed the goal of problem solving during the initial interview. The presence of this goal was never suggested again. In fact, the only evidence that such a goal may exist was the relatively large portion of higher level questions on Don's tests. However, classroom practices were quite contrary to the achievement of this goal. As has been suggested, such a contradiction may be evidence of a weakly held belief or may reflect the lack of the pedagogical skills needed in order to implement this belief into practice.
In addition, it should be noted that Don’s goals for both his students and his own SMS were based on content. Don was concerned that his students have a “basic understanding” of the content. But despite this goal, Don was willing to allow units to last until he ran out of activities (as opposed to selecting activities which taught and/or reinforced specific objectives), could rarely state a teaching agenda with confidence for more than one day at a time, and allowed the content coverage of biology to be terminated at the end of the year without an effort being made to adjust the rate of content presentation. This evidence suggests that Don may not have had clearly formed content objectives and was more interested in filling the time than he was with providing his students with a well rounded understanding of biology content.
Ed: Following the Logical Sense of Biology

Academic and Professional Profile

Ed was recommended for inclusion in this study by a friend who taught in the area. Ed was contacted by phone the spring prior to the study and he agreed to participate. The initial interview was conducted in Ed’s classroom two weeks prior to the first day of class. Ed was a tall, personable man of athletic build. He had an easy going demeanor and seemed to be excited to be involved in the study.

A teacher of 13 years, Ed was proud of the biology program he had developed and enjoyed having the opportunity to share what he did in the classroom with others. In fact, Ed mentioned several times that he wished more visitors - administrators, school board members, parents and community people - would make the effort to "come to the back of the building" where his classroom was located and observe the activities of the science department.

Ed received a BA in Zoology from a large, prestigious university in the East. Despite the Zoology title of his undergraduate degree, Ed described his career content focus as being cellular and molecular biology. This description was supported by his coursework, which was slightly skewed toward chemistry, genetics and biotechnology. Following his BA, Ed attended a large city university, also in the East, where he obtained a Master’s degree in Education with a minor in Science. As part of this program Ed was involved in a half-day internship teaching in a school for an entire year. The other half of the day was occupied by coursework at the university.

Ed’s biology content background included extensive coursework in zoology, botany, genetics, ecology and anatomy and physiology, in addition to the content previously mentioned. For Ed, science interests seemed to exist on both a professional and personal level. His college science background was enhanced by a series of National Science Foundation (NSF) workshops aimed specifically at science teachers during the late 60’s. In addition to these experiences, Ed had been involved in other science workshops and classes, volunteered on local archaeological excavations and worked with the local chapter of the State Natural Resource Council.

Ed described his university experiences as "adequate." He felt that as a result of his science coursework he "didn’t have any problems with the content. In fact, there was way too much." When asked about his educational training, he replied:

The classes were okay, but not very exciting. I hated statistics. Some of the methods classes were a little silly. One really good class was A.V.
That was really fun... But the most valuable thing was the internship where you just worked half a day [in the schools].

Though Ed seemed to appreciate the intern experience, he later described it as a "baptism by fire. You just jump in there and do what you can do," because his assigned supervisor was too busy studying to be a lawyer to provide help.

Ed’s two previous teaching jobs were in the East. There he taught junior high science and 9th grade Biology. Despite attending the NSF workshops and feeling fairly successful in his teaching, Ed left teaching after four years, feeling “burnt out.” He remained out of the teaching profession for ten years, though he maintained his teaching certificate and was employed in the construction industry. When the construction market softened, Ed moved with his family to his current location where he returned to teaching.

At the time of the study, Ed was in his ninth year of biology teaching and his ninth year at his current school. As one of six science teachers in a 9-12 high school, Ed was one of four teachers who taught at least one section of biology. Ed taught a combination of sophomore Biology, freshman Physical Science and Physics. Advanced sections of Biology and Physical Science were taught on an every other year basis. Ed traded the teaching responsibilities for the advanced courses with another teacher in the building each year so that each was involved in teaching at least one advanced section of one of the courses on a yearly basis.

Though at one time Ed coached high school skiing, he “learned real quick that you can’t do that and teach too.” Following this experience he chose to limit his school related activities to working with the school’s Staff Development Team and the Science Club, the latter which he considered a natural extension of his job.

Ed’s high school is one of two in a community of approximately 40,000. With a student population of over 1200, Ed’s school is the more established and has adequate facilities. The science wing was added to an older part of the building sometime in the last ten years. Ed’s room is large and arranged with tables for students in the center of the room and a lab area on the side. Open shelves in the lab area displayed preserved plant and animal specimens, science texts, and popular science magazines. Attached to the back of the room is a greenhouse which is separated from the rest of the room by a drawn curtain.

The community in which Ed taught had been experiencing rapid growth due to an upsurge in the recreation based economy. The community is the largest within a 100 mile radius and supported light industry, a community college and a large variety of service based jobs. Despite the current growth, the town had traditionally been based on an unstable lumber and ranching economy.
When asked about the community and their support of education, Ed said that the town had a "tradition of budget failures and tight money and not much of an appreciation for teachers and education in general." When asked about how this affected his teaching, Ed said that "there are always ways around the [classroom] material problems," but expressed deep concern for the manner in which the attitudes toward education affected his students. Ed felt that there was a general "apathy toward science" that often originated with the parents. He described the problem as follows:

The attitude from the parents is "biology was hard for me, so it is going to be hard for my kid" and "it [biology] hasn't had any real meaning for me in my life so it probably won't have any meaning for this kid in his life." We [science teachers] fight that. I have a feeling that it's the same all over. What happens is that 80% of the kids will take biology and only 20% of those will [go on to] take chemistry.

Ed felt that this attitude stemmed from the fact that the community didn't "value education and science as an end in itself and as a means of getting something out of your world," though he felt that the influx of new people into the area would raise some of the formerly low expectations. He also hoped to see an increase in the number of students which aspired to go to college, a number which he described as being approximately 10-15% of the high school graduates. Again, Ed attributed the low numbers of students with college aspirations to low family expectations:

[Academic] support [for students] at home is minimal, except for a group of people who have really high expectations for their kids and expect them to go on to college and expect them to do well in science and in school. I don't know what percentage of the population that is, but they are there. The rest of them are real busy at work and are not too tuned into their kids. They are more interested in having their kids excel in sports than in science.

Keeping the student population in mind, Ed was asked about the goals that he had for his students. He replied:

They [my students] should come out [of biology] with an understanding that all living things are somehow related. That all organisms interact and are alike. They [all organisms] are very similar, and they should have some sort of appreciation of that. Not just that they can like animals and hate plants, but to get a whole picture of living things as being related and yet different.

Ed's comment about liking animals and hating plants had been expressed by other teachers in the study. When asked to explain the comment, Ed elaborated:

I like plants. A lot of biology teachers don't know that plants exist. But I like botany and one of the teachers we just hired here at X High has her PhD in botany. So it is really nice to have a couple of botanists around. I don't know much about botany, but I think it's important to stress it to the kids.
Since Ed had the opportunity to work with a number of classes with varying levels of students, he was asked about the students that he liked to teach best and his favorite topics and classes to teach. He replied:

I think the most interesting [class] is advanced placement biology. You get really outstanding students and the curriculum is really interesting. We had a really good class last year and that was fun because it was cellular and molecular [emphasis] and it was oriented more toward what I think is interesting. You can really go with it [the content] and there was a lot of effort to stay ahead and stay on top of things. It was rewarding.

Ed taught Biology the last three periods of the day and was open to the selection of any class period for observation. Fifth period was selected because it followed the lunch hour and would allow a few minutes prior to the class to collect classroom materials, etc. Ed also extended an invitation to attend additional class sessions beyond those observed for the study. To facilitate the selection of the specific class periods to be observed, Ed encouraged the collection of the weekly schedule of activities which he provided for his students on Mondays. This schedule allowed for a researcher based selection of class sessions which were deemed the most interesting and informative.

Ed's class was observed 15 times over the course of the semester, or 17.9% of the days which he actually taught. Ed was very cooperative during this time and offered the option of sitting anywhere in the room that would aid in the collection of data, including seats in the middle of the students.

In addition to the 15 classroom observations, copies were obtained of each week's schedule (which acted as Ed's and the department's lesson plans) and copies of the worksheets and tests. Ed's final interview, which was conducted five weeks after the last classroom observation, lasted 2 hours and 15 minutes.

Course Specific Perceptions and Concerns

The science department in general and the biology teachers in particular seemed to value the coordination of similar programs and the professional discussion fostered by such coordination. Additional program coordination, on Ed's initiation, was also occurring both within the department and across the district. Prior to the beginning of the school year, the biology teachers within the department decided upon the basic topics which would be taught in biology and the sequence in which they would be covered. Asking Ed about the rationale behind such an approach, he replied:

One of the teachers that retired here a few years back was the kind of person who would try to do a chapter a week and go for 36 chapters and cover all of biology. But we have since learned that you can't do that.
The process of making such decisions seemed to occur quite smoothly with a minimal number of disagreements. Ed described the agreed upon basic sequence of topics for biology as follows:

We are starting off with ecology. Then we go to the cellular stuff, then heredity and evolution and then go off into the five different kingdoms. So we start with the simple organisms and then go to plants first and then animals. Except some people want the option to do animals first and then plants.

More specifically, the sequence more accurately resembled the following: introduction to biology, ecology, biochemistry, cell biology, cellular energy, cell division, genetics, evolution, classification, and the five kingdoms. Ed described this as a "logical sequence" which naturally leads from one topic to another (i.e., from genetics to mutations to evolution to diversity and classification). Ed elaborated on the organization of the five kingdoms by saying that he would deal with the "smaller" kingdoms first and then plants and animals.

When asked about the variables which went into the decision concerning whether to teach plants or animals first and the flexibility that seemed to be built into the sequence as a compromise by the department, Ed replied:

Ed: It's funny, when we [the department] talked to the other schools, some people definitely did not want to do plants. They didn't like botany so they were doing animals first and then plants second and didn't care if the year ran out.

Researcher: I always heard the rationale was to do plants last so that you could take advantage of the plants when they are blooming outside.

Ed: That's bull. They just don't like botany! (laughs). If people feel comfortable with a subject they will teach to that more often. A lot of times, most people have not taken botany and are not showing much interest in it. You can get bogged down in botany. They have all kinds of terms that seem to have very little meaning to human beings. So you have got to put it on a different plane.

The statement that teachers will teach topics which they enjoy and are more comfortable with is an intriguing one. Since Ed had admitted to having a personal preference for topics related to cellular and molecular biology, he was asked if this had an effect on his own teaching. "Absolutely....The most valuable things I have ever done were those summer institutes. I really worked hard, learned a lot, and am able to teach it to other people." Ed claimed that his preference also affected his class in other ways:

I enjoy biochemistry and molecular biology the most just because that is what I am most interested in. That is why I thoroughly enjoy teaching AP biology [with a biochemistry/molecular biology emphasis] because it makes sense to me. I understand some of it and I think that's probably the part I get most excited about. However, that is not the part of biology most kids really get into because it is kind of esoteric. You can't really put your hands on it.
What the students enjoyed and seemed to understand also had an influence on what went on in the classroom. For instance, Ed talked about the decision concerning whether ecology should be taught first, the agreed upon sequence, or last as it occurred in the text. Ed described the ecology unit as maybe one of the easiest for the students. He explained the department's rationale for teaching it first as follows:

I feel that if you were to jump right in with chemistry and cell and organelles, you [would] lose all touch with the living world. I think it gets the kids in touch with the fact that what we are going to do all year is going to be something to do with the living world, with the biosphere, all the diversity and things like that. We can always relate back to that when we are doing photosynthesis and respiration. It always comes back to where you started. So I still feel that is an advantage. I wouldn't change it.

Time and the idea of not having enough time to adequately cover a topic seemed to be another variable in the decision regarding the placement of ecology. This issue seemed to be indicative of the value that teachers placed on various units and seemed to be of concern not only in Ed's school but also in the district-wide biology meeting, as Ed explained:

You know what we decided when we talked [at the district meeting]? It [the sequence of topics] doesn't make any difference. You could do it any old backward way and it's all the same stuff. You are given the same themes. The ideas are still the same. What difference does it make? At the end of the year you are always going to run out on something. But what do you want to put at the end of the year that you want to run out on? Do you want it to be ecology? I didn't want it to be ecology so I put that first. I don't care if I run out on animals. Kids hear about animals all the time. I can get through the first few phyla of animals that they have probably never heard of before, before the year runs out.

The value that Ed placed on ecology was mirrored in his stated goals, expectations and hopes for his students. When asked what he felt his students knew as a result of being in the first semester of biology, Ed stated:

Interrelationships, I think. I have confidence in that they understood relationships between everything in an ecosystem kind of thing. They got the cycle idea. They got the interdependence. They got the flow of energy materials. I think that [content] was pretty straightforward.

But, Ed emphasized:

Everything we have done, I mean I wouldn't have done it unless I thought it was valuable. You have got to think that the kids are going to go on [to college]. If they don't have a background in this material, they're lost. The kids who aren't going to go on, it isn't going to kill them to know that when they read an article about DNA that they may have heard about that when they took tenth grade biology.

When asked about the sources of his ideas for individual lectures and presentations, Ed admitted that much of the material came from textbook series which had not been
adopted but which provided complimentary materials. Over the years Ed claimed to have "collected a bunch of them." Once faced with these materials, Ed said that he looked at the materials from "basically a topic kind of view: What is my topic for today? What makes sense to me? How can we draw it [the content] all together?" This methodology allowed Ed to bring together the basic elements of his presentation. Following the material selection, Ed organized his lectures around the idea that he would "tell them what makes sense to me. Whatever pops into my head." However, Ed cautioned against the view that this practice was more complicated or labor intensive than it actually was:

First of all, as I teacher, I don't have the time to sit down in my library and find five books on this and read it. Who does? It would be really neat if life were that way, but it isn't for me. I teach what I know. If I don't know it and I think I need it to teach, I will find some book somewhere that has something and just learn it. Write an outline for it and put it on the overhead or something like that.... You try to pick ones [materials] that look like they will fit in a 47 minute period [and] that look like they are exciting or interesting. Some of them, you look at and say "that's boring." It would be boring for you, so it has got to be boring for the kids. I just go through and give it [the material] an affective look. It has got to be new and different and interesting for me too or it gets old. I believe in change.

Time has been mentioned in Ed's conversations in several instances (time to teach, time to prepare for class, etc.) Not surprisingly, when asked what the key factors were that affected his teaching, time was mentioned once more:

It all comes back to time, time to prepare, the limitation of time in the classroom. As far as what we can teach, there are no constraints from the district. My own knowledge is a limit. What do you know? How can you fit it in for the day?

Though Ed mentioned that availability of materials also had an influence on what he could actually do in the classroom, he emphasized that, even with "a ton of money...[it] still isn't going to give us anymore time. It doesn't give me anymore time to prepare a lab or to clean up from a lab or to get the papers graded."

Ed's fifth period class was selected for observation for this investigation. The class consisted of about 24 students, a number which Ed described as "just about average." The majority of the students in the class were male; only six of the students were female. Ed later described this class as follows: "You got my best biology class....The most cooperative, the most capable and willing to do basically what I asked them."

Within the context of the semester, Ed said that he had a "good feeling about these kids. I think they will do well. But, boy, I didn't get nearly as far today as I thought I would!" Ed seemed to place the blame for not completing the planned content more on his miscalculation of time than on the students lack of understanding of the material.
The attitudes expressed about the fifth period class were in contrast to Ed's opinions of the biology classes which he had later in the day. Ed described these classes in retrospect as part of the final interview:

Six and seventh periods were just a disaster last semester. Anything I tried in seventh period last semester just died. No matter what, they wouldn't listen to lectures, they wouldn't cooperate in cooperative learning... We spread them around this semester (laughs). In fact, seventh period now is just fine.

When asked to generally describe the students in his current classes compared to biology students he had worked with elsewhere, Ed stated his current students were:

Less interested in school. Less interested in working with each other. More interested in dinging each other all the time. They are real negative. In fact, it's real unsafe for a student, I think for a lot of students in X High, to volunteer any kind of a statement because there is likely to be somebody back there ready to zap you for whatever you say. Even if you give a right answer in class, somebody is likely to make a negative comment. There are too many put-downs around here.

Perceptions of the biology students such as those expressed above prompted Ed to look for alternative teaching methods that he could use in his classroom to address such problems. A grant, obtained by the assistant principal, allowed several of the teachers to attend workshops on cooperative learning strategies. Ed, as a member of the Staff Development Team, became one of the first teachers in his school to receive such training. The primary advantage that he saw in such techniques had to do with fostering social skills, as he explained:

I find that the students have fewer and fewer of the social skills...that allow them to get along in life or even to get through a class period. They need as much of that as they can possibly get.

Ed's original plan was to incorporate cooperative learning strategies specifically into lab situations to combat the problems which he perceived in terms of students' social skills. This plan later expanded to the use of this technique for warm-up exercises, small group problem solving, brain storming, and peer teaching.

Ed described his success with cooperative learning strategies as "mixed." The planning time necessary for cooperative lessons versus content lessons eventually forced a prioritization and Ed's use of cooperative learning techniques decreased as the semester progressed. Ed gave the following reasons for this decrease:

It is really difficult to try and teach content and social skills at the same time. At one point I made the choice that social skills were probably more important. But time is still a problem...When it [cooperative learning] is well planned, it usually works quite well. I think it has a lot of potential in the biology classes. But it takes a lot of planning time to be ready to do it. It is easy to get up there and just lecture or something like that. But to be prepared like we're doing here where you have cooperative learning, it
takes a little bit more. Some of them [the lessons] were really good and some of them were kind of disasters.

Despite Ed's mixed reactions to the success of cooperative learning, he claimed that he "would do it again, and will try and do it more often" in the future.

Ed seemed have a genuine interest in providing his students with a quality experience in biology and trying an assortment of teaching strategies and techniques in order to make cognitive and social contact with as many students as possible. Based on this observation, Ed was asked why he taught the way he did. He laughingly replied:

I don't know any other way, that's the answer to that question! You do what sort of matches your personality. What makes logical sense to you. I don't think you can teach any way that doesn't seem logical to you. I've got a picture, a construct in my brain, of what it is that I want to get across and I can only see that if you present this, this, this and this that it will all makes sense together. There may be some other ways of doing it but you have got to be trained in it, I guess. I teach the way I teach because, A) it makes sense to me, B) I was trained that way and is there a C to this? I don't know.

What I am trying to do with things like cooperative learning and things like that, is to make it so it isn't all the same, so there are various strategies. And hopefully you can get a few more kids that way, because my way I am sure is only [reaching] one segment. The others you try and scoop in when you do homework and that sort of thing. But if you can come up with some alternate strategies, you have got to be trained in them. You can't just say to a teacher "go do this" [try a new strategy] because it's hard, it's really hard. I took a course in cooperative learning. I tried to do a tiny bit of cooperative learning in the classroom and had mixed success with it. Train me some more and I will try it some more. You do what you do because that's the way you do it.

The ideas of variety, logical sense, and doing what he did because that is the only way he knew how to teach (without additional training), seemed to be key in understanding Ed and the rationale behind what he chose to do in the classroom. Ed was asked questions about some of the specific classroom strategies that he used in order to investigate these influences more directly.

When asked about lectures, Ed commented that he felt that lectures represented the "ultimate in how you can present the way you see the things [in the content] fitting together." The organization of Ed's lectures came from his personal understanding of the content, what "makes logical sense to me."

Ed's hope was that students would read the textbook prior to the lecture so that he could use the lecture to help pull the various pieces of the content together. Unfortunately, Ed found that his students only read the book enough to answer the assigned homework questions and rarely used this opportunity to enhance their understanding of the content. Ed explained why he encouraged the students to read the text:
I think if you have some knowledge of what is being talked about you can pick up on the subtle things that are being said and hang them on something inside your brain...So you read it first, then you hear the lecture and know that something fits into something...then you read it again and say, "here is something that the book said that the lecturer didn't say or that we didn't learn in class."

Unfortunately, Ed felt teachers were swayed by the knowledge that their students were not reading: "One trap we fall into is because they don't read the book we tell them about it."

Ed found that he purposely tried to avoid such a trap:

I don't lecture out of the book. I don't like that. It is there for the kids to read. That would be disastrous for a kid who read the book to listen to the lecture. What I also don't like is someone who will come in and put on the overhead an outline of what we are doing in the book. I hate that. I have hated that from when it was done to me so I don't do it for the kids. [However,] for some kids that may be a disservice because they aren't going to read the book.

Ed assigned questions out of the book in "an attempt to get them to read" and worksheets to provide practice because: "If you just talk at them, they are not doing anything and they have missed another level of learning where you are interacting somehow." To encourage students to do the assigned work, Ed described the grading of assignments in class on almost a daily basis. He claimed that this system worked because: "if you don't have it, you get nothing for it. There are no excuses and it forces them to do it."

Ed felt that the use of movies and filmstrips to accompany his lecture was "appropriate" if they were "short enough and they fit in fine [content-wise]." Ed continued:

They are as good as a teacher lecturing about the thing, probably better because they are more visual. I think they are a great advantage or addition to the lecture process where you are supposed to present something in a logical sequence, in an order that kind of fits in a package.

As with other teachers in the study, Ed seemed to have problems placing labs in his program. Though he admitted several times that he felt that he was not including enough labs and hands on activities, he found this difficult to do for several reasons. One reason had to do with the poor quality of the labs available. Ed felt that the lab books that he had access to were "cookbookish or the same old stuff we always do just in a different format." A second problem with the incorporation of labs had to do with time, time for lab preparation and time within the already crowded curriculum. These first two concerns are illustrated in the following statement:

Another problem with labs is they are very difficult to get ready for and carry out. It's a lot easier to get up and lecture in terms of preparation or to pass out a worksheet in terms of preparation rather than gather everything together for a lab and pull it off. You get exhausted doing that. I understand the value of it [labs], but getting it in there is the problem.
Especially when you are expected to cover this much content in this much time. You can't be spending two or three days dawdling around. You try and get your labs as organized as you possible can, but then they end up being cookbookish. "This is the expected result," and if you don't get the result, then you basically failed the lesson.

Ed also claimed that many students thought of labs as "just a routine. You get in there and do something that has no meaning, no relationship to reality." Despite these aforementioned problems, Ed kept returning to the idea that more labs needed to be incorporated into his curriculum: "We are just swamped. We have got way too much to do. So we make choices and I think in my own mind that we are always kind of pushing the lab [out]." To remedy this problem, Ed came up with a proposal which he presented to his department:

We get hung up in the idea that as we go along with our logical sequence of content that our labs should match the logical sequence of content. At several meetings this year we [the department] have talked about it and I've said: "Why bother? Why not just do some processing. Processing labs where you are just measuring and recording and gathering data. Why does it have to correlate? Why not every Wednesday have a lab? Who cares what the content is?"

Classroom Profile

Ed's class was highly routine oriented. Rather than such a description fostering an image of a dull class, the situation was quite to the contrary. As a function of the routines which Ed had established, his class operated with great efficiency, maintained a great deal of variety and allowed time for the completion of large amounts of work. These routines seemed to set up a consistent framework and set of expectations under which the students could work. As an apparent result, few disruptions due to behavior problems occurred and students seemed to have an increased ability to concentrate on their daily work. Overall, Ed's class could be characterized by strong routines, consistent enforcement of rules, and generally high expectations of what could be achieved during a class period.

Ed's fifth period class was observed for the purposes of this investigation. The class occurred directly following the lunch period and was the first of Ed's three biology classes. Since Ed taught physical science elsewhere in the science wing in the morning, he seemed to enjoy the few minutes that the lunch hour provided him to "change gears" and collect his materials for the upcoming classes. He also needed a couple of minutes to set up the room since another teacher had used it for the morning. To facilitate the necessary changes, Ed reserved the few minutes prior to the class for himself. He usually left his
classroom door locked until immediately before the beginning of the class period and let
the students collect outside the door.

The first students usually entered the room as a group upon the opening of the door.
Once in the room, they were expected to pick up a folder with their name on it from a box
near the doorway and then take their seats. The folders contained evaluation sheets
concerning their performance on cooperative learning tasks and name tags which the
students were requested to wear for the first several weeks of class while they learned the
names of their classmates. Ed explained the anticipated function of the folders and the
assessment forms which they contained:

   Ed: The idea of that [the assessment forms] was that whenever we did
cooperaive work, they would process how well they were doing. So in the
first few weeks I had them write down "today I was really good at
cooperating." You know that was a lie! (laughs)

   Researcher: And they did that on their own then each day?

   Ed: No, I had trouble fitting that in, with timing and everything else. As the
semester went on, we did less and less and less.

Additional students entered the classroom in a less hurried manner, though they usually
arrived before the bell rang. Students not in their seats when the bell rang were
considered tardy, a rule that was consistently enforced.

The students sat in seats assigned by the teacher. This facilitated the taking of the
role, allowed Ed to control whom various students sat next to and helped guarantee that all
students learned to work with, and had the opportunity to work with, a variety of other
students. Ed changed the seating plan once every 3-4 weeks, restating his emphasis on
the importance of learning to work with others. As Ed explained:

   With the difficult classes you have to identify who was able to do what and
who was unable to do certain things and make sure that the people who
were going to be poking at each other aren't any where near each other. It
helps in the grouping. I have always wanted to be in control of who is
sitting where and who is interacting with whom.

Students were expected to be in their seats, quiet and ready to go, when the bell
rang. On many occasions, Ed had something for the students to do during the first few of
minutes of class while he took roll. In some cases, he would put a set of notes on the
overhead which he expected the students to copy down for later discussion. In other
cases, he would verbally or in writing instruct students to form themselves into working
groups of three or four. Once formed, the groups were expected to discuss/review some
aspect of the curriculum, draw a diagram that explained a concept, or generate a list which
answered an assigned question which was later used for discussion. On the days when
Ed had no such warm up exercise planned, the students often talked quietly or attempted to finish an assignment that would be graded during the course of the period.

If Ed finished roll before the students finished the assigned warm-up task, he often wandered out into the room to check their progress. Frequently, he was heard asking students about their work, listening to them explain a concept or answering a student question. These contacts seemed to be equally initiated by the teacher and the students. Ed often used this as an opportunity to check student understanding and compliment students on a job well done, where students seemed to use these interactions to show Ed how well their learning had progressed.

Depending on the day of the week, the typical class progression varied. On Monday's, the next item of business was to discuss the weekly schedule. Schedules were distributed to all students and were covered item by item. Included on the typed page were the required readings, assignments (including date assigned and date due), and the basic biology content to be covered on each of the days. In addition, upcoming dates of importance such as tests or the last day of the grading period were noted. Students were also reminded to sign up for Wednesday Reports, an extra credit opportunity which will be described later in this section.

With many of the normal classroom activities formatted in some sort of routine, Ed was usually able to conduct at least three separate types of activities each day. Examples of such activities included: completing warm-up exercises, lectures, worksheets, grading homework, working in small groups, starting or finishing a lab, listening to Wednesday Reports, or watching a movie. Each of these activities and their typical formats will be (or has been) discussed.

Regardless of the type of activity, each was conducted with Ed's friendly and easy going style. Classwork was conducted in a supportive and safe manner, allowing students the opportunity to express themselves and be heard by others. Discipline problems, when they occurred, were handled quickly and efficiently with a minimum of interruption to the flow of the class. Ed always seemed to have a good sense of humor in the classroom while maintaining a business-like atmosphere with high expectations for student work. Everyone in the class, both teacher and students alike, seemed to enjoy being in the class and with each other.

Lectures of some sort occurred on approximately 40% of all class days (as determined through an analysis of lesson plans). This seemed to be the primary method of introducing new content, which usually seemed to be conducted with a "college prep" orientation. Specifically, when options presented themselves to "water down" or extend the content beyond that covered in the text, Ed often chose the latter option, effectively using
materials that he had collected from sources other than the text. Despite the increased amount and difficulty level of the content, the students seemed to be fairly successful in learning the material and seemed to enjoy the challenges the materials presented.

Lectures were usually accompanied by notes pre-written on overhead transparencies or written by the teacher on the board as the lecture progressed. Students were expected to copy these notes into their notebooks, a fact of which they rarely needed to be reminded. Student behavior during lectures was generally appropriate, an expectation reinforced by Ed's frequent movement among students' seats and through his use of facial expressions, gestures and eye contact. The lectures were often complemented by visuals such as commercially prepared overheads, textbook illustrations, or images of microscope slides projected through a video camera onto a television screen, all of which helped in maintaining student attention.

Perhaps most importantly, Ed's lectures promoted a great deal of student involvement. Ed often asked questions while he was presenting new information. These questions were directed equally to volunteers and non-volunteers. Though callouts occurred and were not ignored, the format of Ed's questions and the flow of the classroom discourse usually discouraged such interruptions. The following dialogue should help illustrate Ed's style of classroom discourse. This example occurred while students were engaged in grading a homework assignment from the text:

Ed: Number Five: Suppose you observed an ant carrying a grain of sugar to an ant hill. Soon after you saw hundreds of ants moving to the spot where the first ant found the sugar. What hypothesis would you suggest to explain how the first ant communicated the location of the sugar to the other ants? How might you test your hypothesis? Kristy?

Kristy: I don't know.

Ed: Okay. Amanda?

Amanda: By the scent?

Ed: That is a real good one. How would you test it?

Amanda: I don't know, I made it up. (pause) By plugging their noses?

Ed: (Laughs) By plugging the ants' noses? That's good because it tells me that you are able to test the hypothesis in that way. Tracy?

Tracy: Communicate by dance.

Ed: How would you test that?

Tracy: Watch them to see if they dance.
Ed: If they dance. Great! Sean?

Sean: Communicate physically, like rubbing their antennae or something. To test it, remove their antenna.

Ed: That is another good hypothesis to rub their antennas together. Bryson?

Bryson: About Amanda's hypothesis. When you take a stick and stir up an ant hill and then move the stick to someplace else, the ants will follow.

Ed: Excellent! So you go looking for the [source of the] scent yourself. Those are great. If you gave a hypothesis and you gave this [question] a good try, you can give yourself two points. Now we go on to page 14.

In addition to verbal responses in class, Ed often had the students use non-verbal signals to indicate their understanding of a point or their opinion on some issue. For instance, Ed may have students hold up their right hand if they thought one answer to a question was correct, their left hand if they agreed with a second. By making a quick visual scan of the room, Ed could assess student understanding, information used to determine whether he should introduce new content or review content discussed previously.

Three or four assignments were due in Ed's class each week. The majority of these assignments came from questions either in the text of the chapter or from the questions in the back of the book. A typical assignment involved reading two or three sections of the text and then answering 4-7 questions about that reading. The answers to these questions were graded in class by the students so that "everybody hears the right answer."

Papers were usually exchanged with neighboring students for grading. Large red markers were used to decrease students' temptation to fill in answers during the grading. "Correct" answers were offered by students, either voluntarily or by being "next" in a predetermined sequence. Ed provided time to discuss each of the questions and the possible answers, settle disputes and collect the graded papers for recording.

Worksheets provided an additional source of daily grades as well as a classroom activity. The worksheets were highly complementary to the material which was being discussed in class and often acted as a method to review, enhance or expand upon content previously covered in a more traditional classroom presentation. For example, when the class was covering a unit on cell division, Ed selected two worksheets that dealt with cancer, its causes and the populations in the highest risk categories for certain forms of cancer. These worksheets, which the students completed in small groups, challenged students' graph interpretation skills as well as provided an application of the class content.
to a familiar health issue. Worksheets comprised 38% of the daily classroom materials whereas homework assignments from the text comprised 33%.

Movies or film strips were shown at least once a week. These audio-visuals were used to introduce new material such as in the case of a movie series on the various biomes of the world, or were used to review concepts, often by showing them immediately prior to a test. In all cases, these films were short, usually less than 15 minutes and complemented other activities which were taking place in the classroom as opposed to replacing them.

Wednesday Reports were the primary source of extra credit in Ed's class. On Mondays, students were encouraged to turn in a science topic of their choice on a 3x5 card. Upon approval, the student would prepare a 3-8 minute presentation on the selected topic which would be presented to the class verbally on Wednesday. Extra credit points were awarded based on the length of the report. The students seemed to enjoy these reports, which were often read directly from the students' papers and occasionally accompanied by a diagram. Ed encouraged the class to applaud following each presentation in a show of support for the student. In general, 3-5 reports were presented each Wednesday, usually by the same small group of students. Though the topics presented were varied and interesting, Ed made no effort to discuss the ideas presented or to tie the presented content in with that being covered in class.

Labs and hands-on activities, which were used on less than 10% of all class days, came from a variety of sources including past textbook series. They were usually conducted in a short period of time (15-20 minutes per day) and were accompanied by the presentation of other content. Prelabs and postlabs, though they existed and were sufficient, were not extensive. "Traditional" labs were the most common, followed by labs which taught science related skills (i.e., measurements and microscope use) or verified concepts learned in lecture. Rarely were labs or activities used in an inquiry manner.

With the wealth of activities conducted each day, the class usually continued until, and sometimes past, the bell. At the bell, the students dismissed themselves, something to which Ed did not seem to object. If he had not finished what he was saying, he often talked through the bell. Ed seemed to assume that the kids who really cared would stay to listen, though this was a small minority of the class.

Ed seemed to be one of the few teachers who adjusted his schedule based more on student learning than on the school calendar. Tests were given about once every two weeks, but not until the course content had been covered sufficiently and the students seemed ready for the evaluation. As Ed explained: "We are moving along at a pace at which we [the teachers] feel like we are presenting the material [so that] the kids are getting it." Ed often complained of being behind his anticipated schedule by at least one
day each week. This resulted in tests rarely being given on the days for which they were
scheduled. Vacations and grading periods did not seem to constrain this pattern
significantly. If closure was needed on a unit prior to a grading period’s conclusion, Ed
gave a quiz and then continued with the unit until the students were ready for a test.

Before each test, the students were asked to construct 20 flash cards on 3x5 index
cards. These cards included a student generated question from the chapter on one side
and the answer on the other. Credit was given if the card was complete rather than being
judged on the quality of the question. Flash cards were graded prior to each test and were
expected to be kept for review for the quarter and semester finals.

Tests, including quarter and semester exams, were constructed by the department
and were given to all the biology classes. For this reason, the content and format of the
exams were as much a function of the department’s philosophy as it was representative of
Ed’s. Each test usually had over 50 questions, primarily selected from the textbook’s test
bank. These questions were primarily short answer, objective questions and were
answered on Scantron sheets by the students. As was the case for the other teachers who
depended on the test bank, 88% of the questions were of a lower level nature. The 12% of
the questions which assessed higher level reasoning could be characterized as an
application of learned material to a similar, but unfamiliar, situation. Despite Ed’s
characterization of his fifth period class as being his “best class,” average grades on the
first quarter exam averaged 65%. Nine week grades were evenly spread across the five
letter grades, a fact that did not seem to overly concern Ed.

In addition to the classroom activities described, Ed provided students with an option
to complete a science project. Participation was voluntary and students who completed a
project were awarded extra credit. About four students per class elected to do such a
project, which were displayed for parents and the school community at an Open House
held in January.

Classroom Subject Matter Structure

Ed taught the following units in the sequence listed during the semester of
observation: Introduction to Biology, Ecology Basics, Ecological Systems, Basic Chemistry,
Cell Biology, Cell Energy, Cell Division, DNA/RNA. It was based on the data collected from
these units that Ed’s classroom SMS (Figure 13) was generated. Methods for the derivation
of this SMS can be found in Chapter IV, Textbook Subject Matter Structure: Methods. The
reader is referred to this section if questions concerning methodology arise. In addition,
the evidence used for the generation of the SMS can be found in Appendix K and cross referenced to Figure 20. Classroom observations were made in all the units listed above.

Ed loosely followed the content and format followed by the text. There are several specific instances where Ed rearranged the text content to meet his personal needs. First, Ed combined the content from Chapters 1 and 2 of the text into a single unit: Introduction to Biology. Though the same content which occurred in these two chapters was essentially covered, Ed’s organization and areas of emphasis were uniquely his. For instance, very little time was spent on the topics of metric measurements or the characteristics of living things. A greater amount of time was spent in an experiment which demonstrated the use of these various skills and allowed students to practice the steps of the scientific method.

Second, Ed reorganized the flow of content within the Ecology sequence. Biomes were introduced early in the first unit and then used as an organizing framework for information about communities, abiotic and biotic factors, and interactions among organisms and their environment. The first unit, Ecology Basics, also included a sub-unit on cycles developed by the school district’s biology teachers (which included Ed). The concept of cycles was then carried through the second ecology unit as well. Such interactions between the two ecology units can be seen in Figure 13. In addition, Ed blended the content from text Chapters 37 and 38 into a single unit, Ecological Systems.

The final variation from the content and format suggested by the text occurred in the chapter under Cell Reproduction. Like many of the other teachers in this study, Ed segmented this chapter into two distinct units: Cell Division and DNA/RNA. Despite the separation of this unit for the purposes of testing, strong interactions remained between the content of these two units.

Overall, the SMS generated from Ed’s classroom data is very integrated. Though it cannot be seen in the SMS created, this integration extends not only between units, but also very strongly within units. There seem to be two components of Ed’s SMS which are not integrated as deeply as the others: the introduction and the ecology sequence.

The introduction unit, which primarily introduced the nature of science and scientific methodology, was rarely referred to in future units. This may be because Ed did not see the connection of this unit to other aspects of the curriculum. A lack of connections may also be a product of Ed’s own relatively weak knowledge in this area. Ed’s only content errors existed in this unit, specifically in the area of the nature of science. For instance, Ed taught “The Scientific Method” as a series of steps which must be followed in a specific order if scientific understanding was to be achieved. Ed’s stated goal for his students was that they “know what the steps [in the scientific method] are and why they are in that location [in the list].” To do this, Ed discussed the advantage of using a mnemonic when
Figure 13. Ed's Classroom Subject Matter Structure.
trying to memorize a sequence of things. Ed also did not understand the difference between a theory and a law. According to Ed, "A law is a theory that has stood the test of time."

Neither of Ed’s misconceptions concerning the nature of science were unique or unusual. In fact, many textbooks present the same content which Ed taught in his classroom. Thus, Ed may not have realized that a weakness in his understanding of these concepts existed. In addition, many of the lessons used to illustrate nature of science concepts were suggested by another teacher in the district (Alex, in fact) and were being used by Ed for the first time during the year of the current investigation. Such an adoption of another teacher’s lesson sequence may also be a symptom of Ed’s insecurity concerning the content covered in this unit. However, an equally plausible explanation may be that the adoption of Alex’s nature of science units may have been fostered by Ed’s desire to include more lab activities in his curriculum.

The second content area which was somewhat removed from the general content integration in Ed’s classroom SMS was the ecology sequence. The integration within the ecology sequence was strong, as has been previously discussed. However, this sequence had limited contact with the rest of the curriculum except through the introduction of cycles within the context of cell respiration and photosynthesis. Additionally, the connection of this unit to an evolution theme, which was prevalent in the text, occurred only through Ed’s use of classroom materials. For this reason, it is possible that the evolutionary connections were only artifacts created by the accidental selection of materials with such a slant. Another possibility was that Ed did not feel that evolutionary connections to Ecology were important enough to reinforce in class, but could be handled adequately through the worksheets and materials which he had assigned.

Finally, the largest portion of Ed’s SMS can be described as an integration between molecular and cellular biology. Strong interaction of content occurred both within and between units. These connections were both forward and back-reaching, with a tendency toward more back-reaching references, a directional tendency opposite that provided by the text. Within the context of a classroom presentation, such references were often accomplished by a short question directed to the students which addressed content from the past in terms of how it related to the current content. This "recycling" of content kept the students involved and provided avenues of content integration from past units to present. It is interesting to note the role played by the Cell Energy unit in the integration of the content. This unit provided a framework for potentially fragmented content items through the themes of cycle, energy transformations, and the role of enzymes in cellular
activities. Again, it should be noted that this was not the model followed by the text and thus can be attributed to Ed's personal understanding of the content.

As previously mentioned, Ed's classroom presentations only loosely followed the format and organization of the text. In many instances, Ed expanded the content provided in the text. Examples of such expansions include the teaching of carbon chemistry, including the families and nomenclature for carbon compounds; developing the relationship between chemical structures, potential energy, enzymes, and the energy released in respiration or stored in photosynthesis; and the elaboration of the cycle of cell division to include not only mitosis, but also cytokinesis and the patterns of growth, synthesis and division involved. Such expansions came from Ed's personal knowledge base and provided many of the connections illustrated on his SMS. In addition, it should be noted that Ed taught his content, including his expanded topics, to mastery as opposed to just introducing the content in a superficial manner. Thus, it is probable that the students truly understood many of the connections provided in Ed's class.

When asked about the rationale behind the expansion of the content beyond that included in the text, Ed commented that he included content that "seemed to make logical sense" to him in terms of the development of a concept. In addition, when the comment was made that many teachers disliked teaching the topics of photosynthesis and respiration due to their complexity, Ed responded: "Really? I love teaching photosynthesis!" This enjoyment showed in Ed's enthusiasm for the topic and his care in constructing his classroom presentations.

The evidence seems to support the conclusion that the integration apparent in the molecular and cellular biology was a function of Ed's own content background. Other units outside this area (i.e., Introduction to Biology and the ecology sequence) did not produce such intricate interactions. Unfortunately, further support for this speculation would rest on observational data collected in Ed's classroom for the entire year. Such data would provide evidence supporting or refuting a tendency toward the integration of content regardless of topic or differentiate the inclination to only integrate those units within Ed's content specialty.

The final components which appear in Ed's SMS are the use of examples and the weak appearance of a STS theme. The majority of examples which Ed used while teaching occurred within the units. For instance, when talking about cell energy, Ed used examples from the unit on Cell Biology, or alluded to the use of these systems in Cell Division. However, Ed did discuss examples and thus provide connections, which went beyond the surrounding chapters. Most of these examples expanded concepts developed at the cellular level (such as osmosis) to the level of the organism (such as water regulation in
aquatic organisms). STS issues appeared only as a weak theme in Ed's teaching, occurring in only three instances. As a group, these issues do little to develop a greater understanding of Ed's views of the structure of biological knowledge.

Self-Described Subject Matter Structure

Ed was asked to draw and explain his SMS of biology for the first time as part of the final interview. When asked to complete this task, Ed questioned if what was required was a web. When told that the format used to represent this information was open, Ed began the task. After a few moments of thought, Ed asked for several sheets of paper because he felt that the task would "take four or five tries." As he began, he made the following comment:

You know, when you take an individual topic, it's easy to get a picture and a sequence and a logic about it. But when you take ALL of biology, it's tough to get an overall picture. I don't know what I will be able to come up with...I don't know how I'm thinking about this. I have got to admit though, I'm enjoying doing this! How am I thinking today? Am I thinking today? It's not like this is a test either. Questions are much more fun when there aren't really any right or wrong answers!

Ed worked for about 15 minutes on his SMS. During this time he made several attempts which he abandoned. When Ed decided that "this is about all I'm going to come up with," he volunteered to explain his diagram (Figure 14):

Basically there are three main themes: Interdependence of all living things, Alikeness of all living things, and the Great Diversity that we see. Now, some of the little things and how they fit together. First of all, Interdependence just takes in all the ecology and cycles, so I put those [ecology] out there [connected to Interdependence].

Between these two things, Interdependence and Alikeness, is the idea that living things all have similar needs, and that is why they are interdependent and all that sort of thing. So, I see that [Needs] as coming off of that [the line between Interdependence and Alikeness].

In Alikeness, we have a couple of things. Cells and Organelles would include division of labor and stuff like that. On the other side of Alikeness I had the terms of Chemical Similarities, DNA, and all the metabolic pathways and all the genetic kind of things. Those comes off of there [Alikeness].

Alikeness and Diversity leads us to Evolution. There Alikeness is [included] because it takes mutations and changes over time to produce the Great Diversity. So, that [Evolution] kind of comes off the middle there [between Alikeness and Diversity].

Under Diversity then, of course we have got Classification and the Five or Six Kingdoms. And everything that comes off the Five or Six Kingdoms is
Ecology

Interdependence of All Living Things

Needs

Cell

Organelles

Evolution

Mutations

Changes Over Time

Alikeness of All Living Things

Chemical Similarities

DNA etc.

Metabolic Pathways

Great Diversity of Living Things

Classification

5 or 6 Kingdoms

Figure 14. Ed's Self-Described Subject Matter Structure.
down here [below the diagram and not represented]. It is like, if you are
going to concentrate on these three main ideas, then you are going to want
to concentrate on those kinds of things [the topics listed on the diagram].
That is why plants and animals end up down here, way off the charts.

Another word I wrote down [while thinking about what I wanted to include in
the SMS] was "quantification." In other words, we wouldn't understand any
of all of these things [pointing to the entire diagram] unless we were able to
quantify somehow. I was thinking up here [pointing to interdependence],
how do you know that all of these things are interrelated? Someone had to
go out and measure the biomass and the number of individuals and
quantify it in some way and put it on some kind of a chart and graph it and
things like that.

Alikeness, you have to quantify that by looking at the DNA, comparing DNA
and looking at organelles and how they are the same and why is that the
same. That is kind of the quantification idea. I was trying to think of how it
might fit into diversity. I suppose, just in terms of numbers. But that
[quantification] is kind of a big word that goes with science.

So, for Ed, there are three main ideas that make up biology: Interdependence,
Alikeness and Diversity. When asked if the three main ideas were of equal magnitude and
importance, Ed stated "yes, I think so." The central ideas provided points of connection to
other, less central ideas, which typically contained the content found in the units of the text.
All of the ideas were then tied together by the idea that scientists need to quantify their
findings in order to understand and report their findings. When asked if he would be happy
if his students left his class knowing the relationships within biology as he just described
them, Ed said:

As long as they could support it with some of the things that we talked
about in class. If I just said that "this year you are going to learn that there
is an interdependence of all living things," I could quit [teaching] in a half
an hour! They need to be able to support it [that statement] with some of
the basics of ecology that show interdependence and show the cycles and
all of that. And some of the basics of cell models and organelles and the
chemical similarities and some of the basics of classification. Then I would
be happy.

Ed considered his SMS relatively complete when asked if there was anything else that
he thought should be added to it or anything that he felt was important that he couldn't
represent in his diagram. When asked initially if he had ever thought about biology in this
way before, Ed commented, "I should probably say 'yes,' but I don't know whether I could
explain that answer." After some thought, Ed could think of one stimulus to thinking about
the "big picture" of biology:

I guess I have thought about it before because you get asked, especially
on parents night and things like that, "what are you doing here and what is
that all about?" I have used these terms [pointing to his SMS] before. Yes, I
have thought about it.
These comments seemed to represent a bit of a revelation to Ed. Up until the point in the interview where Ed made the above comment, he had not realized that he had consciously considered the structure of biology prior to that time. The fact that past situations had encouraged him to consider the structure of biology was reinforced when Ed was asked if he had always thought about biology in the manner he had described on his paper. Ed stated in a laughing manner, "No. It's evolution. Change-over time. I may not even come up with that same scheme [SMS] tomorrow. But who knows, maybe I would!"

When asked about any events which have helped shape his personal SMS, Ed replied:

I think the more you learn the more you can generalize. When I first started out, I was just learning little pieces here and there. And I suppose that's the way it should be with all students, that you've got to learn a piece here and a piece there. Maybe I am wrong, but it's probably a rare student that can write an essay on the interdependence of all living things and bring in all the aspects of ecology and show how they all relate. You have got to have a pretty broad base of knowledge in order to do that. And I don't even know that I could do a very good job of writing an essay about that. There are a lot of things I could bring into it. But I am sure there are people out there who could do a lot better job at it. Come to think of it, I'm not sure I could have come up with that diagram [SMS] before last year. You keep learning more content all the time.

When Ed was asked if evidence of the SMS that he just described could be found in his teaching, he said:

I think it ought to be, but I don't know whether it always is. When you are presenting something I think it [the content] ought to be going back to that [SMS]. But to verbalize that [SMS] every time is something that I probably personally don't do very well. To do a good job with that [the presentation of the SMS], I think you have got to start at the beginning of the year and say "these are the main themes." And every time something that relates to it [the theme] comes up, we are going to go back to that theme and see how it works [relates]. I think you have got to start the year with that [the presentation of the themes] and I never have. I say, "this is where we are going," but drawing road maps like that might be really helpful to the students.

Ed felt that evidence of a SMS in classroom practice would have to take conscious effort on the teacher's part. Maybe for that reason, Ed was surprised when he was told that he made a large number of connections for his students during his own teaching. When told, Ed commented, "I never knew. I had no clue that I made any connections at all."

When asked about his own students' ability to recognize the interrelatedness or the big ideas which bind biology together, Ed said that he would have "very little confidence that the kids would be able to write that [SMS] down." Part of the rationale behind Ed's statement was that Ed believed that learning is, or should be, a continuous process and that students simply did not have enough background knowledge and experience to create
such a structure. Ed admitted that his own structure may not have formed until "past the age of 40," and if he could give other biology teachers one bit of advice, it would be that they should be "back [in school or workshops] learning something all the time."

**Summary of Ed**

Ed described his SMS of biology as being structured around three primary themes: the interdependence of all living things, the fundamental alikeness of all organisms, and the great diversity of the organisms which exist. These three themes provided a framework for the inclusion of the topics which are most typically associated with biology textbooks. This SMS and all of the items listed therein were then discussed from the standpoint of the role of quantification in biology. For Ed, quantification represented the manner in which scientists made sense of their natural environment. The organization of the knowledge collected through quantification then comprised the specific content under each of the topics listed in Ed's SMS.

Ed felt that his SMS represented his evolving conception of the organization of biology. For Ed, this framework, or schema as he described it, changed as a function of his increased understanding of biology. For this reason, Ed did not consider the SMS as static, but as part of a dynamic process. In fact, Ed was uncertain if he possessed a similar SMS prior to the year of the investigation. In light of this statement it is interesting to note that Ed's description of his content goals for students during the initial interview included the goals of possessing an understanding of the interrelationships which exist among living things and an appreciation for the "alikeness" of all living things despite the surface appearance of great diversity. Thus, at least a portion of the SMS described at the end of the study was consistent with comments made at the beginning of the study. However, since Ed's SMS was not directly assessed at the beginning of the study, the exact correlation of these initial comments to the SMS which he may have possessed cannot be evaluated.

Ed felt that his SMS was formed as a result of his more than 40 years worth of experiences and content understandings. According to Ed, content was first learned in "pieces." As large numbers of the pieces of content knowledge were learned they could be generalized into a larger structure such as he had described in his SMS. As more knowledge is gained the SMS should change to accommodate the new information. When asked if there were any specific experiences in his career which helped with the elucidation of such a structure, Ed felt that such instances existed, but he seemed unable to recall specific situations. After a period of reflection, Ed realized that Parent's Night,
held early in the school year, stimulated him to justify in his own mind and to the parents, what the content of biology was and how it was going to be taught within the context of his course. Such periods of justification seemed to help establish the SMS which he currently held.

Ed seemed to enjoy the opportunity to create a representation of his SMS as part of the interview process. However, Ed did not consciously attempt to directly translate this SMS into his classroom practice, though such a translation was considered to be potentially desirable. Ed thought it would be foolish to only teach students the SMS since this task could be accomplished in a very short period of time. For Ed, the important part of the SMS involved the numerous examples which could be used to illustrate each of the topics and connections included. To actually teach this structure in class, Ed felt that the SMS would need to be presented the first day of class and then be systematically built upon and referred to in order for students to effectively master this conception. Ed did not actively try to teach his SMS, though he felt that providing his students with such a "road map" may be a helpful teaching technique.

However, since much of Ed's SMS represented the manner in which biology made "logical sense" to him, it would not be unusual to expect to find evidence of his conceptions of biology translate subconsciously into classroom practice. This seemed to be the case.

A comparison of Ed's SMS to that derived from classroom practice showed more dissimilarities than similarities. For instance, the existence of the three large themes identified by Ed do not appear in the SMS created from the classroom data. However, the two SMSs are not incompatible. Both SMSs have an integrated orientation and provide a framework for the content taught through the establishment of themes and the interrelationships of content. It may be, as Ed recognized, that his personal conceptions of the nature of biology were not purposely being translated into classroom practice, but that the underlying nature of the connectedness of the content was subconsciously conveyed by Ed as he constructed his lessons to reflect the "logical sense" that the content made to him.

The specific instances in which the "logical sense" of biology showed in Ed's classroom practice seemed to be in the establishment of themes within content topics, a situation of which even Ed did not seem to be aware. This tendency was particularly evident in the content areas in which Ed had the greatest expertise. For instance, when teaching the molecular and cellular biology units, Ed did an exceptionally strong job of integrating the units through the themes of nutrient cycling, energy transformations, and the role of enzymes in metabolic processes. The presence of such strong themes in areas outside of Ed's content specialty were different in nature: less frequent and less oriented
toward a thematic integration. Such evidence seems to indicate a strong influence of Ed’s content knowledge on his classroom presentations and his ability to relate content topics to other topics presented in the biology course. Such conclusions can be further strengthened when one recalls Ed’s relatively weak knowledge concerning the nature of science (i.e., conceptions of the nature of science which are not commonly accepted today, an inability to create laboratory experiences which promote a process orientation) and the infrequent use of “building” on ecology content even though the use of this section at the beginning of the year was justified on the basis that this would be done. However, it should be noted that Ed’s use of the ecology units for the purpose of providing a framework for the rest of biology may have become more clearly evident if his second semester teaching had been observed.

A comparison of the SMS which Ed produced to the SMS produced from the text showed that Ed followed the same basic sequence in the text with a few minor exceptions. In general, Ed’s SMS can be described as more integrated than that found in the text. This was particularly true for the chapters which involved content concerning molecular and cell biology, Ed’s identified area of content specialty. Connections within this unit were fostered by extensive coverage of content not contained in the text and a recursive nature within the presentation of content, typically through the format of back references which related current content to that which had been previously covered. It should also be noted that as of the school year of the investigation, Ed realized that the order in which the content was presented was less important than the emphasis of the themes which tied the units together. This realization, though not totally articulated, may have also fostered some of Ed’s independence from reliance on the textbook for content.

In general, it may be concluded that Ed’s fairly strong content background allowed him to elucidate the themes in biology which he identified, though his translation of these themes into classroom practice seemed to be differentially effective. In addition, Ed seemed to reinforce some content themes (i.e., nutrient cycling, energy transformations, enzymatic reactions) which he had not consciously identified.

The factors which seemed to influence the overall interpretation of Ed’s SMS and its influence on his classroom practice seem to be his content knowledge, a personal love of learning, an internal locus of control, and the influence of external constraints, especially time and departmental coordination. The influence of Ed’s content knowledge has already been discussed in detail. Evidence supporting the influence of the other variables mentioned and the role each plays in the interpretation of Ed’s SMS follows.

In many instances Ed alluded to the importance of learning in what he was able to do in the classroom. Of obvious impact was the role of content knowledge. Ed admitted that
he could only teach the content which he knew or could learn. To foster his own learning, Ed attended NSF content/education workshops, participated in science related activities, and attended workshops on new teaching techniques such as cooperative learning. As he acquired new knowledge, Ed felt that his SMS of biology changed, as did his ability to teach his content to his students. In addition, Ed enjoyed the challenge that the learning of new content presented. Such challenges often manifested themselves as opportunities to teach advanced sections of science courses. Other opportunities to learn were stimulated through the professional discussion of teaching at both the department and district wide level. All such opportunities not only increased Ed's content background, but also provided Ed with a stimulus for reflection on his content and teaching knowledge. In addition, these opportunities may have encouraged him to justify his views to others, be they parents, colleagues, or students. The combination of these experiences, though they could not be specifically described by Ed, seem to have contributed to the content and organization of his SMS. From Ed's perspective, the value of these situations may be summarized in the advice that he had for new teachers: Never stop learning.

Secondly, Ed seemed to have a personal feeling of efficacy within the teaching situation, or an internal locus of control. For instance, Ed seemed to take personal responsibility for the learning of his students, set up classroom routines which fostered student learning, had high student expectations for behavior and content understanding, controlled the seating arrangements in his classroom to ensure the appropriate classroom atmosphere, controlled the level of content taught in his class by being willing to expand the content beyond that in the textbook, and allowed student understanding to control the pace of his teaching rather than the school calendar. The above evidence for a internal locus of control may not have affected Ed's SMS directly, but may have allowed for the greater translation of his own "logical sense" understanding of the biology content to be evidenced in his classroom practice.

Finally, the external constraints of time and departmental coordination may have decreased some of Ed's ability to transfer his thoughts into classroom practice. Time, both in terms of the time to teach and the time to prepare, may have limited what Ed was able to do in the classroom. The removal of these constraints may have changed the SMS portrayed in Ed's classroom teaching. Additionally, it should be remembered that the general teaching methods, materials and tests used in Ed's biology program were agreed upon by the department as opposed to being under Ed's direct control. Thus, it is unclear how much of Ed's understanding of the content and his SMS was compromised within this framework of coordination. The combination of these variables may help explain why Ed's
SMS, though fairly well developed, may not have been directly reflected in his classroom practice.
CHAPTER V
DISCUSSION AND CONCLUSIONS

Introduction

Four general questions were posed at the outset of this study. These were:

1. What is the nature of biology teachers' subject matter structures?
2. What is the source of the current SMS held by teachers, and what factors can be identified which may have contributed to its formation?
3. What is the relationship between teachers' stated SMSs and classroom practice?
4. Does a testing effect occur in the process of assessing the content of teachers' SMSs?

Conclusions concerning the answers to each of these questions will be addressed in the following sections. Such conclusions will be drawn from across the data collected and analyzed for each teacher as presented in each case study. Though it is recognized that the conclusions drawn from a specific case study will not be generalizable to the total population of biology teachers, it is hoped that generalizations formed across the case studies can provide hypotheses which can be further explored with a larger sample of teachers in other teaching contexts.

In addition to the conclusions and the attending discussions, comments concerning the limitations of the study, recommendations for future research, and the implications of this study for the field of science teacher education will be addressed.

The Nature of Biology Teachers' Subject Matter Structures

Content

Generalizations concerning the nature of biology teachers' SMSs were formed through a comparison of the SMSs created by the teachers as part of the pre- and/or post-interview. In general, all teachers' SMSs can be claimed to be content based. The primary terms used in the SMSs related to major groupings of content (e.g., cells, ecology, evolution, genetics, botany). This terminology is consistent with the terms used to classify content into textbook chapters or university content courses. The use of such terminology is consistent with that found by Gess-Newsome and Lederman (1991) when they used a
similar questionnaire with preservice biology teachers. However, the use of such terminology is inconsistent with that provided by card sort tasks typically used to elucidate biology teachers’ conceptions of SMS. Baxter, et al. (1985) provided the teachers in their study with "universal" biological themes identified by a group of science educators (e.g., science as inquiry, complementarity of structure and function). The terminology used by Hauslein and Good (1989) was somewhat similar to that found in this study in that there was a concentration of terms which reflected content topics. However, the scope and hierarchical designation of the topics used in their card sort were distinct. For instance, common in the Hauslein and Good card sort task were terms such as photosynthesis, symbiosis and digestion. These terms are much more specific than those used by the teachers in this study.

In all cases, the teachers in this study seemed to recognize an interaction among the content items which they listed in their SMSs, though the degree of integration varied with each teacher. Such interactions were illustrated in a variety of ways. For instance, Don's pretest SMS showed the interrelationship among content topics as a series of double headed arrows. His posttest SMS represented such interrelationships as a series of concentric boxes which described the foundational designation of some of the content components. Carl and Ed also used arrows and lines to indicate the relationship of the various content components, though this use differed for each teacher. Carl's lines represented a logical order used in the presentation of content and the foundational importance of the content taught earlier in the year (i.e., cells). Ed constructed the framework of his SMS on three content related themes. This initial framework then acted as the foundation for the connection of the remaining content. In his final SMS, Alex listed his content in essentially the same order as that in which it was presented, but had earlier indicated "blocks" of these topics which were more closely related. For Alex, integration of topics was more a function and responsibility of the teacher's classroom presentation through the "building" of background knowledge in students, but he verbally acknowledged that all content had the potential to be integrated with other content. Thus, though the integration and interrelationships of the content topics were recognized verbally, such relationships were not particularly evident in the SMS he created. The teacher with the least evident integration of content was Ben. Ben divided his content into the categories of Theoretical and Applied biology, terms which were primarily used to describe the ability of the content categories to be directly "observed" within the classroom context. The content items listed below these two initial categories did not seem to have an interactive nature in terms of the SMS drawn or described. However, it should be noted that Ben specifically stated that he recognized that the nature of the content topics in biology were "interwoven."
If one were to actively seek the presence of themes in the SMSs of the teachers in this study, such themes, when they did occur, can generally be limited to those which have strong content orientations. For instance, Don verbally stated on his posttest that he viewed evolution as an integrating theme which superimposed itself across the other content listed. Carl talked about the importance of students understanding the complexity of life and the ability to classify organisms into the five kingdoms. Though these goals did not actually appear in the SMS which he created, they could be considered themes. Ed can be considered as having recognized four themes. The first three were represented by the three major categories listed in his SMS: interdependence, alikeness, and the great diversity of living things. In addition, Ed recognized the role of quantification in each of the areas listed in his SMS. Ben did not seem to recognize or include any themes in his SMS.

Themes not specifically related to the content topics found in typical biology classes were not particularly evident in the SMSs created by the majority of teachers included in this study. The one exception to this generalization was Alex. Alex identified five themes which he tried to incorporate across his SMS and into the teaching of his content: scientific processes, critical thinking, current events, ethics, and study skills. For Alex, the recognition and integration of these themes across his content was a vehicle to "kill two birds with one stone" by teaching more (in terms of both content and the themes) within a single lesson. Thus, Alex valued the presence of the themes for their pedagogical efficiency (Lantz & Kass, 1987) within the classroom context, as well as for their importance within his philosophy of science and science teaching.

The relatively elusive nature of themes in the SMSs of the teachers included in this investigation is important when one considers the types of card sort items constructed by other researchers in this area. The study by Baxter, et al. (1985) used content related themes for their card sort. However, the terminology which they used was distinct from the types of content themes found in this investigation. Recent work by Gess-Newsome and Lederman (1991) has demonstrated the presence of themes in preservice biology teachers which more closely resembled those identified by Alex (e.g., the nature of science, science process skills, STS interactions). Again, these themes were distinct from those used in the Baxter, et al. study. In the case of the Gess-Newsome and Lederman study, the themes reported by preservice biology teachers seemed to be a direct reflection of the themes reinforced in their science education coursework. Alex acknowledged similar sources for the themes he incorporated into his SMS.
It is interesting to note that, though most of the teachers acknowledged having some form of a SMS in place prior to the onset of this investigation, several of the teachers admitted not actually thinking of their SMS in the terms of a schematic or diagram. Both Ben and Don admitted that they thought about the topics which would be included in their courses and recognized the interrelationships among the topics, but usually just listed the topics in outline format. Ed also admitted not really thinking of his content in terms of a diagram. In addition, he admitted to not really considering the structure of an entire year of biology on a regular basis. For Ed, it was much more typical to consider the structure of a unit or a lesson than to consider the structure of an entire year. This comment, though not explicitly stated, may also be true of other teachers in this study.

Furthermore, it is interesting to note that both Ben and Don, when asked to record their SMSs for biology prior to the classroom observations, both asked if the diagram should indicate how they thought about biology, or about how biology should be taught. When asked to explain the statements made, neither seemed able to do so. The SMS which they and the other teachers in the study drew seemed to be the SMSs of how biology should be taught. This highlights some interesting questions regarding the nature of the SMS and the potential influence of the background of the interviewer (biology in terms of teaching rather than biology as a science). Hauslein & Good (1989) suggested that structures of pedagogy and content are not two separate structures but one, built on the stronger pedagogical knowledge base. The evidence from the current study seems to reinforce such a notion at least in terms of the fact that teachers do not seem able to think about their content separate from how it is used within the context of teaching. Such findings are similar to those proposed by Brown, Collins and Druguid (1989) in the discussion of knowledge acquisition within contextual constraints.

The second question relates to the influence of the teaching context and the nature of the researcher/interviewer’s background. It is unclear whether the teachers in this study would have provided similar answers if they were addressed in a biology context as opposed to a biology teaching context. However, since the interviews concerning content were done in the context of the teaching of biology by a researcher with those obvious interests, it is difficult to separate such a potential ‘interviewer effect’ from the results obtained. In addition, it is possible that the more direct translation of some of the teacher’s SMSs may be a function of a tighter coupling of pedagogical knowledge and subject matter knowledge in the form of the SMS, resulting in a synthesis of the two knowledge bases into a single framework as opposed to two distinct frameworks.
Source and Formation of Subject Matter Structures

Sources of Subject Matter Structures

When asked about the original formation of the SMS which was recorded as part of the final interview, most of the teachers in the study acknowledged that they had held a general framework for their conceptions of biology for a relatively long period of time. This framework to which the teachers referred typically took one of two forms: a recognition of the integrated nature of biology, or a logical order for content presentation. Alex, Ben and Don all seemed to feel that their understanding that all biological topics were interwoven occurred prior to or as part of their college experiences. Alex remembered the integrating power which ecology concepts had for him. The learning of this content, primarily on his own, provided him with a source of reflection and an understanding of the connections which were inherent within the content. In addition, the new focus on environmental awareness which occurred near the end of Alex's college experiences helped him recognize the changing nature of science and the impact of society on science. This realization fostered much of Alex's impetus to focus on a process rather than a content orientation since "these kids are going to face problems we don't even know about yet."

Ben and Don both stated that they felt that a synthesis of the primary topics in biology and an understanding of the integrated nature of the biology content occurred sometime early in their careers, but neither teacher was very specific about the source of this understanding. Don vaguely acknowledged that he had been aware of the major topics which composed biology and the interrelationships which existed among them since his high school science experiences. However, Don was unclear how this understanding was formed, seemed unable to articulate the nature of the relationships among the content topics identified, and lacked confidence that his own students had an understanding similar to his own. Ben was able to consistently describe the major topics in biology, but only tangentially mentioned the interconnected nature of the content.

Carl and Ed also recalled their college experiences as key in the formation of their SMSs. Carl remembered having a "logical order" for content presentation already in place while in college. In addition, the ideas which Carl expressed about the content to be included in his SMS came from his college courses, biology textbooks, and the teaching of biology. It is interesting to note that Carl did not feel that he had the time to really think about his content until he was actually teaching a full year of biology and could see the content "all in one place." Ed also talked about the content making "logical sense," but this
sense came from the culmination of all of his content knowledge, not just that gained while in college.

Four of the teachers mentioned that the SMSs described were dynamic and changed as a result of their experiences. Ben described much of his appreciation of biology as resulting from the culmination of his experiences and his level of maturity. For Ben, the formation of his SMS was analogous to the formation of his personality. The idea that the SMS represented a culmination of experience and knowledge was also echoed by Ed who felt that his increasing level of content knowledge was continually influencing the conceptions which he held about biology. Ed's explanation of the dynamic nature of SMS emphasized was that early content learning occurred as the mastery of isolated pieces of knowledge, but with increasing experience and exposure, these pieces could be synthesized into a larger, more comprehensive framework. Carl also felt that his SMS was changing and would continue to change. However, for Carl, the influence on his SMS came as a result of his teaching. Topics in his SMS would be added, deleted or would change in importance based on his teaching experiences and his students' reactions to the content taught. Don was the only teacher who did not discuss influences which continued to effect his conceptions of SMS.

Of the teachers in this study, Alex can be considered to be the most stable in his conception of SMS. Alex felt that the SMS which he had described had been formed primarily in the first 16 of his 26 years of teaching. The SMS, which now guided his teaching practice, was in the process of being fine tuned in terms of implementation rather than in its actual format.

**Opportunities for Subject Matter Structure Formation**

If a comparison were to be made among the teachers in this study in terms of the strength of commitment to their SMSs, Alex might be on one end of a continuum, representing a well formed, thought out and highly valued SMS. Alex would then be followed by Ed. Carl may be considered to be about midpoint on this continuum with Ben and Don about equal in terms of fairly weak commitments to and only vague ideas concerning the meaning and value of the stated SMS. A comparison of the backgrounds of these teachers may be used to make inferences about the strength of the commitments involved. In particular, two general areas seem to differentiate these teachers along this continuum: opportunities for reflection, and opportunities which would reinforce the proposed SMS.
Both Alex and Ed seem to have had many opportunities to reflect on their SMSs and to then have those SMSs reinforced through both positive and negative confrontations. Alex felt that he was initially introduced to many of the ideas included in his SMS while in college. These ideas were reinforced and challenged during his student teaching and early teaching experiences. In particular, Alex was given reason to reflect on his thoughts about teaching when asked to write his own labs, move to new teaching positions, select textbooks, design biology programs, and when observing other teachers teach. The commitments which Alex made were positively reinforced by other teachers in the department with similar philosophical orientations or by watching student reactions to various teaching styles. The importance of the reinforcement of teachers' beliefs, often through conflict of opinions, has been supported by the work of Hollingsworth (1989). In addition to these opportunities, Alex taught at least one biology class for all of his 26 years of teaching as well as having taught biology exclusively at various points in his career. The combination of these events seems to have fostered many opportunities for Alex to reflect on his SMS and to have his beliefs reinforced.

Ed's opportunities for reflection were quite different. Rather than having a strong teaching orientation, Ed's opportunities to think about his content were often stimulated through extended opportunities in biology. In particular, Ed noted the importance and value of the NSF workshops which he attended and acknowledged the value of staying current in his content through science related activities, coursework, and workshops. Ed's content coursework, similar to that of Alex's, was extensive. Both men essentially had the equivalent of a master's degree in biology to support their background in education. In addition, Ed was continually challenged in his own content understandings by the opportunities to teach advanced sections of biology classes. The fact that Ed had an established set of courses which he taught on a regular basis seemed to help Ed prepare for these classes. Such chances to think about his content were complemented by opportunities to discuss and justify what he believed. Ed enjoyed the opportunity to hold professional discussions about his teaching and fostered such opportunities through department and district wide science meetings. In addition, Ed noted the role of Parent's Night in acting as a stimulus for reflection and source of clarification about his own thinking concerning the teaching of biology.

In contrast, Ben, Don, and Carl to a lesser extent, seemed to have had few opportunities in their teaching careers which encouraged them to think about their content or the teaching of their content. In all three cases, these teachers had only the equivalent of a bachelor's degree in their content areas, had a limited number of courses beyond what was needed to gain or maintain their teaching certificates, and were not generally
involved in workshops which increased their knowledge of pedagogy or content. In addition, all three teachers seemed to have had teaching responsibilities in a wide number of courses throughout their teaching careers. Teaching load requirements were most varied for Ben and Don, partially due to the small size of their schools, and least varied for Carl, Ed and Alex. Such heavy teaching responsibilities in addition to limited time and opportunities to think about their content may have contributed to the somewhat weaker philosophical commitments to the SMSs by Carl, Don and Ben. It is interesting to note that the number of years teaching did not seem to directly affect the commitment of the teachers to their SMS as much as the quality of this experience. Thus, teaching experience was not enough to facilitate learning "on the job," calling into question the simple assumption that teachers learn from experience. Similar cautions have been provided by Buchmann (1982). The teachers in this study were only able or willing to concentrate on the SMSs of their content after they had moved past the mastery of basic skills which were needed to survive in the classroom. These conclusions are similar to those formed in studies which have looked at novice teachers (Doyle, 1977) or compared information processing by experts and novices (Berliner, 1987; Carter & Doyle, 1987). Until basic teaching skills and content mastery were established, the formation of a SMS in a form which could be translated to classroom practice seemed to take a position of low priority. A concentration on such issues then seems to be only possible once the complexity of the classroom has been diminished.

Summary

Subject matter structures, or the components from which they are formed, can be attributed to early content experiences, such as college content courses, and are modified as a result of additional experiences involving the learning or teaching of content. Thus, SMSs are dynamic in their format and structure over the course of one's career, but seem relatively stable within the context of a single semester (at least for the teachers in this study) for experienced teachers. In addition, situations which allow teachers the opportunity to reflect on their SMSs or reinforce the beliefs held seem to be essential in the development of a coherent SMS. Such opportunities vary with individuals, but can be characterized by the time to reflect on the meaning of the content as it is used in practice. These opportunities occur throughout one's career, but teaching experience alone cannot account for the presence of such opportunities. Teachers who have heavy course loads, unusual teaching situations, poor pedagogical skills, and limited content experiences
beyond those needed for certification do not seem to have the time or perceive the need to reflect on the SMSs of their content.

Subject Matter Structures and their Relationship to Classroom Practice

Uses and Translation of Subject Matter Structures into Classroom Practice

The degree of relationship of one's SMS to classroom practice seems to vary. Three different levels of relationships were initially inferred: direct translation, limited translation mediated by the complex interactions of other variables, or no relationship. For the teachers in this investigation, Alex can be considered to have a direct relationship between his SMS and classroom practice. The remaining teachers can be considered to have limited translation mediated by complex variables affecting this translation. How teachers used the SMSs they described and the variables which influenced the translation of the SMS into classroom practice will be described in the following paragraphs.

The teachers in this study used the SMSs which they possessed in a variety of ways. For Carl, his SMS embodied a general organizational pattern which reflected his perceived logical sequence for the order of content for classroom presentation. This pattern was used in his selection of biology textbooks, though he recognized that other patterns of presentation were potentially as effective as the one which he selected. Since the text (through Carl's purposeful selection) mirrored his own logical organization of biology, this basic sequencing of content was reflected in Carl's teaching. This order was deemed important enough that Carl would reorganize a text which did not match his preferred pattern. Superimposed over Carl's SMS were his goals for students. These goals, developed from his own experiences with learning and teaching the content of biology, were to permeate his teaching. However, it was noted that the translation of these goals into the lessons which were observed was not obvious.

Ben used his SMS for the selection and organization of material for a new course or in the selection of chapters to be included in a course which had a large text. Again, since the basic selection of content was part of Ben's designated use of his SMS, there seemed to be a translation of a portion of his SMS to classroom practice, especially since the selection of a text was based on the presence of the content which he felt essential. However, different than Carl, Ben felt that there was no sequence implied as part of his structure. Thus, Ben rearranged several of the content units in order to have suitable weather to take his classes outside for the collection of materials. In all other situations,
Ben deferred to the order of the content presented in the text. Since Ben recognized no additional connections or integrations in his SMS, a direct translation of the SMS into practice would suggest the presentation of units with limited interactions. However, analysis of the classroom data showed that a direct translation of SMS was not the case.

It was difficult to determine what role Don’s SMS played in his classroom practice. Though Don admitted to having the SMS which he described for at least 12 years, this SMS seemed to have no real value or purpose other than reminding him of the major content components in biology and the integrated nature of this content. No real sequence of content was suggested as part of his SMS. In practice, Don seemed flexible in content sequence, easily adapting to district guidelines or the order presented in the text. The translation of Don’s stated integrated nature of biology was only noted in Don’s area of content expertise: ecology. However, it should be noted that the very nature of this content area may also foster such an approach.

Ed used his SMS as a framework upon which to attach biology content. Ed’s SMS was composed of three major themes from which all the additional content included in a biology course could be connected. This structure then represented the manner in which Ed was able to make “logical sense” of biology. This logical sense orientation was evidenced not so much in terms of the SMS which he drew, but in the connections of content through his set of larger ideas or themes. Thus, the SMS which Ed designed represented some, but not all, of the content understanding which he had developed as a result of his own content experiences.

Of all of the teachers in this study, Alex was the only teacher who seemed to have a direct translation of his SMS into classroom practice. For Alex, SMS represented the grand total of all of the understandings and philosophical orientations which he held toward the teaching of biology. This SMS, carefully formed and clarified through many years of experience, acted as a guide for Alex’s teaching practice. Thus, Alex’s SMS was actively recognized and directly translated into his teaching of biology. The order in which content topics were taught were of less value than the importance of integrating content presentations with the various teaching themes which he valued. The identification of themes versus content provided Alex with a pedagogically efficient manner of teaching a greater amount of content at a higher level of quality. Simple changes in the order of the items listed in his SMS did not seem to affect the meanings of the items, but could affect Alex’s ability to effectively introduce these topics and themes in an integrated manner into practice. Since Alex’s teaching was carefully planned to articulate the content and themes which he valued, changes in the order of presentation represented a necessary rethinking.
of his content and the appropriate reinforcement of ideas which he had developed in his current order of presentation.

Comments such as those made by Alex highlight the importance of the content sequences with which the teachers had become accustomed. It can be generally stated that the teachers in this study were conservative in terms of content sequence, whether that sequence had been adopted through the well thought out implementation of a program or the sequence with which the teachers had personally learned or taught biology. Few teachers relished the idea of changing the sequence which they had established. Based on these observations, it is possible to assume that "traditional" sequences may act to reduce the cognitive complexity which is found in the act of teaching. Support for such ideas can be found in research conducted by Leinhardt and Greeno (1986) which proposes the idea of classroom routines to reduce teaching complexity, and Putnam (1987) who suggested the presence of curriculum scripts upon which classroom presentations of content are structured.

It is obvious from the comments made thus far that three important ways in which SMSs are translated into practice include the scope of the course, the sequence of presentation, and the selection of textbooks. Since these forms of translation are so basic to the structure of the course itself, they can almost be considered to be subconscious. Such a subconscious translation into classroom practice was specifically noted by Ben, Carl, Don and Ed. Only Alex admitted to consciously making the transfer of SMS to classroom practice. It is interesting to note, then, the varying levels of influence the above three variables had on the teachers in this study. Of the five teachers, only Alex seemed willing to use the textbook as a resource rather than as the source of his content presentations. Ed embellished his content presentations beyond that included in the text, though the text and district guidelines seemed to establish the basic sequence of content presented. The other three teachers seemed to follow the scope and sequence of the text closely. When variations were made, they were typically in terms of minor adjustments in the sequence of topics or in the "watering down" of content below the level presented in the text.

Variables Which Influence the Translation of Subject Matter Structures into Classroom Practice

Six variables seemed to affect the differential translation of SMSs into classroom practice. These were: teacher intentions, content knowledge, pedagogical knowledge, students, teacher autonomy, and time. Each of these factors will be discussed in terms of
their influence on the SMSs held by the teachers and the translation of their SMSs to classroom practice.

**Teacher intentions.** The degree of translation of SMSs into classroom practice in terms of course scope and sequence has already been discussed. Less obvious levels of translation of SMSs into classroom practice exist in terms of recognizing and presenting the integrated nature of biology. All of the teachers in this study, at one time or another, admitted to believing that all biology content was related. However, the teachers varied in their ability or desire to translate this concept into practice. In fact, teachers varied in their beliefs about whether such understandings should be the basis for classroom teaching.

Alex strongly believed that all of the content of biology is integrated. This integration existed among the various content topics as well as through the use of his teaching themes. This perception of his content was directly translated into classroom practice through his "building of background" when moving to new content areas or the consistent integration of his teaching themes.

Carl believed that the SMS which he held should be translated into practice, but was not clear if such a translation was actually taking place. Carl felt that the integrated nature of the content was probably not realized by his students, but that they should leave his classroom with a minimum of a "table of contents" of the main topics of biology. His hope was that his goals of complexity and the identification of organisms into the five kingdoms would provide his students with a framework from which the rest of the biology content could be integrated. It should be noted that Carl's lack of emphasis on the actual teaching of the integrated nature of biology was based on the perception that his students would not be able to synthesize information at that level.

Ben and Don also seemed to think that the ability of their students to generate a SMS and an integrated understanding of biology was beyond their students' cognitive level. Ben felt that such a cognitive level and appreciation for the integrated nature of biology would only come with experience and maturity. Thus, directly teaching such an understanding did not make pedagogical sense. Don did not seem to feel that there was any particular value to his students having such an understanding, though Don felt that he personally held such conceptions as a high school student. For Don, a "basic understanding" of the content was deemed sufficient for his students.

The idea that his conceptions of the SMS of biology could be considered as a topic to teach seemed to surprise Ed, though Ed seemed to generally value the translations of his personal understandings of biology into classroom practice. Although Ed felt that presenting such information may provide his students with a "road map" of the content
which they would cover, such coverage had not occurred in the past. To be taught effectively, Ed felt that a SMS would have to be presented early in the year and referred back to constantly and consistently. Students' mastery of this framework could not be measured simply by their ability to repeat the structure, but in the ability to explain and embellish the framework with examples from the content taught. Ed seemed to think that his students were capable of learning such content, though he recognized that their explanation of the SMS, as well as his own, would change as a result of their new content understandings.

Thus, Alex and Ed felt that the translation of their SMS into classroom practice was important and possible in terms of student understanding. Carl and Ben felt that student understanding of a SMS for biology would be desirable, but a potentially unrealistic goal for their students. For this reason it is difficult to determine the personal importance they placed on making such a translation. Don seemed to value the SMS which he had, but did not seem to place any value on the transfer of this information into the classroom context. Thus, this information can be used to identify one of the variables which seemed to affect the translation of SMS into classroom practice: teacher intentions. Specifically, the level of teachers' commitment to their SMSs and the value of the SMS for student understanding of the content seemed to differentially affect the translation of SMSs into classroom practice. Additional information concerning teacher commitment to their orientations has previously been discussed in the section concerning the sources and formation of SMSs.

Content knowledge. Level of content knowledge seemed to have a significant impact on how content was taught and on the SMSs as derived from observations of classroom practice. Specifically, teachers seemed to make a greater number of integrative connections among content topics which they considered part of their content specialties than they did when teaching content outside of this area. Such a generalization was particularly obvious in the cases of Don and Ed. When Don was teaching content concerning ecology he made more connections, presented more examples from beyond the coverage in the text, related the content more closely with STS issues and his students lives, and spent more time in the active presentation of content in whole class contexts (i.e., providing lectures and answering questions) than when involved in teaching content from other areas. The suggestion that teachers may utilize whole class instruction in content areas in which they feel confident and use small group or individualized instruction where they lack this confidence has been proposed by Carlsen (1989) and is supported by the results of this investigation.
Similar results can be found in the analysis of Ed's classroom data. Ed made more connections when teaching content related to molecular and cellular biology than he made when teaching content concerning ecology or the nature of science. In addition, Ed's strong content background allowed him to extend and expand the content he presented beyond that found in the text, thus fostering more content connections than may have been otherwise formed.

Content knowledge seemed to affect Ben in a different way. Ben seemed to have several areas in which his content understandings were weak. Perhaps because he felt uncomfortable with his personal level of content understanding or perhaps for reasons related to time, Ben taught his content in a superficial manner. This degree of coverage actually seemed to foster content connections by forcing Ben to refer to examples outside the current unit since few concepts had been developed as a function of the current unit.

Carl and Alex's classroom performance did not seem to be as affected by differential levels of content understanding. Carl seemed to have incomplete content knowledge in a couple of areas, but this incomplete knowledge did not seem to affect the manner in which his content presentations were conducted. However, it is interesting to note the effect of Carl's classroom SMS and content knowledge in terms of the role played by the DNA/RNA and Evolution units. Each of these units, for different reasons, were sources of concern for Carl. However, these "troubling" units also acted as primary points of content transition and connection for many of the other units which Carl taught during the first semester.

There were also few variations which could be detected in terms of Alex's content knowledge. It may be that Alex's general level of content knowledge, his focus on themes, and his relatively large backlog of teaching experience in biology may have neutralized any effects which differential levels of content understanding may have produced in the past. However, it should be noted that Alex seemed to avoid the teaching of a unit on DNA/RNA, a content area which he admitted as having less knowledge in than others which he taught. Such an avoidance may have been a manifestation of Alex's level of content understanding. However, since Alex eliminated this content from his course, it is impossible to determine how this lower level of confidence in content knowledge would have been translated into the teaching of this content.

**Pedagogical knowledge.** A third factor which may have influenced the ability of the teachers in this study to translate their stated goals for content and students' outcomes into classroom practice was level of pedagogical knowledge. Alex and Ed seemed to have very few problems implementing the types of programs which they desired and achieving the results they felt were possible. Though other factors such as time for lesson planning
and for presentation of content in the class may have prevented the total implementation of all such ideals on a consistent basis, the majority of the goals which they set out to achieve were accomplished in some form.

This ability to translate stated goals into practice was not evident for the other teachers in this investigation. Carl talked about the importance of teaching for process but did not attempt such tasks with his biology students. This lack of a process orientation can perhaps be explained by Carl's inability to effectively teach to the level of his biology students. In addition, Carl did not seem able to present his classes in such a way as to achieve the basic goals he stated for his students (i.e., complexity and the five kingdoms). Again, it should be noted that these goals may have been more evident if the second semester of biology had been observed.

Both Ben and Don discussed the value of their students learning how to solve problems, but neither teacher provided opportunities for such learning to occur in their classrooms. In addition, both Ben and Don seemed to have problems with the management of classroom activities. For Ben, management problems were evidenced in his inability to effectively organize a laboratory experience. In Don's case, classroom management concerns seemed to reinforce his use of seat work as the primary source of content delivery and reinforcement. More risky modes of learning (in terms of classroom management), such as group discussions, questions from students, and laboratories, seemed to be avoided. Such use of classroom teaching methods as a means of classroom management has been suggested by Doyle and his colleagues (Doyle, 1986; Doyle, Sanford, Schmidt-French, Clements & Emmer, 1985).

It is difficult to determine from the data collected in this investigation why differential levels of pedagogical knowledge seemed to exist. Further exploration of the educational experiences of these teachers, particularly in terms of their teacher education classes and experiences, may shed some light on such matters. It is equally possible that differences in pedagogical knowledge and ability may be a function of individual personalities and perceptions of adequate levels of classroom control. However, it seems appropriate to state that years of classroom experience alone (as supported by Buchmann, 1982) can not provide a sufficient explanation for these differences.

Students. Students, as they rightly should be, seemed to be one of the most significant variables affecting what actually occurred in the classroom. However, the extent of this effect on each teacher's own conceptions of SMS is somewhat surprising.

As has been suggested by a number of studies (Brickhouse, 1989b; Brown, 1989; Housner & Griffey, 1985; Lantz & Kass, 1987; Thompson, 1984, to name a few), students
exert a strong and real influence on the classroom teacher in terms of what is taught and how it is taught. Such influences were evident in the teachers included in this study. For instance, Alex was sensitive to students' levels of frustration and interest. When shifts in students' attention were noted, Alex changed from the more "rigorous" academic content he was teaching to optional units which he hoped would stimulate more student interest and diffuse frustration. Ed also changed his order of content coverage to help students feel more comfortable. Specifically, Ed and his department elected to teach ecology early in the year based on the perception that this content acted as a less threatening introduction to biology (as opposed to content dealing with biochemistry or cell biology).

Both Carl and Ben were influenced by their perceptions of student ability to effectively learn some content topics. Carl's perceptions of students, which seem to have been consistently reinforced over the course of the semester and his years of teaching, molded his content coverage in such a way that he avoided the introduction of mathematics into lectures or laboratory situations, decreased the complexity of his content coverage, avoided situations in which students were expected to think on their own (deductive versus inductive labs), and continued the practice of having students read the text (despite the difficult reading level) because some students had returned to thank him for emphasizing this practice. Influences on Ben were similar in that Ben eliminated content which his students considered "boring" and "watered down." For both Carl and Ben, the responses of their students to the curriculum taught caused them to rethink the goals of the biology class and to struggle with the ultimate goals and the target audience for which biology classes should be structured.

In similar ways, all of the teachers in this study received feedback, either positive or negative, for the methods by which the content was taught. Alex and Ed received positive feedback for their teaching methods. Such feedback for Alex came from his observations of other teachers and the subsequent reactions of students exposed to their teaching methods. For Ed, positive feedback was obtained in the general success his students had with learning the content which he had taught.

Feedback for Carl, Ben and Don was typically more negative. Poor student reactions decreased the tendency to use laboratories, especially in terms of utilizing labs for problem solving or inquiry, or to ask higher level questions within the context of classroom discussions. In addition, Ben's and Don's relatively poor ability to control classroom management had encouraged them to use methods of teaching (lectures and worksheets) which presented fewer management concerns and considerations.

Finally and perhaps most importantly, it is interesting to note the influence students had on the teachers' personal conceptions of SMSs. Four of the teachers in this
investigation noted the difficulty of teaching the topics of DNA/RNA. For Alex, resistance to teaching this topic was caused by a personal lack of knowledge. But, for many of the other teachers, hesitancy to cover this topic was based upon past experiences with attempting such a task and the noted resistance and difficulty which students had with such content. The critical effect of these student responses was in the effect of the teachers' placement of DNA/RNA within their personal SMSs of biology. Such an effect in terms of teachers' SMSs was probably most evident in Carl. Though Carl saw DNA/RNA as vital content in terms of biology, he felt ineffective in his presentation of this content to students. Based on student reactions, Carl was willing to drop this content not only from his course, but to decrease its importance in terms of his personal SMS. Thus, students seem to have a critical role in the shaping of the SMSs that teachers hold for the content they teach.

Findings such as these renew the question as to whether the SMSs offered by these teachers are their SMSs for biology, or their SMSs for biology teaching. Other researchers have suggested (Brown, Collins & Druguid, 1989; Hauslein & Good, 1989) that SMSs may be "situated" in their use, meaning that the way in which SMSs are formed and subsequently used cannot be separated. Such situated understandings seem to be the case for the teachers in this study and may partially explain the differential transition of SMSs into classroom practice. Specifically, teachers who more closely "situated" or aligned their SMS of biology with that of biology teaching may exhibit greater levels of classroom translation. This alignment supports the contention that teachers with limited translation of SMSs into classroom practice may have SMSs which are more weakly held or conceived. In addition, when these teachers report their SMSs for "biology," the result may only be an artifact of the teachers' SMSs for biology teaching.

Teacher autonomy. Several of the teachers in this investigation have been described as having external loci of control, whereas others seem to feel comfortable in taking charge of their classroom situation and the content which they taught. Variations along this continuum and how such characteristics seemed to affect the implementation of SMSs into classroom practice will now be discussed.

Both Alex and Ed seemed to have strong feelings of teacher efficacy and exhibited control over their classroom teaching. For instance, Alex and Ed both took personal responsibility for the learning of their students, modified their content presentation to more closely align it with the perceived needs of their students and their personal perception of SMS, used the text as more of a resource than as the primary source of content, and controlled the academic calendar to meet their teaching needs. In addition, Ed was
explicit in his manner of controlling the classroom climate by establishing strong teaching routines and regulating student socialization patterns by controlling the seating arrangements. Such characteristics can be considered as indicators of rather high levels of teacher autonomy and control.

Ben and Don both seemed to exhibit a general loss of control over the substance and timing of their content coverage in the classroom. Both relied on the text, were heavily influenced by the school calendar by letting it determine the quantity and quality of their content coverage, and took little personal responsibility for the learning of their students. Such characteristics can be considered to be indicators of low levels of teacher autonomy and control. Carl can be characterized as existing somewhere between these two groups.

Based on these characteristics, Alex and Ed, with higher levels of teacher autonomy, seemed to be more successful in the implementation of their SMSs into classroom practice. It is difficult to determine why these differential patterns existed and no attempt will be made to specifically categorize these teachers in terms of the psychological definitions of locus of control (since no such measure was directly used). However, these characteristics do seem to demarcate the two groups. It is possible that Ed and Alex, through the use of more proactive rather than reactive teaching choices, allowed their own thinking and conceptions of biology to be evidenced in the classroom. Teachers using more reactive teaching choices, such as Don and Ben, may have essentially mitigated the influence of their personal thoughts and perceptions in terms of classroom practice.

**Time.** Finally, time seemed to have a tremendous influence on the teachers in this study. Time was mentioned by all of the teachers and affected them in two ways: time to teach and time to reflect and prepare to teach. Each of these time constraints influenced the teaching which occurred in terms of SMS translation and is consistent with the concerns expressed by teachers in other investigations (Brickhouse, 1989b; Lantz & Kass, 1987; Lederman & Gess-Newsome, 1991; Thompson, 1984).

Time to teach, in terms of simply having enough class time to cover the material required in order to assure student mastery, was mentioned by many of the teachers. Specifically, a tension between covering a quantity of material versus the quality of coverage seemed to exist. For Alex, a conflict between covering district and department guidelines while still having the freedom and time to emphasize process skills and objectives became a source of concern. In addition, increased class sizes and the number of classroom preparations increased the cognitive load of the classroom, for both Alex and his students. Ed’s struggle with time typically seemed to occur in terms of presenting content and discussing it in class in the time allotted. However, Ed seemed more willing
than the other teachers in this investigation to extend the original time schedule in order to bring topics to closure and/or assure student understanding before moving on to the next topic. Carl's struggle with time was increased by his "floating" schedule, as well as the large number of days which he was not able to be in the classroom.

Ben and Don also seemed sensitive to the issues of time, but in different ways. Ben seemed to be racing against a school calendar which did not always complement the content he was teaching. Don seemed to use the school calendar as an arbitrary cut off for units. Beyond this, Don's primary objective seemed to be to fill the time that he was allotted.

Though time in the classroom was definitely a variable in the content which could be delivered to students (and thus the match of the classroom scope of content with the teacher's SMS), time may have been more crucial in terms of teacher reflection and planning. All of the teachers in this study complained about not having enough time to effectively reflect upon and plan for their content presentations. Time was especially crucial for teachers such as Ben, Carl and Don who had multiple daily classroom preparations during the current year, as well as across the expanse of their teaching careers. Such time commitments and constraints may have been critical in terms of the relative inability of these teachers to have well formed SMSs and goals in place for their teaching of biology and the expected outcomes for their students. In addition, time may have influenced the relative inability of these teachers to implement such structures and goals into practice.

Such statements can be confirmed by Ed and Alex who talked extensively about the need to carefully think through the biology content before teaching it. Such opportunities for reflection occurred at different times for each of these teachers. For Ed, some of this reflection was stimulated through department meetings where weekly schedules were planned. In other instances, such reflection occurred as a result of the science content workshops which he attended. Alex was much more specific in his need for time. He attributed the integrated nature of his classroom as being a direct result of long and careful planning and articulation of content goals into practice. Though shifts in content order did not seem to affect Alex's overall conceptions of the content, they did require large amounts of time and rethinking in terms of his ability to present a well orchestrated unit. For Alex, changing his content and not allowing him the time to adjust and plan for creative integration of content and process was the same as reducing him to a "first year teacher," making his teaching erratic and choppy.
Testiing Effects in the Assessment of Subject Matter Structures

All the teachers in this investigation seemed to feel that the SMSs which they recorded as part of this study were in existence prior to the study itself. For Ben and Don, evidence for this conclusion may be derived from the comparison of the SMSs which they recorded as part of both the pretest and posttest. In each case the SMSs were relatively consistent and neither teacher recognized any significant differences. In both cases, each teacher acknowledged that they had thought about the structure of their SMS prior to being asked. Alex, Carl and Ed also acknowledged that they had thought about the structure of their SMS prior to being asked. In addition to their affirmation of this fact, evidence can be found in comments made during the initial interviews and within the content of their teaching. Alex offered information concerning his SMS consistently throughout the period of the investigation without the stimulus of a request. Ed discussed the "logical sense" of biology and his "images" of how certain lessons and units should be constructed. Carl consistently reinforced the importance of the goals of recognizing organisms within the five kingdoms and the importance of the complexity of living things. Since the observations listed above were relatively consistent from the beginning of the study through the end, it may be stated that the SMSs for these teachers were relatively stable during the semester of the investigation. Such stability is in contrast to findings concerning the SMSs of preservice biology teachers (Gess-Newsome & Lederman, 1991) which suggested a fluid and malleable nature of the SMSs which exist prior to years of teaching experience.

Evidence of a potential testing effect occurring in the teachers who were asked about their SMSs prior to the classroom observations was sought. As a result of the analysis of the data obtained in this investigation, no evidence of a testing effect could be identified. For instance, both Ben and Don showed strong consistency between the SMSs which they generated prior to and following the classroom observations. As argued above, such consistency seemed to indicate that the structures provided were relatively stable over the semester of classroom observation. In addition, both teachers claimed that stating their SMS prior to the observations did not specifically affect the manner in which their classes were taught (as opposed to how the class would have been taught if they had not stated this SMS). This lack of effect on classroom practice can be supported through an analysis of the classroom SMSs of these teachers compared to the SMSs which they described. No greater congruence of SMSs was seen for the teachers who completed the pretest as opposed to those who only completed the posttest (in fact, just the opposite was the case). In addition, no evidence of initial congruence following the construction of their personal SMSs of the teachers who completed the pretest could be found.
Such results exist in contrast to those proposed by Gess-Newsome and Lederman (1991) when similar studies were conducted with preservice teachers. Two potential explanations for these contradictions may exist. First, the preservice teachers were asked to state their SMSs three times over a ten-week period. Such constant questioning about the SMSs which they held seemed to create a testing effect which fostered the creation and greater articulation of the SMSs described. Since the teachers in the current investigation were only asked to describe their SMSs a maximum of two times over the course of 18 weeks, the completion of this task did not seem to overly influence the thoughts and actions of these teachers (as compared to those of the preservice teachers).

Secondly, whereas all the teachers in this study acknowledged a form of a SMS for biology prior to the investigation and the exploration of this SMS, the same was not true for the preservice teachers studied. Questions concerning SMS were not only thought provoking but a stressful experience for the preservice teachers. Such a reaction may suggest that a question of this nature required the preservice teachers to formulate a response which addressed a structure of which they were not explicitly aware. For the teachers in this investigation, the time and experience teaching biology content may have been responsible for the increased awareness of their SMSs and may have increased their comfort with answering such a question. More specifically, the act of teaching over a number of years may have sensitized the teachers included in this investigation to the SMSs which they held and/or acted as a factor in the formation of the SMSs described. Since the preservice teachers had not yet been placed in a situation where the confrontation of their SMSs was necessary, this structure may not have been recognized and may have been held implicitly rather than explicitly. Once again, such evidence focuses questions on the nature of SMSs: Can SMSs be firmly embedded and defined prior to the application of these SMSs to a specific use, such as biology research, as suggested by Baxter, et al. (1985), or biology teaching, as suggested by Hauslein & Good (1989)?

Limitations of the Study

There are several aspects of this study that limit the generalizability of the findings reported: the representativeness of the teachers, the number of classroom observations conducted, the manner in which SMSs were conceived and derived, and the inability to make developmental claims based on the data collected. Each of these limitations will be elaborated upon briefly.
No special attempts were made to assure that the teachers included in this study were representative of the biology teaching force in general, largely for logistical considerations. Specifically, only a small group of volunteer teachers from a small geographical area were selected for inclusion in this investigation. To further strengthen the generalizability of these findings, a much larger sample of teachers with characteristics more closely aligned with the nation's teaching force would need to be studied. For practical reasons, such a sample may best be used for the further exploration and support of specific hypotheses generated by this study (as opposed to a qualitative study of this nature). In addition, this study purposely narrowed its focus to the study of the nature of the SMSs held by biology teachers. No generalizations can be made concerning the SMSs of teachers in other subject matter areas, or the constraints which may exist for the implementation of such SMSs to classroom practice. It should be noted that the generalizability of these findings may not be a major issue since the context of teaching and the personal histories of these teachers seemed to influence the results obtained to such a great extent. However, little evidence exists to suggest that the lives and experiences of these teachers were so unique as to preclude the use of these findings as the basis and stimulus for future investigations with other teaching populations.

Secondly, the SMSs for the teachers in this study were generated from observations which constituted less than 20% of the total number of teaching days. Though attempts to mitigate such limited observations were sought through the analysis of lesson plans and classroom materials, it cannot be denied that the final SMSs constructed in this research were a direct function of the classes actually observed. Had a different sample of lessons been observed, the results may have varied to an unknown degree.

Comments concerning observation schedules surfaces another speculation: How different would the results of this investigation have been if the second semester of teaching would have been observed (either in addition to or in place of the first semester), or if the unit of content analysis would have been a teaching unit as opposed to a semester. One of the initial assumptions of this investigation was that teachers would conceive of biology as a year-long endeavor, a complete package which would be molded to the time constraints which existed. However, many of the teachers in this investigation admitted to having stronger "images" of the structure of units rather than the course as a whole. Such comments, as well as the findings of Marks (1989), may warrant additional thought and research on the appropriate unit of analysis for the study of teachers' conceptions of content.

Thirdly, the method designed for the construction of SMSs from classroom observations and materials, by it nature, sought incidences which suggested the
connection of content topics to one another. Such an assumption may have created SMSs which were more integrated than may actually be the case since all instances of connections were considered to be equal in magnitude of importance. Thus, the inferred SMSs may represent levels of complexity and integration greater than may have actually existed. In addition, it was assumed that relationships and strong integration would naturally exist among content units. Though this generally seemed to be the case in this investigation (though such connections were not specifically explored), such an assumption may warrant further research and exploration.

In addition, it must be recognized that two-dimensional diagrams may be inadequate for representing the complex interactions and the interwoven nature of one's SMS. Though the methodology used in this investigation seemed to be superior to those used in other studies, such limitations must be recognized. In addition, though several teachers (Ben, for instance) stated that they felt biology content was interwoven, it is difficult to determine if such statements were representations of actual belief. It is possible that such statements were merely the parroting of an answer which was considered to be "correct" or "appropriate," but stated without a true philosophical or academic commitment. However, in this study, statements of this nature were taken to be statements of belief, though it is recognized that this might not always have been the case.

Finally, though the teachers in this investigation represent a variety of years of teaching experience and experiences, no claims for a developmental process for an individual teacher can be made. However, the results of this study may serve to sensitize researchers to some of the areas of focus which may be pursued in longitudinal investigations exploring teacher development with teaching experience. In particular, the complexity of the individual teaching situation (in terms of classroom preparations, numbers of students, etc.) may be weighed against teachers' opportunities for reflection and reinforcement of teaching ideas and philosophical stances.

**Implications and Recommendations for Science Teacher Education**

Several of the recommendations for future research have been previously discussed in the Limitations section of this report. However, the results of this investigation suggest additional avenues of research as well as implications for both preservice and inservice science teacher education.

Immediate implications for research and practice in teacher education include methodological considerations when assessing the nature of teachers' SMSs and the nature of teachers' SMSs with respect to its effects upon classroom practice. These
findings have significant implications for the feasibility of current calls for reform in science education. Additionally, implications exist for the operational definition of "expert teacher" with respect to the role that teaching experience plays in such expertise.

Research which has been conducted in the past has assumed that the SMSs which teachers possess are coherent during all phases of their teaching careers and directly translate into classroom practice. The results of this investigation question these assumptions on two levels. First, it does not seem that past methodologies, particularly those of card sort techniques, are sensitive to teachers' personal understandings of content. The more open-ended methodology used in this investigation produced significantly different results from those produced in other investigations. Secondly, past research has elected to determine the degree of translation of SMSs to classroom practice through the use of laboratory exercises which simulate classroom experiences. Such practices greatly reduce the complexity of the situation to which teachers need to respond. This fact may have contributed to the assumption that SMSs have direct translation to classroom practice. The results of this investigation demonstrate that the translation of teachers' thoughts into action are much more complex than may have been previously realized. Though there are elements of teachers' SMSs which do directly affect classroom practice, many of these elements are mitigated by factors which only exist in actual classroom contexts. Similar findings have been noted in investigations which have explored the transfer of knowledge of the nature of science into classroom practice (Duschl & Wright, 1989; Lederman & Zeidler, 1987). Thus, in order to adequately measure the translation of SMSs into practice, such assessments must be conducted within the context of actual classrooms.

The SMSs which the teachers in this investigation reported can be considered to be content-oriented and were claimed to be initially formed as a result of college level content courses and then reinforced by the act of teaching. Such statements have two implications. First, teachers seem to be heavily influenced by the types of courses which they take in college, at least in terms of the scope of topics which should be taught in the high school context. Such observations place renewed emphasis on the organization and breadth of coverage found in college level content programs. Programs which are skewed toward a narrow focus of content may inhibit teachers from offering well rounded programs to their students. Second, the order and scope of the SMSs described seem to have a fairly direct relationship to classroom practice. In fact, once the teachers in this investigation determined a teaching sequence, they seemed hesitant, and in some cases resistant, to changes in that order. It is possible that an established teaching sequence acts as a means of decreasing the complexity of both the interactive and preactive aspects
of teaching. Though this assertion should be further explored, such a finding does have implications for the manner in which teachers are prepared to think about their content. It seems that careful thought and purpose, in terms of the initial structure of a class, needs to be introduced very early in teacher education programs. Such an introduction may help to assure that the course structures which are established are built on careful thought and consideration of alternative sequences rather than on the mimicry of programs similar to those which students have been exposed in the past.

Both of the above implications have direct bearing on the feasibility of currently suggested science education reforms and their potential to impact the type of science teaching which currently exists. Many of the current reform movements in education, both science specific (e.g., American Association for the Advancement of Science’s Project 2061, 1990; National Research Council’s Fulfilling the Promise, 1990; etc.) and generic (Carnegie Foundation, 1986; Holmes Group, 1986) suggest that many of the problems plaguing education today can be simply solved through the increased level of content mastery in the teaching workforce. Specifically, many of the reforms for science education suggest that science should be taught as an integrated whole with an emphasis on a few concepts which can act as frameworks upon which all of the science curriculum can be connected. Thus, suggested recommendations for improving educational practice usually come in the form of increased college requirements in the academic areas. Though the results of this investigation suggest that teachers tend to do a more integrated job of teaching the content they know well, caution must be exercised in making such blanket recommendations and assuming that increased content coverage alone will facilitate the teaching of science to a more integrated degree. All teachers in this study had content degrees in biology. Despite this background, inequities in their content expertise still existed. In addition, the possession of a certifiable level of content knowledge alone was not enough to increase the integrated nature of the conceptions of content. It may be that for college content courses to impact a teacher’s global conceptions of SMS, especially in terms of integration, they must be taught in an integrated manner, not in the current style of offering courses as isolated pieces of content knowledge, fragmented from a conceptual whole (Cheney, 1990; Kennedy, 1990). In addition, it is critical that teachers be given the time and opportunity for reflection once content knowledge is gained if it is to be integrated into their SMSs and effectively incorporated into their classroom teaching.

It is interesting to note that, although the teachers in this investigation had varying levels of classroom teaching experience, a simple correlation of years of experience to the degree of SMS articulation or the transfer of SMS and other teacher stated goals into classroom practice could not be used reliably. As suggested by Buchmann (1982),
teaching experience alone does not equate with teaching expertise, though the two are often mistakenly confused. However, opportunities for a teacher to reflect on classroom practice and implement identified changes does seem to be of great influence on teaching "expertise." In addition, feedback concerning teachers' beliefs, both positive and negative, seemed to have a significant influence on the commitment which teachers had for such beliefs. In line with such observations, the most vital factor which seems to mitigate reflection and reinforcement seems to be too many classroom preparations, especially early in one's teaching career. If it is in fact believed that teaching is a purposeful act, it seems critical that teachers be allowed the opportunity to develop an explicit SMS which can act as a guide to their practice. For this to occur, several things need to be concurrently in place: content knowledge, a forum for the application of this content knowledge to a specific act (such as teaching), the time to reflect and formulate a personal SMS, and the time to devise and experiment with methods which will translate this SMS into practice. Such practice most appropriately occurs at two places in one's career: preservice teacher education and inservice teacher education.

Preservice education, particularly in the form of subject specific methods classes, is the first opportunity which teachers have to reflect upon the actual use of their content knowledge within a specific context. Since the application of knowledge seems to be an essential step in the formation of a SMS which can be explicitly used in practice, the importance of such opportunities through such a course cannot be overly emphasized. Specific opportunities for SMS formation should be provided, as well as the introduction of themes which may most appropriately guide instruction (i.e., process skills, nature of science, science-technology-society interactions). As suggested by Gess-Newsome and Lederman (1991), SMSs utilizing such themes seem to be fostered through consistent reinforcement in science specific methods courses. In addition, preservice teachers must be provided with specific opportunities to translate the SMSs they devise into classroom practice. Though many students at this stage in their careers find such a translation difficult to achieve due to their concerns for classroom management, sensitization to the formats through which such translations can take place should occur at this stage, as well as feedback concerning the effectiveness of such attempts.

Provision of similar opportunities would also need to occur early in one's teaching career. As noted above, management concerns often overwhelm the novice teacher, suggesting that refinement of the teaching process in a manner which may effectively translate one's conceptions of SMS and classroom goals may not be able to occur until management and classroom routines are mastered. In order to facilitate the transition from "survival teaching" to "reflective teaching," it may be necessary to provide novice teachers
with a limited number of classroom preparations and with relatively greater amounts of time in which to design and evaluate their curricular programs in comparison with more experienced teachers. In addition, novice teachers should be given repeated opportunities to reflect on the effectiveness of their practice as fostered through formal feedback and questioning about the goals of their teaching and the best means to achieve those goals. The provision of time and feedback may be adequate in reducing the time that it takes for novice teachers to achieve a more expert status in terms of implementing beliefs, ideas and goals into classroom practice through pedagogically effective techniques.

In addition to the implications just mentioned, the results of this investigation highlight several additional areas which may facilitate the disentanglement of many of the issues which surround the complexity of the teaching situation and the translation of teacher knowledge into classroom practice. Of primary importance may be the issue of knowledge structure formation as it is related to use. As previously mentioned and elaborated upon in several of the previous sections of this report, the teachers who exhibited the greatest degree of SMS translation into classroom practice were also those teachers who seemed to be reporting their knowledge structures of biology teaching rather than biology. Are there two knowledge structures used in teaching (content and pedagogy) or only one which is a result of the application of knowledge in the domains of content and pedagogy to a single act, subject matter teaching? If this is the case, it is possible that knowledge structures for the teaching of biology can only be formed through the process of teaching or thinking about teaching biology. Consequently, a renewed emphasis may need to be placed on content specific methods courses as well as the support and reinforcement of these knowledge structures as they form over the first several years of a novice teacher's career. Additional research needs to be conducted that would determine the best experiences which should be incorporated into preservice and inservice education programs to promote such a welding of knowledge bases, as well as for the determination of the most developmentally appropriate placement for such subject matter reflection.

In addition, since SMSs do seem to potentially guide teaching practice, methods for the facilitation and formation of effective knowledge structures need to be explored through experimental means. Of particular importance may be the exploration of the specific types of information and experiences which are necessary for the formation and reinforcement of SMSs. For instance, many of the teachers in this study suggested that SMSs could be formed only as a result of the learning of numerous content pieces and then the reflection on this knowledge. What implications do such statements have for learning theory? Are SMSs a result of inductive learning and synthesis, or is the act of SMS formation more recursive in nature? With such data in hand, it would be important to determine the
relative effectiveness of the various SMSs which teachers develop, as well as the role which SMS coherence plays. The relationship of SMSs to a teacher's ability to teach as well as its ability to facilitate the learning of new content would be equally important. Such information may lead to a greater understanding of what it means to be an "expert" teacher and provide avenues which will enhance the progress of teachers from novice to expert status. Ultimately, and perhaps of greatest importance, this line of research would need to include the influence of teachers' SMSs on student learning.

In tandem with the line of research suggested above, the issue of the appropriate unit of analysis for looking at teachers' conceptions of subject matter knowledge (unit, semester, year or disciplinary field) will need to be addressed. Such information would not only facilitate research efforts in this area, but would also help guide efforts in developing teachers' conceptions of content at both the preservice and inservice level. In addition, such results would be vital in the formation and implementation of curricular reforms. For example, if teachers cannot effectively conceive of content coverage over the course of a year, it is possible that curricular reforms and inservice programs may be more effective focusing on units and would only later attempt an integration of units into a conceptual whole.

And finally, many of the results of this study suggest that teachers' abilities to effectively achieve the results that they desire within a classroom context may be closely tied to teacher characteristics such as teacher autonomy, risk taking and reflectivity. The further elucidation of such factors and ways in which such influences can be mitigated may help produce a more effective teaching workforce as well as promote the professional development of individual teachers.
REFERENCES


APPENDICES
APPENDIX A

Letter of Introduction

May 23, 1990

Dear Colleague:

I am currently a Ph.D. student in the Department of Science and Math Education at Oregon State University and am making arrangements to conduct my dissertation research in the central Oregon area. In general, I am interested in studying how biology teachers choose to teach their subjects. Although it is well recognized by classroom teachers that there are a variety of effective ways to teach any subject matter, educational researchers continue their attempts to identify the one best approach to instruction. As a former biology teacher, I clearly understand that different approaches were effective on different days, with different students, and with different topics. It appears that educational researchers have failed to consider or recognize the importance of teachers' objectives and intentions when evaluating or describing "effective" instruction. In particular, science educators have failed to ask teachers what their intentions and purposes were for lessons which have been observed during research investigations. The purpose of my study is to identify the various ways in which high school biology is effectively taught. Most importantly, an attempt will be made to correlate teachers' classroom methods and strategies with their objectives and intentions.

Biology is a particularly intriguing content area to study because there are so many acceptable alternatives in the sequencing and presentation of topics. I am hoping to find six teachers with a range of experience in the teaching of high school biology who will allow me to collect data in the form of interviews and classroom observations during the fall semester of the 1990-91 school year. In order to accomplish my goals, several types of data will need to be collected for each teacher involved in the study. The following is a sequential listing of these types of data:

1. Two one-hour interviews prior to the school year

2. Classroom observations (one per week in a biology class chosen by the teacher)

3. Audio-tapes of classes which are observed

4. Classroom materials (e.g., handouts, exams, lesson plans) which have been used during the fall semester

5. Two one-hour interviews following the fall semester
This research represents an initial attempt to identify the "rich" and varied ways in which biology teachers attempt to accomplish their instructional goals with their own students in their own localities. It is hoped that this information may foster a greater understanding of the diverse and dynamic needs of teachers and students in specific teaching contexts and will eliminate the perennial attempt to identify a single instructional approach which is prescribed for all biology teachers regardless of goals, localities, or instructional settings. The results may be used to promote a model of science teacher education which is based upon the belief that the teacher is a professional decision maker and best able to determine the instructional approaches which best meet their needs and teaching situation. Consequently, teacher preparation would focus upon the delineation of appropriate instructional goals and the development of a repertoire of techniques to accomplish these goals.

I am pleased to announce that my research is being supported by a Spencer Dissertation-Year Fellowship in Research Related to Education. Since only 30 of these fellowships are awarded each year across the country, I can assure you that there is national interest in the outcomes of this project.

I am very excited about the possibility of working with you or other members of your staff this fall. I would appreciate an opportunity to talk to interested teachers, individually or as a group, before the school year draws to a close. I am still teaching courses at OSU, but I can make arrangements to be in the Bend area several days during the weeks of May 28 or June 4. I will try to contact you on Tuesday, May 29 to schedule a possible meeting time.

If you have any questions feel free to contact me at my department office (737-4031) or at my home (753-1475). You may also contact my dissertation advisor, Norm Lederman, or our department chair, Maggie Niess, for information or references. Thank you again for your time and consideration of this project.

Sincerely,

Julie Gess Newsome
APPENDIX B
Letter of Confirmation of Participation

June 3, 1990

Dear Colleague:

Thank you for agreeing to participate in my study concerning how teachers choose to teach biology to be conducted next fall. To help me make final arrangements, I would appreciate getting some information from you. Please fill out the form below and return it in the enclosed envelope before June 15th. This will allow me to contact you at the end of the summer to set up an interview appointment. If you have any questions between now and then, please feel free to contact me at my office (737-1823 or 737-4031 until July 1) or at home (753-1475 till June 20, 389-2267 after). Best wishes for a relaxing summer vacation!

Sincerely,

Julie Gess Newsome

Name: ________________________________
School: ________________________________
[ ] I am not interested in participating.
[ ] I am interested in participating in this study. I may be contacted at the following address and phone number in August:

________________________________________
________________________________________
Phone: ________________________________

Years teaching: ________________________________
Years teaching Biology: ________________________________
Years in present school: ________________________________
Anticipated number of sections of Biology next year: ________________________________
Name and address of any administrator who should be contacted in order to obtain permission for you to participate this study:

________________________________________
________________________________________

Name: ________________________________
Phone: ________________________________
APPENDIX C

List of Content and Education Coursework

Name

Please list the content and education courses you have taken as part of your preservice or inservice preparation below.
APPENDIX D

Subject Matter Structure Questionnaire

Name ________________________________

What topics make up biology? If you were to make a diagram of these topics, what would it look like?

Have you ever thought about biology in this manner before? Please explain.
APPENDIX E

Subject Matter Structure of the Textbook

The following list identifies and describes the chapters taught by the teachers in this study during the first semester. This coverage includes Chapters 1-8 and Chapters 36-39. The listing below identifies the chapter number (sequence within the text), title, and the primary contents.

Chapters which were not specifically taught during the first semester are also included in this listing. These chapters have been listed according to the units which the authors of the text identified. Specific contents of these units are not listed, but chapter titles under each unit are provided for reference.

Chapter Numbers, Titles and Topics

Unit I - Introducing Biology

1. Studying Life: nature of science, scientific methods and terminology, metrics, tools of science (e.g., microscopes, computers), laboratory safety.

2. Understanding Life: spontaneous generation, characteristics of living things.

3. Basic Chemistry: the nature of matter (i.e., atoms, compounds), interactions of matter (i.e., chemical formulas and reactions, acids and bases), organic compounds, conservation of mass and energy.

4. Cell Biology: cell theory, prokaryotes vs. eukaryotes, cell structure and function (organelles), cellular transport.


Unit II - Continuity of Life

7. Basic Genetics: Mendel, dominance, segregation, probability, monohybrid crosses, dihybrid crosses, multiple alleles, polygenic inheritance, incomplete dominance, chromosomes and genes, sex-linked genes, linkage and crossing over.

8. Applied Genetics: mutations, alterations in chromosomes (i.e., nondisjunction, translocation), genetic disorders in humans, selective breeding, genetic engineering, environmental affects on gene expression.

Unit III - Microbiology


Unit IV - The Plants


Unit V & VI - Animals (Invertebrates and Vertebrates)


Unit VII - Human Biology


Unit VIII - Ecology

36. The Environment: biotic vs. abiotic, ecosystems, populations and communities, climate, soil, cycles, food webs and chains, ecological pyramids, symbiotic relationships.

37. Ecological Changes: structure of populations, population dynamics, behavior of populations (e.g., behavioral, rhythmic), succession.


39. Your Environment: natural resources, pollution, energy resources.

Connections Identified Through the Analysis of the Text

The following is a list of the connections identified through the analysis of the chapters which were actually taught by the teachers in this study. The definition for the identification of a connection is discussed in Chapter IV, Textbook Subject Matter Structure. The number listed before each connection corresponds to the number and line as shown in Figure 15. The chapter source and ultimate direction of the connection are stated following the number. A short paraphrasing of the content of the connection has been provided to aid the reader in the interpretation of the connection.

1. Studying Life (SL) -> Animals. Examples of invertebrate and vertebrate behaviors are used to identify and explain the concepts involved in experimentation.
Figure 15. Derivation of the Textbook's Subject Matter Structure.
2. Science-Technology-Society Interactions (STS) in SL. Observations of sharks skin as it reacts with water aided in the design of surfaces to increase the speed of sailboats.

3. History of Science (HofS) in SL. The development of the microscope.

4. Understanding Life (UL) -> SL. The use of the scientific methods of investigation helped disprove the idea of abiogenesis.

5. HofS in UL. The history of the experiments which helped disprove abiogenesis.

6. UL -> Protists, Plants and Animals. Organisms from all kingdoms are used as specific examples to enhance the understanding of the characterization of living things.

7. STS in UL. The establishment of the cell theory was aided by technological improvements, specifically, the microscope.

8. HofS in Basic Chemistry (Chem). The development of the atomic model.

9. STS in Chem. Isotopes have medical uses.

10. Chem -> Human Biology (Human Bio). Most chemical activities in the body take place in water, or are regulated by the chemical properties of water (i.e., thermoregulation, solvents for materials, transport in the body and in cells).

11. Chem -> Cell Chemistry (Cell Energy). Photosynthesis requires water in order to combine with carbon dioxide to produce sugar.

12. Chem -> Basic Ecology. Carbon, which is found in all organic matter, follows a cyclic path of use and reuse.

13. Chem -> Cell Biology (Cell Bio). Cellulose is a complex carbohydrates which is present in the cell wall.

14. Chem -> Plants. Cellulose in the cell wall provides structural support for plants.

15. Chem -> Cell Energy. Energy transformation are essential for the functioning of living things. The source of this energy is from the breakdown of glucose, ultimately formed through photosynthesis.

16. Chem -> SL. A question at the end of the chapter asks students to describe revisions which have occurred on the current model of the atom. This is related to the tentative nature of theories in science.

17. HofS in Cell Bio. History of the microscope as it related to the cell theory and knowledge about the cell.

18. Cell Bio -> Human Bio. Cells with large numbers of mitochondria are found in cells which use large quantities of energy, such as muscle cells.

19. Cell Bio -> Evolution. A inferential connection is made between cells and evolution in a series of charts which compare structures of eukaryotes to prokaryotes, and plant cells to animal cells.
20. **Cell Bio -> Plants.** Cell membranes influence the transport of materials in and out of the cell. Turgor pressure helps plant structures maintain their shape. Movement of ions from the soil to plant roots are aided by carrier molecules.

21. **STS in Cell Bio.** Cell fractionation is a technological tool developed in order to more clearly understand cell structures.

22. **Cell Energy -> Chem.** Organic molecules which make up the cell are synthesized from simpler materials through chemical processes.

23. **Cell Energy -> Plants and Animals.** ATP is the generic energy "package" which powers both plants and animals. Examples: nerves, muscles, nutrient movement in plants.

24. **Cell Energy -> Basic Ecology.** Cycles of carbon are important in food production by photosynthesis and breakdown by cellular respiration.

25. **Cell Energy -> Chem.** Energy transfer occurs in photosynthesis where light energy is converted to chemical energy.

26. **STS in Cell Energy.** Alternative energy sources may be provided through photosynthesis: chlorophyll to capture solar energy, ethanol production by plants.

27. **Cell Reproduction (Repro) -> Cell Bio.** To maintain genetic continuity and to follow the cell theory, all cells must be produced from other cells.

28. **Cell Repro -> Cell Bio.** During interphase, cells carry out all of the functions normally attributed to cells: transport of materials, use energy, etc.

29. **Cell Repro -> Genetics.** The great variation in sexual reproducers can be attributed to the independent assortment of alleles and the crossing over of chromosomes.

30. **Cell Repro -> Microbiology.** Experiments which support that DNA is involved in the transmission of pneumonia involved bacteria as identified by their outer coat characteristics.

31. **Cell Repro -> Cell Energy.** RNA can act as an enzyme even when no proteins are present.

32. **Cell Repro -> Cell Bio.** Cell structures are made of proteins. Proteins are ultimately coded for by the DNA.

33. **Cell Repro -> Cell Energy.** Enzymes are made of proteins and control cell functions. Proteins are ultimately coded for by the DNA.

34. **STS in Cell Repro.** The pictures of cell produced by transmission electron microscopes have increased our knowledge about cell structures.

35. **HofS in Genetics.** A discussion of Mendel's early work with pea plants and the influence of this work on the field of genetics.

36. **Genetics -> Plants.** The structure of the pea plant flower prevents cross pollination unless initiated by outside sources, such as humans.
37. Genetics -> Evolution. Genetic mutations are a source of adaptations which may be maintained or eliminated through natural selection. (Implied connection)


40. Basic Ecology -> Chem. Plants must obtain nitrogen from the soil in order to synthesize proteins and chlorophyll.

41. Populations and Succession (P&S) -> Evolution. Social and rhythmic behaviors found in populations have adaptive value in terms of protection and food collection. (Implied connection)

42. P&S -> Basic Ecology. Populations within different ecosystems form different communities with unique food webs.

43. Biomes -> P&S. Biomes include all stages of succession.

44. Biomes -> Evolution. Convergent evolution explains why organisms from different biomes may resemble each other.

45. Biomes -> P&S. Migratory patterns, which vary with climatic conditions, are rhythmic behaviors used to increase reproductive success of some populations.

46. Biomes -> Evolution. Evergreen trees have needle adaptations which slow down water loss and freezing.

47. Biomes -> Basic Ecology. Unique food webs exist in all biomes.

48. Biomes -> Plants. The root structures in prairie grasses are important in plant food storage and soil formation.

49. Biomes -> Basic Ecology. Mulch, as found in grasslands, contributes to the abiotic conditions of water retention, soil temperature, soil stabilization, and is advantageous for seed germination.

50. Biomes -> Evolution. Extinction of species is often caused by man's misuse of certain biomes.

51. STS in Biomes. The straightening of the Kissimee River has had affects on climate, plant and animal species, tourism and farming.

52. Biomes -> Evolution. Animals are adapted both structurally and behaviorally within specific biomes.

53. Natural Resources (NR) -> Basic Ecology. Water and nitrogen cycles are each dependent on the quality of the soil.

54. NR -> Plants. Plant roots are important in water retention in the soil and to prevent erosion.
55. NR -> Biomes. The life zones in the ocean provide us with differential quantities and quality of food production.

56. STS in NR. Food production often involves issues of biome use and accessibility, pollution, and over-harvesting by man.

57. NR -> Evolution. Loss of genetic information and diversity through the extinction of plants and animals is a concern.

58. STS in NR. Pollution, specifically from the burning of fossil fuels, creates additional environmental issues, such as acid rain and global warming.

59. NR -> Chem. The production of nuclear power is based on the understanding of the model of the atom.

60. NR -> Basic Ecology. Biomagnification of pollutants is created by passing pollutants up the food chain.
APPENDIX F

District Scope and Sequence

The following comments are excepts from a document produced by science teachers from one of the school district which was involved in this study. Specifically, Alex, Don and Ed were members of this committee.

Purpose:
This committee of biology teachers from the School District was brought together for the purposes of: ...determining the scope of the Biology course with agreement on approximate time spent on agreed areas....

Decisions Reached:

The SCOPE of Biology will include the following topics with the proposed percentages of time to be spent on each area:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods and processes of science</td>
<td>5%</td>
</tr>
<tr>
<td>Ecology</td>
<td>10%</td>
</tr>
<tr>
<td>Cell Structure and Function</td>
<td>15%</td>
</tr>
<tr>
<td>Energy Relationships</td>
<td>5%</td>
</tr>
<tr>
<td>DNA (Protein Synthesis)</td>
<td>5%</td>
</tr>
<tr>
<td>DNA and Genetics</td>
<td>15%</td>
</tr>
<tr>
<td>Evolution</td>
<td>10%</td>
</tr>
<tr>
<td>Classification; Kingdom Survey</td>
<td>10%</td>
</tr>
<tr>
<td>Plants</td>
<td>12%</td>
</tr>
<tr>
<td>Animals</td>
<td>13%</td>
</tr>
</tbody>
</table>

Units and subtopics are listed below along with the approximate number of class days for each unit.

Methods and Process 8 days
Lab safety, scientific processes, experimental design and error, metric measurement, microscope, data collection and analysis.

Ecology 17 days
Communities, cycles and flows, biomes, interactions, human effects, pond communities.

Cell Structure and Function 25 days
Cell theory, plant and animal differences, organelles - structure and function, organic molecules, translocation.

Energy 8 days
Enzymes, ATP, respiration, photosynthesis.

DNA (Protein Synthesis) 8 days
DNA, replications, RNA, transcription, translation, codes, transformation.
DNA (Genetics)  25 days
   Mitosis, meiosis, crosses, Mendel, crossing over, linkage, continuous variation, incomplete dominance.

Evolution  17 days
   Variation, mutation, natural selection, Darwin, gene pool, geographic isolation, adaptations, speciation, convergence, divergence.

Classification  17 days
   Historical, need for classification, binomial nomenclature, basis for classification, five kingdoms, uses of keys, kingdom survey (include three small kingdoms).

Plants  20 days

Animals  22 days
   Diversity, invertebrates, vertebrates, dissection, systems (circulatory, digestive).

The district biology teachers agree that the sequence of main topics, as is listed above, is an approximate sequence but that no teacher should feel locked in to this exact sequence.
APPENDIX G

Derivation of Alex's Subject Matter Structure

The following list identifies and describes the units of instruction taught by Alex during the semester of observation in this study. This includes Chapters 1-6 in the text. The listing below identifies the units in order of sequence presented in the classroom, and provides a title and the primary contents of the chapter.

Units of instruction not specifically taught during the first semester may appear on the subject matter structure, but are not elaborated on below, since it would only be speculation as to the final sequence and content of these units.

1. Introduction to Biology: What is life?, characteristics of living things, scientific process skills, nature of science, hypothesis formations, metrics, graph interpretation, science careers and hobbies, experimental error, microscopes.

2. Cell Biology: cell theory, cell structure and function (organelles), characteristics of living things.

3. Basic Chemistry: chemical terminology, interactions of matter (i.e., chemical formulas and reactions, dehydration synthesis and hydrolysis), organic compounds.

4. Nuclear Power: a discussion on the pro's and con's of nuclear energy stimulated by a ballot measure which would shutdown a local nuclear power plant until greater safety measures were met.

5. Translocation: diffusion, osmosis, passive and active transport.


8. Science Careers: discussion of careers in science, levels of education needed.


The following is a list of the connections identified though the analysis of the transcripts from the observed lessons and the materials which were used in the context of the class. The definition for the identification of a connection is discussed in Chapter IV, Textbook Subject Matter Structure. Connections are listed in sequential order. Each connection is stated as the chapter of origin, the referent, and a paraphrasing of the content of the connection. The number listed before each connection corresponds to the number and line shown in Figure 16. The sources of connections (transcript or materials) are distinguished by labeling in the list below and are differentially identified in the diagram by...
the use of circles (for connections identified through analysis of the transcripts) and squares (for connections identified through the analysis classroom materials) drawn around the numbers in the diagram.

Connections Identified Through the Analysis of Classroom Transcripts

1. Science Methods and/or Process Skills (SM/PS) in Introduction to Biology (Intro). Determining whether seeds are living or not requires evidence as opposed to just speculation.

2. SM/PS in Intro. Controlling variables and having controls are necessary when gathering experimental evidence.

3. SM/PS in Intro. Caution must be used in separating observations from inferences when characterizing objects, especially living things.

4. SM/PS in Intro. Critical thinking depends on clear distinctions between observations and inferences and then using this distinction appropriately when making decisions.

5. SM/PS in Intro. Observational skill and recall is a function of interest.

6. Careers in Intro. Observational skills are important in many science careers, such as in microscope or computer work.

7. Intro -> Ecology. The terms autotrophic and heterotrophic can be used to characterize living things.

8. Intro -> Classification. Can all living organisms be separated into plants and animals based on their surface characteristics?

9. SM/PS in Intro. Observations that are made, including quantitative measurements, can be biased for a number of reasons.

10. SM/PS in Intro. Evaluating the accuracy of data is a complex process which includes an evaluation of the methods used, incoming assumptions, characteristics of the data collector, hidden variables, experimental error, intellectual dishonesty, etc. All such potential threats to accuracy must be judged before relying too heavily on the data collected.

11. SM/PS in Intro. Experimental error can be eliminated through repeated trials.

12. Intro -> Cell Biology. Determining the field of view under a microscope is important when describing cell characteristics.

13. Intro -> Protists. Pond organisms have features which can be identified (such as spores) and can aid in their identification.

14. Intro -> Animals. Some microscopic pond organisms are multicellular animals.
Figure 16. Derivation of Alex's Subject Matter Structure.
15. Nature of Science (NofS) in Cell Biology (Bio). A model concretely represents something abstract. A drawing of a cell showing the organelles is a model. Changes, such as scaling, have been changed for convenience of use.


17. NofS in Cell Bio. Scientific models and theories are tentative and subject to change based on new information and different interpretations of the facts.


19. Cell Bio -> Cell Division. Chromosomes carry hereditary information, thus, their accurate separation during cell division is important.

20. Cell Biology -> Genetics. Genetic traits are passed on to offspring through the chromosomes.

21. Cell Bio -> DNA/RNA. Genetic traits are passed on according to the code contained in the DNA structure.

22. Cell Bio -> Intro. Since all cells are living, they have all the characteristics which we associate with all living things.

23. SM/PS in Cell Bio. Determining whether something is living or dead, for instance, an apple, can be difficult. What evidence is needed in order to make this decision?

24. Cell Bio -> Intro. Bromothymyl blue can be used to determine carbon dioxide generation by seeds. This may be evidence in determining whether or not a seed is alive.

25. Cell Bio -> Cell Energy. Cells need energy to function. This is obtained through cell respiration.


27. STS in Cell Bio. Whether or not something is living or dead is an important issue surrounding abortion and euthanasia.

28. NofS in Cell Bio. In science, answers such as whether something is living or not is not always clear cut.

29. Cell Bio -> Protists. Paramecium are single-celled freshwater protists which have food vacuoles with enzymes which can break down food.


31. Cell Bio -> DNA/RNA. Golgi bodies modify proteins which are produced on the ribosomes through protein synthesis.

32. Cell Bio -> Intro. Desks must be an estimated two decimeters apart before a test.

33. Study Skills in Cell Bio. Having study guides done in advance allow one to study in as relaxed manner. This will also allow you to come into a test being confident and aggressive.
34. Study Skills in Cell Bio. Seminar review sessions are one way to check you level of preparation when preparing for a test.

35. Biochemistry (Chem) -> Cell Bio. Carbohydrates are chemical compounds important in the formation of the cell wall and in the storage of energy.

36. Chem -> Cell Bio. Mitochondria are responsible for breaking down carbohydrates and releasing energy.

37. Chem -> Human Bio. There are biochemical reasons why coaches have their runners eat carbohydrates the night before a race.

38. Chem -> Cell Bio. Processes in the cell must remove the water from molecules in order to form larger compounds.

39. NofS in Chem. The paper cut-outs used in activities related to organic compounds are models which represent more abstract concepts.


41. Chem -> Cell Energy. Photosynthesis produces simple sugars which can then be made into more complex carbohydrates by the cell.

42. Study Skills in Chem. The processes discussed in the carbohydrates labs will also apply in future labs. Understanding these concepts now, by taking your time, reading, and asking questions of yourself and others, will help you in the future.

43. SM/PS in Chem. Group data can be analyzed by looking for patterns. Inconsistent data should signal the need for further testing before conclusions can be made confidently.

44. SM/PS in Chem. Many tests have inherent limitations which must be evaluated before drawing conclusions from the data.

45. SM/PS in Chem. Experimental data is a factor in all experiments.

46. SM/PS in Chem. Repeated trials of an experimental procedure can increase the confidence with which results can be stated.

47. Chem -> Human Bio. Many fats, produced by both animals and plants, can be associated with high cholesterol levels and are thus avoided by people.

48. Chem -> Human Bio. Whether or not vegetarians are getting all the amino acids they need from plant materials alone is a point of controversy.

49. Chem -> Intro. Desks must be an estimated two decimeters apart before taking a test.

50. STS in Nuclear Power. Nuclear power, nuclear waste, plant and personal safety, alternative energy sources, economics, and environmental effects all must be evaluated when deciding on the appropriateness of nuclear power for a certain region.

51. SM/PS in Nuclear Energy. All of the facts must be considered and evaluated when making an informed decision on the use and safety of nuclear energy.
52. SM/PS in Translocation (Trans). Inferences about the structure of the cell membrane can be formed through the results of experiments.

53. Trans -> Cell Bio. The movement of materials into and out of the cell is regulated by the cell membrane.

54. Trans -> Chem. Explanations for the movement of materials in and out of the cell can be based on the chemical composition and size of those materials.

55. NofS in Trans. Our understanding of how the cell membrane works has been developed into a model of its structure.

56. Trans -> Human Bio. Diffusion is important in the process of breathing, particularly in the exchange of carbon dioxide and oxygen at the cellular level.

57. Trans -> Cell Bio. Biological processes, many of which occur at the cellular level, are critical to the health of the entire organism.

58. Trans -> Plants. Plant roots obtain water through osmosis based on a difference of salt concentration between the inside and the outside of the cell. Water can then move from one cell to the next through diffusion.

59. Trans -> Plants. Special tissues in plants are available to conduct food and water over great distances.

60. Trans -> Plants. Turgor pressure, created by osmosis, is essential to the health and structural support of many plants.

61. Trans -> Animals. Pouring salt on a slug kills it because it causes it to dehydrate (via osmosis).

62. Trans -> Ecology. Homeostasis is a balance within an organism and it's cells. Ecology is a study of the balance of the environment.

63. NofS in Trans. Dialysis tubing and sugar labs are models of how a root cell gets water.

64. SM/PS in Trans. Several of the variables in the diffusion lab can be changed to study the influence of each variable on the system. Students are encouraged to select a variable of their choice, and design and conduct an experiment.

65. SM/PS in Cell Energy. Students are asked to design an experiment which will test the effects of light on the rate of photosynthesis. Three days were used in which students designed their lab, collected and analyzed the data, discussed experimental error, re-designed the lab and ran it again.

66. SM/PS in Cell Energy. Everything that is said in an advertisement may not be true.

67. SM/PS in Cell Energy. Controls are needed to judge the influence of a new procedure or variable.

68. SM/PS in Cell Energy. Each variable testes must be isolated and run against a control.

69. SM/PS in Cell Energy. A large number of trials are needed to support a conclusion.
70. SM/PS in Cell Energy. As a consumer and a scientist, claims made by a producer of goods must be carefully evaluated against the evidence provided.

71. STS in Cell Energy. Practical applications exist for the experiment determining the effect of light intensity on the rate of photosynthesis. For instance, the amount of lighting needed in a greenhouse.

72. Cell Energy -> Chem. The number of bonds in glucose helps identify the amount of potential energy it contains.

73. Study Skills in Cell Energy. Spending time doing homework and studying can improve understanding of content. Taking and studying notes and diagrams is one method that works. Cramming is not an effective method of studying.

74. Cell Energy -> Chem. ATP has a sugar in it which can be recognized by its structural formula.

75. Cell Energy -> DNA/RNA. Structural parts of ATP can also be found in the structure of DNA and RNA.

76. Study Skills in Mitosis. Textbook definitions and glossaries can be important tools in finding the meanings of terms. However, glossary definitions don't provide context cues, which are also important in determining word meaning.

77. Study Skills in Mitosis. Reading for meaning is important. To do this, one must understand the vocabulary.

78. Study Skills in Mitosis. There are methods which can make one a more effective reader and improve studying. These methods were outlined.

79. NoS in Mitosis. "Stages" in mitosis are created for human convenience. The cycle of cell division and growth is actually a continuous sequence of activity.

80. Mitosis -> Cell Energy. Calling interphase in mitosis can be misleading because this is the stage where processes such as photosynthesis and respiration (to name a few) occur.

81. Mitosis -> Cell Bio. Part of mitosis requires the breakdown of the nuclear membrane which is made up of proteins and lipids.

82. Study Skills in Mitosis. Explaining the definition of terms to a partner can help one identify which terms they know and which terms they need to study more thoroughly.

83. Science Careers unit.

84. Meiosis -> Genetics. Fertilization is the end product of meiosis and illustrates the importance of chromosome reduction and the process of genetic recombination.

85. Meiosis -> Evolution. Failure of a reproductive cell to undergo division can result in polyploidy.

86. Meiosis -> Genetics. The random mating of sperm and egg produced through meiosis is what make the field of genetics so fascinating.
87. Meiosis -> Plants. Cloning and plant propagation techniques are methods of producing identical offspring without the process of meiosis and fertilization.

88. STS in Meiosis. Mutations, often caused by human influence, such as excessive exposure to radiation, drugs, environmental hazards, etc., can result in cancer or birth defects.

Connections Identified Through the Analysis of Classroom Materials

89. Cell Bio -> Intro. (Test). The functions of living things can be associated with many specific structures within the cell.

90. Chem -> Cell Bio. (Test). Questions related to previous content as review.

91. SM/PS in Cell Energy. (Test). Given a described experimental design, what are some ways the experiment could be improved to reduce experimental error?

92. Meiosis -> Genetics. (Test). Given a cell with various traits which has undergone meiosis, what combinations of traits could be found in the resulting gametes?

93. Careers in Intro. (Worksheet). List careers and hobbies which have to do with science, and list the advantages of being scientifically literate.

94. Cell Bio -> Intro. (Study Guide). List the characteristics of living things and relate them to structures in the cell.

95. Cell Bio -> Plants. (Lab). Cork, such as that found in bottles, is obtained from the bark of a tree.


97. SM/PS in Chem. (Lab). Experimental error occurs when testing for the organic molecules in food.

98. Trans -> Animals. (Study Guide). Explain how osmosis and diffusion would affect aquatic organisms.

99. NofS in Trans. (Lab). Dialysis tubing and sugar acts as a model for the cell in experiments dealing with osmosis and diffusion.

100. SM/PS in Trans. (Lab). Make observations and form hypotheses on the movement of materials when placed in or outside of a model cell.


102. SM/PS in Cell Energy. (Lab). Design an experiment which tests the rate of photosynthesis as affected by light intensity.

103. Study Skills in Mitosis. (Handout). Outline of methods to improve reading efficiency and general study skills.
APPENDIX H

Derivation of Ben's Subject Matter Structure

The following list identifies and describes the units of instruction taught by Ben during the semester of observation in this study. This includes Chapters 2-9 and parts of Chapter 36 from the Prentice Hall text. In addition, the Introduction to Biology and the Ecology units were partly taught out of BSCS-Green. The listing below identifies the unit of instruction in order of sequence presented in the classroom, and provides a title and the primary contents of the unit.

Units of instruction not specifically taught during the first semester may appear on the subject matter structure, but are not elaborated on below, since it would only be speculation as to the final sequence and content of these units.

1. **Introduction to Biology**: Science skills (reading, using and constructing diagrams, tables, charts and graphs), cause and effect, observation and inference, problem solving, the scientific methods, test taking skills.

2. **Ecology**: Food webs and chains, energy transfer, ecosystems, niches, biosphere, human influence, climate and cycles, webs and pyramids, symbiosis, predator-prey relationships, ecological changes, the environment.

3. **Understanding Life**: Spontaneous generation, characteristics of living things.

4. **Basic Chemistry**: Nature of matter (atoms, compounds, etc.), chemical reactions, organic compounds, conservation of mass and energy.

5. **Cell Biology**: Microscopes, organelle structures and functions, translocation.


7. **Cell Division**: Mitosis, meiosis.

8. **DNA/RNA**: DNA, replication, RNA, transcription, translation, protein synthesis.

9. **Genetics**: Mendel, dominance... (Observations ended mid-unit)

The following is a list of the connections identified though the analysis of the transcripts from the observed lessons and the materials which were used in the context of the class. The definition for the identification of a connection was discussed in Chapter IV, Textbook Subject Matter Structure. Connections are listed in sequential order. Each connection is stated as the chapter of origin, the referent, and a paraphrasing of the content of the connection. The number listed before each connection corresponds to the number and line shown in Figure 17. The sources of connections (transcript or materials) are
distinguished by labeling in the list below and are differentially identified in the diagram by
the use of circles (for connections identified through analysis of the transcripts) and
squares (for connections identified through the analysis classroom materials) drawn around
the numbers in the diagram.

**Connections Identified Through the Analysis of Classroom Transcripts**

1. Ecology -> STS. The multiple viewpoints for which the land surrounding a creek may
   be used is introduced in order to show students the importance of being prepared to make
decisions based on their knowledge of biology and living systems.

2. Ecology -> Introduction to Biology (Intro). Appropriate data from biological systems
   must be collected if it is to be used to base decisions on. This is part of the scientific
   method.

3. Ecology -> Cell Energy. Organisms need food in order to produce energy to maintain
   other functions, such as reproduction.

4. Understanding Life (UL) -> Human Biology (Bio). Human biology examples can be used
   when describing the characteristics of living things. In particular, the human body is not in
   a state of homeostasis when it is growing. (This misrepresentation of content is discussed
   in Ben's case study.)

5. UL -> Cell Biology (Cell Bio). Cells must balance water, nutrients, etc., in order to
   maintain homeostasis.

6. UL -> Evolution. Populations depend on reproduction, but individuals do not.
   Extinction occurs if populations fail to reproduce.

7. UL -> Organisms. The two forms of reproduction, asexual and sexual, will be discussed
   in detail elsewhere. (This is an inferred location for this discussion.)

8. UL -> Evolution. Reflexes are "programmed" into all organisms. Other responses to
   stimuli are learned. (Implied connection).

9. UL -> Organisms. Response to stimuli occurs in all organisms, including bacteria,
   plants and elephants.

10. History of Science (HofS) in UL. Discussion of the scientists and experiments used to
    provide evidence to refute abiogenesis.

11. Basic Chemistry (Chem) -> Cell Energy. Chemistry provides the "theoretical"
    background so that the chemistry of the cell can be understood.

12. Chem -> Evolution. Terrestrial organisms and the cells of which they are composed
    have evolved in such a way as to effectively deal with the air pressure exerted on them.

13. Chem -> Intro. Our model of the atom has been formed through inferences and
    evidence gathered through observing reaction which we can see. (Inferred connection.)
Figure 17. Derivation of Ben's Subject Matter Structure.
14. Chem -> Cell Energy. Glucose, which comes from the food we eat, is burned by cells to provide energy.

15. Chem -> Cell Energy. Cellulose has large amounts of energy (as evidenced by burning wood in a fire), but this energy cannot be used by humans because we lack the proper enzymes to break it down.

16. Chem -> Human Bio. Some types of fats are more harmful to the human body. These types can be determined through their chemical makeup.

17. Chem -> Human Bio. Amino acids come from the proteins that we eat. They are broken apart in the digestive system and then reassembled in the cell into "human" proteins.

18. Cell Biology (Bio) -> DNA/RNA. Ribosomes are responsible for joining amino acids together into proteins. (This comment was stimulated by a movie shown in class.)


20. Cell Bio -> Chem. The bonds in glucose are broken down to release energy for use in the cell.

21. Cell Bio -> DNA/RNA. Chromosomes are made of DNA. The DNA controls the formation of proteins.

22. Cell Bio -> Cell Energy. Cell structures need energy to do work. This energy is provided by the burning of sugar in the mitochondria and is delivered as ATP.

23. Cell Bio -> Ecology. Organisms cannot be moved between fresh and salt water environments without disturbing the osmotic balance established between an organism and its original environment.

24. Cell Bio -> Organisms. Plants will dehydrate if watered with salt water due to the principles of osmosis.

25. Cell Bio -> Human Bio. Humans would dehydrate if they were to drink salt water.

26. Cell Energy -> Chem. Enzymes, which control the activities of the cell, are made out of proteins.

27. Cell Energy -> Cell Bio. Proteins are produced by the ribosomes and their formation is regulated by DNA.

28. Cell Energy -> Cell Bio. ATP is produced by the mitochondria and is transported within the cell to the location where it is needed.

29. Cell Energy -> Cell Bio. Oxygen in the body is obtained by breathing. This is used in respiration to "burn" glucose and produce ATP in the mitochondria.

30. Cell Division -> Cell Bio. The division of chromosomes is important since this is the site of DNA which controls cell functions.

31. Cell Division -> DNA/RNA. Chromosomes are made of DNA which control the cells functions.
32. Cell Division -> Genetics. The codes carried on the DNA can be divided into segments called genes.

33. HofS in DNA/RNA. Story about the unraveling of the structure of DNA.

34. DNA/RNA -> Cell Energy. The components which make up DNA can be obtained from breaking down food or can be synthesized by cells.

35. DNA/RNA -> Cell Energy. When bonds are broken through hydrolysis, they are not electrically stable, thus, they are more likely to bond.

36. DNA/RNA -> Chem. DNA codes for proteins which are sued to make cell structures and to form enzymes which control chemical reactions.

37. DNA/RNA -> Genetics. Differences in organisms can be accounted for differences in proteins which are influenced by differential sequencing of the DNA. However, DNA in all organisms contains the same essential components.

38. HofS in Genetics. Discussion of Mendel's role in our current understanding of genetics.

Connections Identified Through the Analysis of Classroom Materials

39. Ecology -> Intro. (Test). Students are asked to interpret a graph on biomes and a diagram of overlapping niches.

40. UL -> Intro. (Test). Questions concerning the use of experimental evidence to disprove the theory of spontaneous generation.

41. Cell Energy -> Cell Bio. (Test). Cellular processes, such as respiration, are linked back to organelle structures and functions.

42. DNA/RNA -> Cell Bio. (Test). Protein synthesis is important since proteins make up many of the cell's components.

43. Ecology -> STS. (Worksheet). Questions related to feeding the human population based on student understanding of food chains and ecological pyramids.

44. Cell Energy -> Human Bio. (Homework). Enzymes are denatured as they move from the stomach to the intestine due to a change in pH.
APPENDIX I

Derivation of Carl's Subject Matter Structure

The following list identifies and describes the units of instruction taught by Carl during the semester of observation in this study. This included Chapters 1-9 in the text, and an additional unit called "Nature Week." The listing below identifies the units of instruction in order of sequence presented in the classroom, and provides a title and the primary contents of the unit.

Units of instruction not specifically taught during the first semester may appear on the subject matter structure, but are not elaborated on below, since it would only be speculation as to the final sequence and content of these units.

1. **Studying Life**: Using the book, the scientific method, microscopes, safety, using biological terms (understanding the meaning of word root, prefixes and suffixes).

2. **Understanding Life**: Spontaneous generation, characteristics of living things.

3. **Basic Chemistry**: Nature of matter (atoms, compounds, etc.), chemical reactions, organic compounds, energy transformations.

4. **Cell Biology**: Cell theory, organelles, cell structure and function, cell membranes, translocation.


6. **Cell Division**: When and why cells divide, mitosis, meiosis.

7. **DNA/RNA**: DNA, replication, transcription, translation, genes, protein synthesis.

8. **Nature Week**: Wildlife films, winter wilderness, marsupials, nature's half acre.

9. **Genetics**: Mendel, genotypes and phenotypes, dominance, monohybrid crosses, probabilities, dihybrid crosses, multiple alleles, incomplete dominance, sex-linked traits.

The following is a list of the connections identified through the analysis of the transcripts from the observed lessons and the materials which were used in the context of the class. The definition for the identification of a connection is discussed in Chapter IV, Textbook Subject Matter Structure. Connections are listed in sequential order. Each connection is stated as the chapter of origin, the referent, and a paraphrasing of the content of the connection. The number listed before each connection corresponds to the number and line shown in Figure XX. The sources of connections (transcript or materials) are distinguished by labeling in the list below and are differentially identified in the diagram by the use of circles (for connections identified through analysis of the transcripts) and
squares (for connections identified through the analysis classroom materials) drawn around the numbers in the diagram.

**Connections Identified Through the Analysis of Classroom Transcripts**

1. Basic Chemistry (Chem) -> Models. Ball and stick models are representations of what scientists believe molecules really look like.

2. Chem -> Human Biology (Human Bio). Chemical reactions are occurring in our bodies constantly.

3. Chem -> Cell Energy. Basic chemistry provides the framework for our understanding of the chemistry of living things.

4. Chem -> Human Bio. Ammonia, use in soap, is "abrasive." Thus, washing someone's mouth out with soap is dangerous.

5. Cell Biology (Bio) -> Models. The diagram used for the cell membrane is a model of what we think exists, of what we think a cell membrane looks like.


7. Cell Bio -> Chem. The chemical structure of lipids influence the way cell membranes work.

8. Cell Bio -> Chem. Brownian motion and molecular motion are influenced by heat. All three influence the rate of diffusion.

9. Cell Bio -> Processes. Students are asked to make predictions, observations, collect data, form conclusions, and perform multiple experiments in relation to the movement of BB's on a vibration plate. It is unclear if these process skills are connected to topics covered in the SL chapter.

10. Cell Bio -> Human Bio. Humans who drink salt water can die of dehydration. This can be explained by osmosis.

11. Cell Bio -> Animals. Some fish have physiological systems which are adapted to movement between fresh and salt water. Without these mechanisms and adjustment periods, the fish would not be able to make this transition.

12. Cell Bio -> Evolution. Adaptive mechanisms to deal with osmotic pressures have occurred as a result of evolution. Thus, individual freshwater organisms cannot make this adaptation simply by drinking increasingly large doses of salt water.


14. Cell Energy -> Chem. Basic chemistry if the background material to understand the chemistry of living things, such as photosynthesis and respiration.

Figure 18. Derivation of Carl's Subject Matter Structure.
16. Cell Energy -> Chem. Structural formulas, such as for simple sugars, are used to discuss dehydration synthesis and the formation of more complex compounds.

17. Cell Energy -> Human Bio. Enzymes which exist in one part of the digestive tract are denatured in other parts of the digestive tract by a change in pH.

18. Cell Energy -> Human Bio. High body temperatures, such as those produced by fevers, can act as activation energy for other reactions, which can cause problems.


20. Cell Energy -> Chemistry. Neutralization of stomach acids can be done in the same manner as the neutralization of other acids, by using a base.

21. Cell Division -> Cell Bio. Cells are three dimensional. The surface area to volume ratios change as cells grow. This decreases the efficiency of the cell membrane to transport materials into the cell.

22. Cell Division -> Genetics. The wrong number and type of chromosomes caused by faulty meiotic divisions can cause miscarriages.

23. Cell Division -> Genetics. Chromosomes are the carriers of genetic information, which will be discussed in more detail in the genetics chapter.

24. Cell Division -> Cell Bio. Cells are three dimensional even though we tend to represent them two dimensionally. Evidence: focusing the microscope on the nucleus.

25. Cell Division -> Evolution. Mutations which can be passed on can occur through mistakes in cell division during meiosis.

26. Cell Division -> Plants. The cite of cell division is near the end of a onion root tip.

27. Cell Division -> Cell Bio. The difference between plant and animal cell division are related to their differences in cellular structure.

28. Cell Division -> Genetics. Genetic defects are caused by mistakes in meiotic divisions.


30. Cell Division -> Genetics. Genetic diversity is created through crossing over at synapse, independent assortment during meiosis, and random chance at fertilization.

31. Cell Division -> Genetics. Twining is sometimes caused by the release of two eggs simultaneously.

32. DNA/RNA -> Cell Division. Interphase id the time of DNA replication and protein synthesis.

33. DNA/RNA -> Cell Bio. DNA and protein synthesis take place within the context of all the other cell organelles, not in isolation.
34. DNA/RNA -> Cell Energy. Amino acids are obtained through the digestion of plant and animal matter and are then used to synthesize new proteins according to the sequence specified on the DNA.

35. DNA/RNA -> Chem. The order of the amino acids which make up a protein are determined by the DNA. Different sequences of amino acids result in proteins which look and function differently.

36. DNA/RNA -> Genetics. The sequence in DNA codes for different protein types which are expressed as different genetic characteristics.

37. DNA/RNA -> Cell Energy. Enzymes are involved in DNA replication. (Inferential connection, made without elaboration)

38. DNA/RNA -> Protists. Evidence for the structure and function of DNA was gained through experiments involving bacteria and the pneumonia virus.

39. Genetics -> Cell Division. Meiosis decreases the number of chromosomes so that each parent contributes only one allele for each trait.

Connections Identified Through the Analysis of Classroom Materials

40. UL -> SL. (Lab). Lab safety rules in terms of determining if yeast cells are alive.

41. Cell Energy -> Human Bio. (Homework). The denaturing of enzymes within the human digestive system are due to changes in pH.

42. Cell Energy -> Chem. (Worksheet). Vocabulary assignment reviewing the vocabulary from the chemistry unit as an introduction to the cellular energy unit.


44. Cell Bio -> Chem. (Test). The identification of the organic molecules which make up certain cell structures, such as the cell membrane, and role in transport.

45. Cell Energy -> Human Bio. (Test). The denaturing of enzymes within the human digestive system are due to changes in pH.
Derivation of Don's Subject Matter Structure

The following list identifies and describes the units of instruction taught by Don during the semester of observation in this study. This includes Chapters 1-6 and Chapters 36-39 in the text. The listing below identifies the units in order of sequence presented in the classroom, and provides a title and the primary contents of the unit.

Units of instruction not specifically taught during the first semester may appear on the subject matter structure, but are not elaborated on below, since it would only be speculation as to the final sequence and content of these units.

1. **Introduction to Biology**: safety, science process skills, the nature of science, metrics, microscopes, spontaneous generation, the characteristics of living things.

2. **The Environment (Basic Ecology)**: abiotic and biotic factors, ecosystems, populations and communities, transfer of energy, food chains and webs, ecological pyramids, cycles (a sub-unit on the definition of cycles and their occurrences across science content).

3. **Ecological Changes (Populations and Succession)**: structure of populations, population dynamics, behavior of populations (e.g., behavioral, rhythmic), succession.

4. **Biomes**: biomes, climates, terrestrial biomes, aquatic biomes.

5. **Your Environment (Pollution)**: natural resources, pollution.

6. **Basic Chemistry**: the nature of matter (i.e., atoms, compounds), chemical reactions (dehydration synthesis and hydrolysis), organic molecules.

7. **Cell Biology**: Cell theory, prokaryotes vs. eukaryotes, cell structure and function (organelles), cellular transport.

8. **Cell Energy**: dehydration synthesis and hydrolysis, enzymes, ATP, photosynthesis, respiration.

9. **Cell Division**: mitosis, meiosis (?).

The following is a list of the connections identified though the analysis of the transcripts from the observed lessons and the materials which were used in the context of the class. The definition for the identification of a connection is discussed in Chapter IV, Textbook Subject Matter Structure. Connections are listed in sequential order. Each connection is stated as the chapter of origin, the referent, and a paraphrasing of the content of the connection. The number listed before each connection corresponds to the number and line shown in Figure 19. The sources of connections (transcript or materials) are distinguished by labeling in the list below and are differentially identified in the diagram by
the use of circles (for connections identified through analysis of the transcripts) and squares (for connections identified through the analysis classroom materials) drawn around the numbers in the diagram.

**Connections Identified Through the Analysis of Classroom Transcripts**

1. STS in The Environment (Basic Eco). Abiotic conditions create very specific habitats, such as the old growth forests for the spotted owl.

2. STS in Basic Eco. Issues surrounding the greenhouse effect becomes complicated because it is unclear if global warming is part of a natural cycle or created by humans.

3. STS in Basic Eco. Local bark beetle infestations are cyclic and density dependent.

4. STS in Ecological Changes (P&S). Bark beetle infestations are density dependent, as are many other diseases.

5. P&S -> Evolution. Social behaviors, such as territoriality and social hierarchies, help ensure that only the strongest members of a population reproduce, thus contributing to the "fitness" of a population to an environment. (Inferred)

6. P&S -> Animals. Pheromones, such as those produced by dogs in estrus, are a form of chemical communication which results in social behaviors.

7. P&S -> Plants. Trees communicate chemically, particularly in cases of insect infestation and disease. This is a form of social behavior.

8. P&S -> Basic Eco. Rhythmic behaviors (i.e., circadian rhythms) exhibit characteristics found in other cycles.

9. P&S -> Animals. Circadia are insects which exhibit life cycles based on 7 year patterns. Other animals have population density cycles based on 7 and 13 year patterns.

10. Biomes -> Basic Eco. Terrestrial biomes are distinguished by abiotic factors such as precipitation and temperature. (Inferred)

11. Biomes -> Basic Eco. Aquatic ecosystems are distinguished by factors of light and salinity.

12. Biomes -> Basic Eco. Food chains are important elements in all biomes. For instance, light in aquatic ecosystems limits photosynthesis and thus the food available for other organisms.

13. Biomes -> P&S. Factors in biomes, such as light and oxygen, can be limiting factors and prevent organisms from reaching their biotic potential.

14. Biomes -> Basic Ecology. All biomes have abiotic factors which can limit population growth.

15. STS in Your Environment (Pollution). Acid rain is a form of environmental pollution created by the burning of fossil fuels.
Figure 19. Derivation of Don's Subject Matter Structure.
16. Pollution -> Basic Eco. Acid rain affects organisms at all levels of the food chain. Unfortunately, the ultimate effects on fish are often the only ones recognized.

17. Pollution -> Basic Eco. Pollutants are concentrated as they move up the food chain. This process is called biomagnification.


19. STS in Pollution. Mercury poisoning can be caused by a process used in mining gold. This creates conflict between wanting a product and creating a pollutant.

20. Cell Bio -> ?. Knowledge of cell structures and functions will be important in upcoming units.

21. Cell Bio -> Intro to Bio. Viruses do not have all of the cell parts, not do they have all of the characteristics of living things. Are they living? How do they fit into the cell theory?

22. Cell Bio -> Intro to Bio. The cell theory is related to the previous definition given for the term "theory."

23. STS in Cell Bio. Advances in technology, especially the microscope, has improved our understanding of the cell.


25. Cell Bio -> Animals. Many aquatic animals have physiological adaptations to deal with differences of salt concentrations between their bodies and the environment.


28. Cell Energy -> Basic Chemistry (Chem). Dehydration synthesis and hydrolysis were "accidentally" taught in Basic Chemistry and will now be discussed again because they appear in the text under Cell Energy.

Connections Identified Through the Analysis of Classroom Materials

29. STS in Pollution. (Test). Questions on how individual students can take actions to effectively deal with environmental issues.


31. Chem -> Basic Eco. (Test). Questions on how plants and animals obtain carbon, as in food chains and the carbon cycle.

32. Chem -> Cell Bio. (Test). Questions which link organic compounds to the location and/or role in the cell.
33. Intro -> Microbiology. (Worksheet). The use of the scientific method in establishing the germ theory.

34. Basic Eco -> P&S. (Worksheet). Abiotic factors can affect the population size of whooping cranes.

35. Basic Eco -> P&S. (Worksheet). Abiotic factors can affect the population size of insects.

36. Basic Eco -> Plants. (Lab). Tree rings can be used to establish patterns in tree growth which can be related to abiotic factors.

37. STS in P&S. (Worksheet). Limiting factors which affect the population growth of simple organisms, such as duckweed and yeast, can also affect the population of humans.

38. STS in Pollution. (Worksheet). Students are asked to write a letter to a public official about the disposal of hazardous waste after they have been presented with the pros and cons of the issue, including economic, political, and environmental consequences.

39. STS in Pollution. (Lab). Calculation of the amount of waste paper generated by each person during one week.

40. STS in Pollution. (Worksheet). Methods of reducing air pollution which can be conducted by individuals as well as industry.
APPENDIX K

Derivation of Ed's Subject Matter Structure

The following list identifies and describes the units of instruction taught by Ed during the semester of observation in this study. This includes Chapters 1-6 and Chapters 36-38 in the text. The listing identifies numbers the units of instruction in order of sequence presented in the classroom, and provides a title and the primary contents of the unit.

Units of instruction not specifically taught during the first semester may appear on the subject matter structure, but are not elaborated on below, since it would only be speculation as to the final sequence and content of these units.

1. **Introduction to Biology**: lab safety, the scientific method, the nature of science, graphing, metrics, microscopes, characteristics of living things.

2. **Ecology Basics**: biotic vs. abiotic, ecosystems, biomes, populations and communities, cycles (including a sub-unit designed by the district), food webs and chains, ecological pyramids, symbiotic relationships.

3. **Ecological Systems**: structure of populations, population dynamics, succession, biomes, climate, terrestrial biomes, aquatic biomes.

4. **Basic Chemistry**: the nature of matter (i.e., atoms, compounds), interactions of matter (i.e., chemical formulas and reactions, acids and bases, dehydration synthesis and hydrolysis), carbon compounds (families and nomenclature), organic compounds, conservation of mass and energy.

5. **Cell Biology**: cell theory, prokaryotes vs. eukaryotes, cell structure and function (organelles), cellular transport.

6. **Cell Energy**: dehydration synthesis and hydrolysis, activation energy and catalysts, enzymes, ATP, respiration, fermentation, photosynthesis.

7. **Cell Division**: when and why cells divide, the cell cycle, mitosis, meiosis.

8. **DNA/RNA**: DNA structure, DNA replication, RNA, transcription, translation, protein synthesis.

The following is a list of the connections identified though the analysis of the transcripts from the observed lessons and the materials which were used in the context of the class. The definition for the identification of a connection is discussed in Chapter IV, Textbook Subject Matter Structure. Connections are listed in sequential order. Each connection is stated as the chapter of origin, the referent, and a paraphrasing of the content of the connection. The number listed before each connection corresponds to the number and line shown in Figure 20. The sources of connections (transcript or materials) are distinguished by labeling in the list below and are differentially identified in the diagram by
the use of circles (for connections identified through analysis of the transcripts) and squares (for connections identified through the analysis classroom materials) drawn around the numbers in the diagram.

Connections Identified Through the Analysis of Classroom Transcripts

1. Introduction to Biology (Intro) -> Genetics. Mendel worked with large numbers of pea plants to reduce experimental error.

2. STS in Intro. The results of many experiments have practical applications. These applications can be beneficial, harmful, or controversial.

3. Intro -> Physical Science (PSci). Newton's second law is an example of an equation where the independent and dependent variables can be graphed.

4. Intro -> PSci. Weight is a function of a force created by gravity.

5. Intro -> Protists. Potatoes placed in water for several days start to smell. This odor is caused by bacteria which are using the potato for food. These organisms can be seen under the microscope and will be studied along with yeast and molds.

6. Intro -> PSci. Decomposition of organic materials is part of the process of entropy in which all things move toward disorder.

7. Intro -> PSci. The original thermo-nuclear energy from the formation of our solar system is the ultimate source of all energy, including that radiated by the sun.

8. Intro -> Cell Biology (Bio). Movement, in terms of plants, is often defined as the movement of materials inside the cell, such as chloroplasts in response to the sun.


10. Eco Basics -> Eco Sys. Biomes are large ecosystems which are defined by their abiotic features and the organisms that live there. These organisms interact to form communities, etc.

11. Eco Sys -> Eco Basics. Cycle is a concept that is found throughout ecology. For instance, cycles in temperature and precipitation help define biomes.

12. Basic Chemistry (Chem) -> Plants. Plants are the primary producers of carbohydrates through photosynthesis.

13. Chem -> Animals. Solubility of gases vary with temperature. This relates to the ability of fish to survive in water systems at different temperatures.

14. STS in Chem. Water is heated in the process of producing nuclear energy. This warm water can be detrimental to aquatic ecosystems.
Figure 20. Derivation of Ed's Subject Matter Structure.
15. Chem -> Cell Bio. Cells, and the organisms they compose, are primarily made up water, making water a very important solvent for living things. Thus, understanding solubility is important.


17. Cell Bio -> DNA/RNA. DNA is an example of a nucleic acid, is found in the nucleus, contains hereditary information, and controls the production of proteins.

18. Cell Bio -> Plants. The cells in plant stems (xylem, phloem, cortex) look different under the microscope as a result of their different functions.

19. Cell Bio -> Plants. The cells in the reproductive structures look different as a result of different functions.

20. Cell Bio -> Cell Division. Mitochondria may be simple cells that invaded eukaryotic cells and established a symbiotic relationship. Evidence - mitochondria have their own DNA.

21. Cell Bio -> Chem. The change in color of starch when it comes in contact with iodine is a result in the molecular structure which reflects a different color back to the eye.

22. Cell Energy -> Chem. Dehydration synthesis was discussed in both units.


24. Cell Energy -> Human Bio. Enzymes in one portion of the digestive tract are denatured as they enter another portion due to changes in pH.

25. Cell Energy -> Chem. Energy is stored when electrons change electron shells in atoms. This is how potential energy is stored in chemical bonds.

26. Cell Energy -> Chem. Organic compounds, depending on the number of bonds they have, are capable of storing varying amounts of energy.

27. Cell Energy -> Intro. The energy released in respiration is used for carrying out the functions which characterize living things.


29. Cell Energy -> Eco Basics. The energy for photosynthesis ultimately comes from the sun. Even though house lights can provide the energy for photosynthesis, these lights are powered by hydroelectric dams which operate based on the water cycle which is driven by the sun.

30. Cell Energy -> Plants. For photosynthesis to occur, water enters the leaf through the petiole, carbon dioxide through the stomata, etc.

31. Cell Energy -> Cell Bio. Chloroplasts are the organelles which contain the chlorophyll in a plant cell.
32. Cell Energy -> Plants. The process of photosynthesis will be discussed again in the spring in the unit on plants.

33. Cell Energy -> Eco Basics. The photosynthesis-respiration cycle is part of the carbon cycle. Oxygen and water cycles are also involved.


35. Cell Division -> Cell Bio. One limit to cell size is the efficiency of moving material across a membrane.

36. Cell Division -> Cell Energy. All cells need oxygen, food, and water moving in and carbon dioxide and waste materials moving out as a result of respiration.

37. Cell Division - DNA/RNA. Another limit to cell size is the efficiency of the nucleus to control the cell’s activities through protein synthesis.

38. Cell Division -> Cell Bio. Cell growth occurs (in part) by the growth of cytoplasm which is made up of water and protein and supports the other organelles.

39. Cell Division -> Cell Bio. Mitochondria and chloroplasts have their own DNA. Their involvement in cell division is during cytokinesis rather than mitosis. The presence of DNA is evidence that these structures may be symbiotic invaders.

40. Cell Division -> Cell Energy. Enzymes are needed in cell division to build up and break down fibers, membranes, etc.

41. Cell Division -> Cell Energy. Activation energy is needed to start the reaction where the chromosomes are pulled to the poles.

42. Cell Division -> Eco Basics. Cell division is a cycle similar to the other cycles studied.

43. DNA/RNA -> Cell Division. The structure of DNA is important since this is what is being copied so carefully and moved around during cell division.

44. DNA/RNA -> Chem. DNA is made up of building blocks just like the other organic molecules, such as polysaccharides and fats.

45. DNA/RNA -> Cell Energy. Phosphates in DNA are bonded to the sugars through dehydration synthesis, releasing water as a by-product.

46. DNA/RNA -> Chem. Deoxyribose is a 5-carbon sugar. Since that makes it a carbohydrate, the ratio of hydrogen to oxygen must be 2:1.

**Connections Identified Through the Analysis of Classroom Materials**

47. Eco Sys -> Evolution. (Test). Plant and animal adaptations allow their survival only within a specific biome.

48. Cell Bio -> Animals. (Test). Aquatic organisms must have physiological mechanisms which regulate water gain and loss through osmosis.
49. Eco Basics -> Evolution. (Homework). Natural selection can be used to explain niche occupation following an extinction.

50. STS in Eco Basics. (Worksheet). Humans can reduce food shortages by eating lower on the energy pyramid.

51. Cell Bio -> Intro. (Worksheet). The role of the nucleus can be studied through experimental tests on large, single celled organisms which contain only one nucleus.

52. Cell Bio -> Plants. (Worksheet). Macroscopic single celled algae with only one nucleus exist. Changes in the structure can be related to information carried in the nucleus.

53. Cell Energy -> Human Bio. (Homework). Enzymes in one portion of the digestive tract are denatured as they enter another portion due to changes in pH.


55. Cell Division -> Genetics. (Homework). Mitosis helps maintain the genetic continuity within organisms.