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For Community College Instruction

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Problem-based learning (PBL) is one type of inquiry-based learning. Many community college instructors use inquiry-based learning as an instructional strategy. There is much literature on the use of problem-based learning in undergraduate, graduate and medical school education, with a multitude of examples of specific techniques and problems to be addressed, but very little on how to ascertain what level of PBL may already exist in established curriculum. The objective of this research is to understand how problem-based learning in lower division undergraduate science education is distinguished, in practice, from other types of inquiry-based learning and lecture-based teaching strategies. To accomplish this objective the researcher determined the continuum of use of PBL in science curriculum from problem-based to purely lecture-based learning and developed a tool to analyze existing science curriculum for PBL components. The resulting PBL Classification Rubric can assist instructors to make a transition to PBL easier. Hopefully, this may open the door to more research in PBL at the community college level, which will lead to expansion of documentation for future use by community college instructors.
Development of a
Problem-Based Learning Classification Rubric
For Community College Instruction

by
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Leah J. Knelly, Author
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Development of a Problem-Based Learning Classification Rubric For Community College Instruction

Chapter 1: Introduction

Problem-based learning (PBL) is one type of inquiry-based learning. Many community college instructors use inquiry-based learning as an instructional strategy. There is a need for more documentation of the use of PBL at the community college level, yet there is a paucity of such literature available. This study examines the curriculum of one instructor using inquiry-based learning for identification of components that resemble those of PBL. The purposes of this research effort were to determine specifically defined curriculum components of PBL and discover and document elements of PBL that may already exist in community college curriculum. Examination of past and current PBL literature revealed manageable components of PBL. Analysis of existing community college curriculum using a modified version of an Innovation Configurations (IC) checklist (Hord, et al., 1987) discovered the implementation of many operational features of PBL. This led to the development of a PBL Classification Rubric that provides a framework to study the degree to which existing curricula have components of problem-based learning. Hopefully, this may open the door to more research in PBL at the community college level, which will lead to expansion of documentation for future use by community college instructors.

Problem Statement

There is much literature on the use of problem-based learning in undergraduate, graduate and medical school education, with a multitude of examples of specific techniques and problems to be addressed, but very little on how to ascertain what level of PBL may already exist in established curriculum. Most college instructors are specialized experts in a specific content area and aren't really clear on what PBL looks like in practice, therefore they aren't able to assess if their curriculum is PBL or has any elements of PBL.
in it. What they need is a practical guide that uses language understandable by instructors of any discipline.

**Purpose of the Study**

The first objective of this study was to understand how problem-based learning in lower division undergraduate science education is distinguished, in practice, from other types of inquiry-based learning and lecture-based teaching strategies. To accomplish this objective the researcher determined from published literature the continuum of use of PBL in science curriculum from problem-based to purely lecture-based learning. The second objective of this study was to develop a practical, easy to use tool (rubric) to analyze existing science curriculum for PBL components. To accomplish this objective the researcher analyzed the curriculum of a local community college biology instructor. This was done by studying the student notes packet developed by the instructor and by interviewing the instructor on classroom implementation of her curriculum.

**Theoretical Framework**

Lecture and rote memorization, the core methods of instruction used by instructors since education was established in this country, are still pervasive in post-secondary education. There is a great deal of literature available and public school policy written to facilitate change in the methods of curriculum implementation at K-12 levels. The use of “hands-on” and inquiry learning has been around for a long time. John Dewey said of instructional methods: "Careful inspection of methods which are permanently successful in formal education will reveal that they give pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; then learning naturally results" (Dewey, 1938).
H.S. Barrows and R.M. Tamblyn popularized problem-based learning, a type of inquiry-based learning, in the 1960s as a result of research into the reasoning abilities of medical students (Savin-Baden, 2000; Barrows & Tamblyn, 1980). PBL was implemented in medical schools and other professional schools including education, nursing, and pharmacy where patient "cases" are a natural venue for research (Savin-Baden, 2000; Arambula-Greenfield, 1996; Boud & Feletti, 1991). PBL was also implemented at the high school level, although primarily for gifted students and mostly in science (Arambula-Greenfield, 1996). A few institutions of higher education such as the University of Delaware are taking it upon themselves to make broad changes with the help of grants from organizations such as the Pew Charitable Trusts.

Realizing that many instructors were unfamiliar with, and intimidated by, active student-centered learning in general, a core of PBL-active faculty at the University of Delaware created, with support from NSF’s Institution-Wide Reform program, an Institute for Transforming Undergraduate Education (ITUE) (Duch, et.al. 2001). The institute provides workshops and individual training and has established an online database clearing-house of problems contributed by instructors all over the country (http://www.udel.edu/pbl/). Data are still being collected on the impact of PBL on student learning or motivation to learn. This data includes whether or not discipline content imbedded in the PBL format becomes evident to the students. It also includes information about the student ownership of their own learning with the increased responsibility of group participation in class assignments. Many educators in secondary and post-secondary education report that test scores are generally the same or better than lecture-based courses with long-term retention and ability for self-directed learning being greater with PBL (Monguet, et. al. 2006, Mowshowitz, 2006; Dinan, 2002; Evensen, 2000; Heppert, 2002; Thomas, 2000; Abrahams, 1997; Arambula-Greenfield, 1996; Wilkerson, 1996).
Definitions

Lecture-Based Learning

Traditional didactic lecture-based instruction began as the only form of disseminating information to students before the advent of printed books (Fyrenius, Bergdahl & Silen, 2005). It consists primarily of standing in front of a group of students verbally presenting discipline content with the role of students as passive learners or empty vessels needing to be filled with content (Slatta, 2004). Traditional non-interactive lecture-based instruction is being challenged by a good number of secondary and post-secondary instructors in a variety of disciplines as not being as effective as the different types of inquiry-based instruction (Lee, et. al. 2004; Duch, et. al., 2001; Savin-Baden, 2000). Lectures are still the main component of most college and university classes, however many instructors are beginning to adapt their lectures into more interactive instructional tools to facilitate inquiry-based instruction (Kelly, 2005; Hodges, 2005; Fyrenius et.al, 2005; De Lorenzo & Abbott, 2004; Van Kampen, et.al, 2004).

Inquiry-Based Learning

Inquiry-based learning is a more student-active form of learning. Inquiry-based learning is defined by The National Science Education Standards (National Research Council, 1996) as:

"A multi-faceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations." (p.23)

North Carolina State University defined "inquiry-guided" learning in terms of what actually happens in the classroom. This is a range of teaching strategies used to promote learning through students' active, and increasingly
independent, investigation of questions, problems and issues, often for which there is no single answer (Greene, et. al. 2004). They state that these strategies may include interactive lecture, discussion, problem-based learning, case studies, simulations, and independent study.

**Problem-Based Learning**

Since the 1960s problem-based learning has signified many things to many people. H.S. Barrows defined PBL as "the learning which results from the process of working towards the understanding of, or resolution of, a problem" (Barrows, 1986). Barrows (1986) also proposed taxonomy of the many ways PBL has been put into action at college and professional/ technical school levels, with the purest form being the introduction of a "problem" before students have been given content instruction. It has been argued that PBL should be understood as a general educational strategy rather than merely a teaching approach and that there is no fixed agreement as to what does and does not constitute problem-based learning or instruction (Fyrenius, Bergdahl & Silen, 2005; Hodges, 2005; Duch, et. al. 2001; Savin-Baden, 2000).

Increasing references to the use of PBL in college undergraduate classes have led readers to question when, how and why to use these strategies (Batzli, 2006; Smith, KA, et. al., 2006; Hodges, 2005). As a community college biology instructor interested specifically in PBL, it might be more useful to identify a continuum of PBL components in a science specific context.

**Research Questions**

The three main questions that were the focus of this study and determined the literature search strategy for background information are:

1. What are the components of problem-based learning?
2. What are the possible variations in these components?
3. How can we assess to what extent these components are present in existing curriculum?
Chapter 2: Literature Review

The search for literature on the various forms of inquiry-based learning with emphasis on PBL focused on books and articles that contained information on what the specific curriculum components should look like along with details of implementation. The search began with article databases focusing on education and professional development in the area of inquiry-based learning. This resulted in a broad range of papers that included educational programs in medicine, science, math, business, and psychology. These articles were sorted through the filter of college and university level implementation of PBL. A further search of the literature-cited sections of these collected papers also produced books and papers not appearing in the original database search. These sources were also sorted with the same filter. After reading through all of these data sources a final filter was used to extract articles and books with information focused on specific definitions and classification of PBL curriculum components and details of implementation with emphasis on science education. The definitions extracted from the final collection of data sources were included in the definition section of the introduction of this paper.

Inquiry-Based Learning

The term "inquiry" has different meanings to different teachers that use labs or investigations in their courses. Three different inquiry approaches to teaching these courses have been identified (McNeal & D'Avanzo, 1997). One is guided inquiry where the teacher asks leading questions throughout the investigation or project prompting new directions with ideas and methods. This method works best when dealing with students with very little experience with science or inquiry. The second method is open-ended inquiry where the teacher comes up with the initial and follow-up questions but the students work as independently as possible by designing the experiment, collecting and analyzing the data and so on. The third approach is the teacher-collaborative
inquiry on a topic of interest to a larger community where the teacher works side by side with the students as a co-researcher. These investigations are genuine research and have no pre-ordained result. The teacher-collaborative inquiry method takes a lot of time and may be the focus for an entire course. All three of these inquiry methods may be as simple as a one or two day laboratory investigation or as complex as a full-blown scientific investigation with a higher community related purpose such as discovery of point-source pollution in a nearby river.

A range of teaching strategies identified as "inquiry-guided learning" was investigated by North Carolina State University as part of an initiative to improve the instruction throughout the university’s undergraduate program (Greene, et. al. 2004). In 1995 North Carolina State University began their Inquiry-Guided Learning (IGL) Initiative in the undergraduate program transforming courses across the entire range of curriculum on campus. They had a shared commitment to (1) four broad student learning outcomes: critical thinking, developing habits of independent inquiry, responsibility for one’s own learning, and intellectual growth and development: and (2) promoting student learning through the active investigation of complex questions and problems.

**Problem-Based Learning**

PBL formally originated at McMaster University School of Medicine in Ontario, Canada in the late 1960s (Magnussen, et.al, 2000). Problem-based instruction directly addresses many of the recommended and desirable outcomes of an undergraduate education: specifically, the ability to do the following (Duch, et.al. 2001, Savin-Baden, 2000, Evensen, 2000):

- Think critically and be able to analyze and solve complex, real-world problems
- Find, evaluate, and use appropriate learning resources
- Work cooperatively in teams and small groups
• Demonstrate versatile and effective communication skills, both verbal and written

• Use content knowledge and intellectual skills acquired at the college to become continual learners

Barrows proposed taxonomy of the many ways PBL has been put into action at college and professional/technical school levels. This taxonomy includes the following: (quoted from Barrows, 1986)

1. Lecture-based cases - where students are presented with information through lectures and then case material is used to demonstrate the information.
2. Case-based lectures - where students are presented with case histories or vignettes before a lecture that then covers relevant material.
3. Case method - where students are given a complete case study that must be researched and prepared for discussion in the next class.
4. Modified case-based - where students are presented with some information and are asked to decide on the forms of action and decisions they may make. Following their conclusions, they are provided with more information about the case.
5. Problem-based - where students meet with a client in some form of simulated format that allows for free inquiry to take place.
6. Closed-loop problem-based - which is an extension of the problem-based method, where students are asked to consider the resources they used in the process of problem-solving in order to evaluate how they may have reasoned through the problem more effectively.

Unfortunately classifications such as these don’t encompass the actual complexities of problem-based learning. These complexities include how to incorporate discipline content, what level of PBL to use, when to use it, how to assess the results, and many other implementation issues. However, consensus was established that three broad areas of differentiation must be present for the distinction of “problem-based learning” to be valid (Duch, 2001; Savin-Baden, 2000; Evensen, 2000; Wilkerson, 1996; Arambula-Greenfield, 1996).
These areas are:

1) Curricula organization around problems rather than disciplines, an integrated curriculum and an emphasis on cognitive skills.

2) Conditions such as small groups, tutorial instruction, and active learning.

3) Outcomes such as the development of skills and motivation, together with the development of the ability to be lifelong learners.

**PBL Implementation Strategies**

There are always issues or problems to deal with in any course of action that is functionally different from the norm. The challenges of implementing PBL are as follows:

1) Initiating change

2) Faculty and administrative support

3) Student acceptance

4) Planning, writing and scheduling effective “problems”

5) Facilitation of various group sizes

6) Availability of resources, including time

7) Implementation of advanced technologies

8) Inclusion of requirements of “real world” employers

9) Evaluation and assessment strategies

The discussion that follows expands on these key issues using information gleaned from recent literature.

1. Initiating change

Few instructors have themselves been taught in a PBL classroom and it is sometimes difficult to envision how a PBL class operates or to anticipate all the situations one might encounter. Most teachers teach how they were taught especially if they were successful. Changes can be accomplished by creating
an entirely new PBL class, transforming one of their already established lecture classes, or transition gradually by introducing a problem-based exercise every week or two (Hockings, 2005; Hodges, 2005; Duch, 2001). The instructor must also be very aware of his or her own personality when attempting to change from being the center of attention as lecturer to taking the sidelines as a learning facilitator. For some instructors it can be extremely difficult to let go of total control of the classroom.

2. Faculty and administrative support

In order for curricular or pedagogical change to be successful, it will need the support of senior administrators. However, the best situation involves the right balance between top-down and bottom-up strategies. For example, a faculty-led initiative to improve student learning through PBL that enjoys early success in improving student performance and results in significant reinvigoration among faculty for their teaching is supported by senior academic administrators. Three key ingredients that maximize the likelihood of a successful blend of top-down and bottom-up strategies are identified as (Hockings, 2005; Duch, 2001; Savin-Baden, 2000; Wilkerson, 1996):

1) Getting the terminology right by using consistent definitions of PBL, discussing and agreeing to the same critical outcomes, and agreeing on the scope of the effort.
2) Removing barriers to innovation such as administrative red tape dealing with tenure, merit pay, and departmental student credits.
3) Making adequate resources available including funding and administrated workload (such as departmental research) to afford more time for planning.

As far as faculty support for PBL, many senior members of the faculty who are not willing to change from their “tried and true” lecture methods try to dissuade early career instructors from trying PBL to avoid the possibility of less
than positive student evaluations that may affect the number of students registering for classes in those divisions. In many cases, this will affect the budget of funds received within those divisions. It is the responsibility of academic administrators to ensure that early-career faculty who choose to try alternative instructional approaches are not affected negatively by their colleagues' opinions.

3. Student acceptance

Another key problem to be addressed is the disparity of students' experience with taking charge of their own learning. Ancillary to this is enhancement of group participation. Students who have never been exposed to PBL may experience discomfort and uncertainty as to what is expected of them unless they are prepared ahead of time. They also may experience stress about how their grade may be affected by working in groups (Batzli, et.al., 2006; Hockings, 2005; Duch, 2001; Savin-Baden, 2000; Evensen, 2000; Boud, 1991). Many students will actually drop a class or avoid taking a class that requires them to work in groups predominantly.

4. Effective problems

Another crucial component of PBL is the introduction of concepts and principles within disciplines through the use of problems or cases. Examples of these concepts in biology are evolution, ecology, and heredity. Good problems share a number of characteristics: (Duch, 2001; Leary, 2001; Wilkerson, 1996)

- They tell engaging stories in settings to which the students can relate, thus solidifying the eventual connection between theory and application.
- They are open-ended, challenging students to make and justify estimations and assumptions
• They engender controversy or require decisions, so their solutions require students to demonstrate thinking skills beyond simple knowledge and comprehension.

• They are complex enough for students in each group to recognize the need to work together to succeed in arriving at a satisfactory conclusion.

The content objectives of the course should be incorporated into the problems, connecting previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and/or disciplines. Planning and writing good, effective problems takes time and focus. The timing of when to introduce the first problem and how many problems will fit into an allotted period of time such as a quarter or a semester is another aspect of PBL that can be problematic (Heppert, 2002; Savin-Baden, 2000; Duch, 1996; Arambula-Greenfield, 1996).

5. Group sizes

Each instructor intent on using problem-based instruction will make many decisions based on the size of their class, the intellectual maturity of their students, the type of course, and the availability of graduate or undergraduate peer tutors (Duch, 2001). Size of groups, structure of content information delivery, and use of assistants are all variables to be manipulated by the instructor. However, for cooperative groups of any size to function successfully each member needs to participate as equally as possible. Inequality of participation may relate to four factors: traditional roles, students’ expectations, and the tutor’s or instructor’s presence and feedback. Other factors that affect students’ behavior in groups are: perceived personal ability and self-concept, current health, past interactions with other group members, and past experiences with groups in general (Evensen, 2000; Savin-Baden, 2000).
6. Resources

Accessing adequate research materials can be a problem for many students in college classes, since many of them may work full time and not be able to get to a library when it is open. Also, many students will not have access to computers outside of the college to use the Internet for research (Arambula-Greenfield, 1996). Increased enrollment at community colleges and universities with job training programs has also had an impact on resources available to the students. Availability of space for classes and library and lab resources are decreasing as the number of students increase. Time as a resource seems to be the ubiquitous problem to deal with (Wilkerson, 1996). In a community college, time for research that brings in grant money may not be an issue, but the same amount of time is required to research current topics in the discipline to be taught, design effective problems or projects, arrange access to resources, design websites, select class assistants, and so on. So, at community colleges there is much less money coming in from grants, and money is a sorely needed resource for lab materials, field trips, graduate or undergraduate group facilitators, computers, software and so on.

7. Technology

Technology and use of Internet based databases to supplement in-class meetings presents more opportunities for access to information to research problems and projects and communication among members of class groups. Most instructors, regardless of their pedagogical inclinations, see the merit of using Internet resources in their courses, and many are currently supplementing their courses with custom individualized websites (Heppert, 2002; Duch, 2001). Two of the problems that technology might help to solve are (1) the tendency of many tutors to assume too directive a role, complemented by a tendency of students to depend too much on the tutor, and (2) disparities in participation and involvement, resulting in some students dominating the group process.
while others withdraw (Duch, 2001). Any sort of computer conferencing system could be expected to alleviate these problems to some extent. However, studies show that students generally do not like computer conferencing very much and that participation is scanty and hard to maintain (Evensen, 2000). Contrary to popular opinion, there are many students and instructors that have not yet mastered the use of computer technology and may require additional help in that arena of learning.

8. Vocational relevance

There is an increasing worldwide demand for institutional accountability to the public and government from all public and private educational institutions, including higher education. There is also increased demand for curricula with a greater vocational relevance at traditional colleges and universities since there is a much broader social access to higher education than in the past. Many professional schools have combined with traditional higher education in order to share resources. PBL is increasingly seen as a means for students to acquire job related skills in the context of curricula (Maricopa Community Colleges, 2006; Savin-Baden, 2000; Abrahams, 1997). The individual instructors determined to use PBL must evaluate the role of their classes in vocational training and be willing to work cooperatively with the community and do continuing research and individual training to make PBL problems more relevant to the “real world”.

9. Evaluations and Assessment

Most faculty are generally comfortable in testing discipline content, but if PBL instructors are expecting their students to be able to demonstrate that they can think critically, evaluate evidence, analyze information, and justify conclusions, they will need to think beyond standard testing practices, particularly in medium to large size classes. The many questions instructors
must ask themselves about assessment of the students’ learning include: (Fyrenius, et.al., 2005; Duch, 2001)

1) What products will students produce when they complete a problem or project?
2) Will it be an individual or group project? How will it be graded?
3) How can an instructor promote group learning but ensure that individual achievement is assessed?
4) How can a problem-based scenario be used in an exam?
5) Should group participation skills and communication skills be assessed? If so, how?

**PBL In Practice**

In response to reports calling for reform in undergraduate Science, Technology, Engineering and Math (National Science Foundation, 1996) Margaret Waterman from SE Missouri State University and Ethel Stanley from Beloit College, Wisconsin obtained National Science Foundation funding to develop and disseminate new, investigative case-based curriculum modules and pedagogies for introductory biology; to prepare a cadre of faculty in the development and use of these modules; and to examine the effectiveness of the modules in college biology classrooms (Waterman & Stanley, 2005). The result was called the LifeLines OnLine project and was centered around Investigative Case-Based Learning (ICBL) that was originally designed for students taking biology as a general education requirement in 2-year colleges. Software, tools, and resources of the BioQUEST Curriculum Consortium at Beloit College were aligned with problem-based learning methods to produce ICBL, a variant of PBL (Beloit College, 2006). This case-based pedagogy adapted for introductory biology classes fits into Barrow's first four levels of his taxonomy of PBL (Barrows, 1980).
Illinois Mathematics and Science Academy (IMSA), an internationally recognized pioneering educational institution created by the state of Illinois, offers a uniquely challenging education for Illinois students in grade 10 – 12 talented in the areas of mathematics and science. IMSA has identified a continuum of instructional approaches from lecture to problem-based. The instructional approaches are lecture, direct instruction, case methods, discovery-based inquiry, problem-centered learning, simulation and gaming, mantle of the expert (roles), and problem-based learning. ([http://www2.imsa.edu/programs/pbl/cpbl.html](http://www2.imsa.edu/programs/pbl/cpbl.html))

There are increasing numbers of “cases” published for use in the undergraduate and graduate levels of colleges and universities that are available for use by instructors worldwide thus reducing the problem of planning and writing effective problems (Maricopa Community Colleges, 2005; University of Buffalo, 2005). Maricopa Center for Learning and Instruction, providing instructional support for twelve satellite community colleges in Phoenix, Arizona, includes PBL in its repertoire of innovations (Harper-Marinick & Levine, 2002). One model of PBL in Maricopa is Rosemary Leary’s Chemistry 130 class at Estrella Mountain Community College, where she uses problems instead of workbook labs (Leary, 2001). These "problem" labs are scenarios of real life research chemists, although some lectures are still a component of Leary's classes. Also within the Maricopa "family", GateWay Community College restructured its Facilities Systems Technician Associates Degree Program into a PBL format. The students do not take classes but fulfill degree competencies by working in learning teams to solve open-ended problems often encountered in the workplace (Harper-Marinick & Levine, 2002).

Linda Hodges from the McGraw Center for Teaching and Learning at Princeton University describes using PBL or case studies in varying degrees in three different class settings (Hodges, 2005). One setting was a small biochemistry survey course that she taught entirely as problem-based learning.
Another was a small organic chemistry class in which she used some case-based teaching with students working collaboratively in groups. The third setting was a large lecture-style biochemistry survey course in which she used cases as homework and in-class exercises.

The medical and nursing programs at the Faculty of Health Sciences, Linkoping University, Sweden have applied PBL since 1986. The faculty decided to keep lectures as a resource for student learning that could be used to: introduce or summarize an area, elaborate on difficult concepts and phenomenon or to introduce relevant research findings that were not available in students' literature (Fyrenius, Anna, et.al., 2005).

Allegany College of Maryland used grant money to development specific curricula to transform the developmental mathematics curriculum from a thirty year-old non-applied passive learner environment to a curriculum that engages students in active learning situations, rich in meaningful health-related applications using PBL. Faculty and administrators at Allegany College have begun the process of launching a learner centered college by expanding their learning communities, increasing communications between various departments, and thereby increasing personal responsibility, problem-solving and communication skills in the students (Shore & Shore, 2003).

Chapter 3: Methodology

During the following process of creation of the classification outline and continuum levels for each PBL component the researcher discovered similar research called the Concerns Based Adoption Model (CBAM) that was developed in the 1970s at the University of Texas. (Hord, et al., 1987) They designed a very similar way of measuring how teachers use an innovative curriculum and therefore called it the Innovation Configuration (IC) checklist. (Hall, 1992)
Classification Outline

After reviewing existing literature on aspects and implementation of the various forms of PBL the intricacies of determining the extent to which a particular curriculum is problem-based are still unclear. One goal of this study was to synthesize the information on PBL operational components into a continuum that can be used by instructors to determine the extent to which they are incorporating PBL into their curriculum. A local community college instructor’s established introductory biology curriculum was used to develop the continuum within each component. The information obtained was then used to refine the classification into a rubric that can be used by other biology instructors to implement changes to their curriculum.

The defined operational components of PBL chosen to delineate the curriculum continuum are as follows: (p. 9 this document)

1) Curricula organization around problems rather than disciplines, an integrated curriculum and an emphasis on cognitive skills.

2) Conditions such as small groups, tutorial instruction and active learning.

These components lend themselves to analysis in a short-term study such as this. The third area of differentiation that must be present for the distinction of PBL to be valid was;

3) Outcomes such as the development of skills and motivation, together with the development of the ability to be a lifelong learner.

This operational component was not used because it focuses on outcomes, not curricula and would require classroom observations, interviews with students, and follow-up surveys after a significant period of time. It also contains goals that apply to all forms of instruction, not just PBL. The researcher further divided the chosen components into smaller pieces for easier identification.
They are as follows:

1a) Is the curriculum organized around problems rather than disciplines?
1b) Is the curriculum integrated?
1c) What cognitive skills are emphasized?
2a) How are small groups used?
2b) How is tutorial instruction used?
2c) How is active learning used?

These PBL components were changed into statements instead of questions and used to form the skeleton of the classification chart or rubric.

Creation of Component Continuum

The first step used to choose the continuum levels within the classification skeleton was to analyze a copy of the required packet of student notes for the class "Marine Biology" easily obtained from the campus bookstore. The second step was to interview the instructor with questions about how the class notes packet is used, structure of the student-teacher interactions, and what additional pieces of curriculum are implemented. The following analysis of the curriculum is based on a synthesis of the review of the materials and instructor interviews.

The analysis of the student packet began with physical separation of the packet into its basic components. The student packet contains ten units (called Parts) of varying lengths. Each "Part" contains five components. These are labeled: Objectives, Exploration, Topic Introduction, Application, Review Sheet, and Reflections. Interviews with the instructor revealed specific examples of the possible facilitation of the components of each unit (Figure 1).
Figure 1: Chart: Outline of Packet Contents

<table>
<thead>
<tr>
<th>Component of Each Unit:</th>
<th>Examples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Questions to determine previous knowledge</td>
</tr>
<tr>
<td>Exploration</td>
<td>Inquiry labs, Stories, Demonstrations</td>
</tr>
<tr>
<td>Topic Introduction</td>
<td>Outline Notes, Overhead pictures, Discussions</td>
</tr>
<tr>
<td>Application</td>
<td>Inquiry labs, Videos, Demonstrations, Web sheets</td>
</tr>
<tr>
<td>Review sheet</td>
<td>From outline notes</td>
</tr>
<tr>
<td>Reflections</td>
<td>Questions to determine understanding/retention of new knowledge</td>
</tr>
</tbody>
</table>

During implementation of the curriculum the instructor will not always use the objectives, exploration, or reflections component, but all units contain the topic introduction component and review sheet. Only two units do not use the application component, but instead use a lengthy exploration component. The application component usually contains a short outline that suggests what will be done as practice to understand the concepts revealed during the topic introduction section of the unit. These are either guided or unguided activities that include "hands-on" inquiry labs, computer activities, or videos. With the help of the instructor, components of applications used in each unit of the class notes packet for a “typical” class were recorded in Table 1.
Table 1: Student packet classification

<table>
<thead>
<tr>
<th>Packet Units</th>
<th>Examples used</th>
<th>PBL continuum levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A: Marine Biology</td>
<td><strong>Objective question</strong> – What is a key? &lt;br&gt; Exploration - Inquiry lab intro to dichotomous key w/common names &amp; discussion &lt;br&gt; Topic intro - Instant Biology – description of Phyla in outline notes - lecture &lt;br&gt; Review sheet &lt;br&gt; Reflection – why use key?</td>
<td>1a(3) 1b(1) 1c(1) 2a(1) 2b(1) 2c(1)</td>
</tr>
<tr>
<td>Part B: Organization of Animals</td>
<td><strong>Objective question</strong> – How is the human body organized? &lt;br&gt; Topic intro - Outline notes – lecture &lt;br&gt; Application - Lab – individual cell construction – 3D models &lt;br&gt; Review sheet</td>
<td>1a(3) 1b(1) 1c(1) 2a(1) 2b(1) 2c(1)</td>
</tr>
<tr>
<td>Part C: Tides</td>
<td><strong>Objective question</strong> – Can you read a tide table? &lt;br&gt; Topic intro - Outline notes using solar system model &amp; overhead diagrams &lt;br&gt; Application - Tides lab – interpret chart &amp; graph results &lt;br&gt; Review sheet</td>
<td>1a(3) 1b(1) 1c(1) 2a(1) 2b(1) 2c(1)</td>
</tr>
<tr>
<td>Part D: Adaptations</td>
<td>Exploration – Demonstration; human analogy – types of metabolism &lt;br&gt; Topic Intro - outline notes – lecture with overhead diagrams from packet &lt;br&gt; Application - Osmosis lab &lt;br&gt; Review sheet</td>
<td>1a(3) 1b(1) 1c(1) 2a(1) 2b(1) 2c(1)</td>
</tr>
<tr>
<td>Part E: Ecology</td>
<td>Exploration – demonstration using whole class &lt;br&gt; Topic intro – Outline notes using overhead diagrams &amp; drawings &lt;br&gt; Review sheet &lt;br&gt; Reflection – draw individual food webs</td>
<td>1a(3) 1b(1) 1c(1) 2a(1) 2b(1) 2c(1)</td>
</tr>
</tbody>
</table>
### Table 1 continued:

<table>
<thead>
<tr>
<th>Part</th>
<th>Activity Description</th>
<th>Sheet(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part F:</td>
<td>Exploration – demonstrate ecology of intertidal zone using whole class</td>
<td>1a(3)</td>
</tr>
<tr>
<td>Habitats</td>
<td>Topic intro – Outline notes lecture with overhead pictures &amp; drawings</td>
<td>1b(1)</td>
</tr>
<tr>
<td></td>
<td>Application – Cut &amp; paste paper lab matching critters to habitat</td>
<td>1c(1)</td>
</tr>
<tr>
<td></td>
<td>Review sheet</td>
<td>2a(1)</td>
</tr>
<tr>
<td></td>
<td>Reflection – describe different habitats</td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(1)</td>
</tr>
<tr>
<td>Part G:</td>
<td>Topic intro – outline notes – lecture with overhead pictures &amp; drawings</td>
<td>1a(4)</td>
</tr>
<tr>
<td>The Seaweeds</td>
<td>Application – Inquiry lab – identify live &amp; dried seaweeds; web sheets</td>
<td>1b(1)</td>
</tr>
<tr>
<td></td>
<td>Review sheet</td>
<td>1c(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2a(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(1)</td>
</tr>
<tr>
<td>Part H:</td>
<td>Topic intro – Outline notes – lecture – taxonomy of living organisms</td>
<td>1a(5)</td>
</tr>
<tr>
<td>Living</td>
<td>Review sheet</td>
<td>1b(3)</td>
</tr>
<tr>
<td>Organisms</td>
<td></td>
<td>1c(4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2a(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(3)</td>
</tr>
<tr>
<td>Part I:</td>
<td>Topic intro – Student photo packet - lecture notes with overhead photos</td>
<td>1a(4)</td>
</tr>
<tr>
<td>Invertebrate</td>
<td>Application – inquiry labs &amp; edible labs with project spin-offs; web sheets; videos</td>
<td>1b(1)</td>
</tr>
<tr>
<td>Phyla</td>
<td>Review sheets</td>
<td>1c(1)</td>
</tr>
<tr>
<td>(Sections</td>
<td></td>
<td>2a(1)</td>
</tr>
<tr>
<td>A – M)</td>
<td></td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(1)</td>
</tr>
</tbody>
</table>

An example application outline from Part C: Tides follows: (see Appendix 1)

**C-3. APPLICATION**

I. Lab/ Movie/ Project/ Article
   
   A. Do lab labeled Tide Lab (20 points)
23

a. Use the following dates for a spring tide & for a neap tide
   ______________________

b. Do a graph for the above dates.

c. Answer all the questions on the tide lab.

B. Discuss newspaper or magazine articles (10 points/article)

C. Do the review sheet.

After this outline of possibilities there are sometimes a large number of pages in the unit that may or may not be used, depending on further direction from the instructor. Decisions as to what curriculum components are used vary according to time constraints. The instructor readily admits to leaving out some of the components such as web sheets and videos as the quarter nears the end. Additional curriculum components were also identified during instructor interviews and include small group term projects, article reviews, and field trips to the Oregon coast. (Table 2) According to the instructor the article reviews are sometimes left out of the curriculum due to lack of time within the quarter.

What follows is an explanation, including implementation examples, of how the curriculum of the local biology instructor fits into the PBL classification skeleton.

1a) The curriculum is organized around problems rather than disciplines.

There are no challenging open-ended problems presented to the students before they are given any lectures or labs. However, only Unit H within the student notes packet is completely implemented by lecture on discipline content.
Table 2: Additional Curriculum Classification

<table>
<thead>
<tr>
<th>Types</th>
<th>Examples</th>
<th>PBL components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Group Projects</td>
<td>Scientific investigations:</td>
<td>1a(3)(4)</td>
</tr>
<tr>
<td></td>
<td>Sponge re-aggregation</td>
<td>1b(1)</td>
</tr>
<tr>
<td></td>
<td>Anemone food preference</td>
<td>1c(1)</td>
</tr>
<tr>
<td></td>
<td>Flatworm regeneration</td>
<td>2a(1)</td>
</tr>
<tr>
<td></td>
<td>Hermit crab shell selection</td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td>Sea star food preference</td>
<td>2c(1)</td>
</tr>
<tr>
<td></td>
<td>Sea urchin food preference</td>
<td></td>
</tr>
<tr>
<td>Article summaries</td>
<td>Current science literature</td>
<td>1a(3)(4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1b(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1c(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2a(NA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(NA)</td>
</tr>
<tr>
<td>Field Trips</td>
<td>Guided discovery tours</td>
<td>1a(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1b(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1c(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2a(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2b(NA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2c(1)</td>
</tr>
</tbody>
</table>

1b) The curriculum is integrated.

Integrated can mean more than one thing in education. In this case it encompasses two realms of instruction. One realm of instruction is the combination of basic skills that students use in class such as listening,
speaking, observing, participating, and so on, with the science discipline content and the basic attitudes the students bring to a classroom such as curiosity, self-discipline, and respect (Lee, 2004; Dunlap, 2004; Savin-Baden, 2000). The second realm of instructional integration is the combination of many types of discipline content such as earth science, biology, chemistry, math, social sciences, language arts, history and so on (Chin & Chia, 2006; Walton & Mathews, 1989). The instructor manages to integrate all of these elements into her curriculum. During lectures she coaxes the students to listen, observe and participate by moving around the room using stuffed animals and models in a theatrical way to display behaviors of organisms. She personalizes lectures by using students as props for demonstrations and calling on students by name to explain a concept she is demonstrating.

To facilitate a demonstration of deep-sea organisms and their habitat she changes the classroom into a submarine by rearranging the tables and hanging glow-in-the-dark organisms in a darkened room. She also changes the classroom into tidal zones with different amounts of gummy worms, as food sources, available in each zone. Moving the tables into rows called "splash zone", "high zone", "middle zone", "low zone", and "sub-tidal zone" designates the zones. For this construct each student, as they enter the classroom, is given the role of a different intertidal organism and they have to decide what intertidal zone they live in. They can only eat the gummy worms available in that zone if they are correct. This scenario occurs before a lecture on what organisms live in each zone and is linked to understanding the adaptations necessary for organisms to survive in a particular habitat. Intertidal ecology is the overarching curriculum concept.

The labs the students do are usually not "cook-book" labs. They incorporate organism and habitat identification with both live organisms from the "Wet Lab" and photographs of local Oregon organisms taken by the instructor or her students. Field trips encourage participation as experiential outdoor trips (day
or weekend) where students help find and identify organisms and habitats discussed in class. The instructor shares her gray whale research, thereby creating opportunities for the students to identify meaningful science related problems and issues. She brings plankton tow samples to class containing several species of plankton that the resident gray whales near Depoe Bay, Oregon have been observed eating. She involves her students in identification of each species and sometimes during a class field trip on a whale watching boat she will have the students help her do a plankton tow to collect the organisms. Then she shares with them her population estimates of the plankton and her estimates of how much plankton it takes to sustain a gray whale and asks them to infer if there are enough plankton available to do this. They don't actually do the statistics necessary to draw a conclusion, but they give her rough estimates that she then compares with her estimates. In this way she introduces them to an authentic scientific investigation.

The instructor's entire curriculum involves the integration of several types of science and many other disciplines as well. In the marine series she introduces volcanology, geology, cell biology, microbiology, invertebrate and vertebrate zoology, oceanography and climatology. She also introduces the history of commercial fishing, whaling, and conservation. The students are required to use skills in cooperative learning, artistry, writing, computer technology, and oral presentation. This is integration of types of communication and expression of ideas.

1c) Cognitive skills are emphasized.

The cognitive skills emphasized in the instructor’s classes are skills most commonly used in scientific research. They are classification, analysis, inference, prediction, critical reasoning and logic (Lee, 2004; Abrahams, et. al., 1997; Walton & Mathews, 1989). Classification is systematic arrangement into classes or groups. The students are required to develop this skill the most
when learning the taxonomy of organisms, definitions of habitats and forces of nature that effect life on earth. Analysis is the separation of an intellectual or material whole into its constituent parts for individual study and the study of such constituent parts and their interrelationships in making up a whole. The students are required to use this skill the most when doing labs that look at the individual parts of organisms and how they have been adapted for use in a particular environment. Inference is the act or process of deriving logical conclusions from premises known or assumed to be true. The students must infer the classification of organisms by identifying physical traits and use inference to interpret the results of their laboratory investigations. Prediction is reasoning about the future, specifically in situations of forming hypotheses to answer a question or solve a problem. The students are required to predict behaviors of organisms to external stimuli, and the results of the actions of humans on the environment. Critical reasoning and logic are the relationships between elements and between an element and the whole in a set of objects, individuals, principles, or events. The students are required to identify and correlate the relationships between organism's adaptations to their habitats and their relationships to humans and the other organisms that they live with in the food chain.

2a) Small groups are used.

Many of the exploratory demonstrations enlist small groups of students. For example, when introducing the ecology unit six groups of students are given separate food webs to demonstrate. Within each group individual students take the role of producer, primary consumer (herbivore), secondary consumer (carnivore), tertiary consumer (carnivore or omnivore), etc. The students represent these organisms by either drawing or cutting out pictures of the organisms they portray. Then each consumer (predator) must find the correct trophic relationships by linking with strings to their possible food sources, either
producers or other consumers (prey). During labs students work in groups of three or four and are responsible for individual reports, drawings, sculptures, and verbal descriptions of many different concepts. Also, a project is due at the end of the quarter. The students at each table (4-6 students) select one of six investigations to complete. These investigations are introduced as each of six invertebrate phyla is introduced in Part I.

The instructor gives background information on each of the organisms in each of these phyla to the whole class but the specific group of students that selected the topic in question collects background information on the subject, determines how they will collect the data and how to record and display the results. For example Phylum Porifera (sponges) are known to re-aggregate into a whole organism if their cells are separated but kept close together. This information is introduced to the class as a whole but the group of students that chose this “re-aggregation” topic would push an available liver sponge through a sieve, observe through a microscope how the cells reconnect, keep track of formation, and measure growth of the new sponge created from the cells of the original sponge. They also research additional information on the names and functions of sponge cells and sponge ecology. The end product is a Powerpoint presentation to the rest of the class that is used as the grade for the final exam. During field trips small groups of students investigate the structure of intertidal habitat and discover what organisms live there.

2b) Tutorial instruction is used.

The instructor circulates through the room during labs pointing out things she wants them to see or asking leading questions to get them to think about interactions she wants them to identify. She also spends all of her office hours tutoring students and helping groups of students with their projects. The instructor advertises the free tutors that are available in the Science Resource Room, which is a diverse source of help for the entire science department.
Therefore, tutorial instruction is used, or at least available, in all components of the instructor's curriculum.

2c) Active learning is used.

Please see the description under the question 1b (p.24-25 this document). In addition, the students are actively involved in the in-class incubation of salmon eggs and in-stream planting of the salmon fry through the Oregon Department of Fish and Wildlife. Therefore, almost every part of the curriculum has some sort of active learning: labs, demonstrations, projects, or participatory lectures. Also, field trips and group projects are very active. Only the article summaries and Part H are not physically active.

Using information from the literature on PBL and the participant instructor’s curriculum each component of the PBL comparison skeleton was given a continuum of implementation of that component. For example, component 1a: Organization is around problems rather than disciplines; is given five levels of implementation ranging from (1) to (5) (Figure 2). Each component has varying numbers of levels of implementation based partly on analysis of the instructor’s curriculum and partly on possibilities described in the PBL literature. For each component the most “pure” PBL class would have the lowest continuum level and the least “pure” PBL class would have the highest level for that component. Once the classification chart was completed (Figure 2) it was used as a rubric to classify each component of the participant instructor’s curriculum (Table 1 & 2).
**Component 1a: Organization is around problems rather than disciplines.**

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor typically poses a complex, very challenging problem or case to the students before they have studied a subject.</td>
<td>Instructor typically lectures on a particular subject and then presents a complex, very challenging problem or case for the students to solve.</td>
<td>Instructor typically conducts an &quot;inquiry&quot; lab or student participatory demonstration and then lectures on a particular subject.</td>
<td>Instructor typically lectures on a particular subject and then conducts an &quot;inquiry&quot; lab or student participatory demonstration.</td>
<td>Instructor typically presents all subject matter in a lecture format.</td>
</tr>
</tbody>
</table>

**Component 1b: Curriculum is integrated.**

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor combines communication skills (listening, speaking, observing, writing, drawing, interacting) with many types of discipline content (earth science, biology, chemistry, math, technology, social sciences).</td>
<td>Instructor combines few communication skills (listening, observing, writing) with many types of discipline content (earth science, biology, chemistry, math, technology, social sciences).</td>
<td>Instructor combines few communication skills (listening, observing, writing) with few types of discipline content (earth science, biology, chemistry, math).</td>
</tr>
</tbody>
</table>

**Component 1c: Cognitive skills are emphasized.**

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor emphasizes all cognitive skills: classification, analysis, inference, prediction, critical reasoning, and logic.</td>
<td>Instructor emphasizes only certain cognitive skills: classification, analysis, inference &amp; prediction.</td>
<td>Instructor emphasizes fewer cognitive skills: classification, analysis &amp; inference.</td>
<td>Instructor emphasizes the least complex cognitive skills: classification &amp; analysis.</td>
</tr>
</tbody>
</table>
**Figure 2 continued:**

**Component 2a: Small groups are used.**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Instructor uses small groups for all aspects of the curriculum: lecture, labs, projects demonstrations, &amp; field trips.</td>
<td>(2)</td>
</tr>
</tbody>
</table>

**Component 2b: Tutorial instruction is used.**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Instructor encourages student study groups, conducts personal and group review sessions with her &amp; promotes free individual tutoring through the Science Resource Center.</td>
</tr>
</tbody>
</table>

**Component 2c: Active learning is used.**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Instructor uses many types of active learning: participatory lectures, instructor designed inquiry labs, small group projects, whole class demonstrations, &amp; field trips</td>
<td>(2)</td>
</tr>
</tbody>
</table>
Chapter 4: Discussion and Conclusion

Local Findings

When taken as a whole, the curriculum of the participant community college instructor is predominantly on the end of the continuum (1) for each component that represents the "purest" form of PBL. The one exception is component 1a where the curriculum is further to the middle (3 & 4) of the continuum. The component of the instructor's curriculum that most resembles PBL is the group projects. However, these projects more truly resemble open-ended inquiry or discovery-based inquiry. According to information obtained from the instructor there is ample support from the faculty and administration in the science department at Lane Community College to facilitate problem-based learning. Adequate free tutoring is accessible in the Science Resource Room, although this resource is directly connected to budget shortfalls and there are no tutors available to the instructor as facilitators within the classroom during group activities. As discussed in the literature review, one of the main problems to deal with in implementation of PBL is the planning, writing and scheduling of effective problems or cases. During talks with the instructor she communicated a reluctance to try designing her own problems or integrating existing problems that fit her existing curriculum mainly because of lack of student acceptance. After teaching the same classes for fourteen years she feels that the non-majors 100-level biology classes do not recruit students with adequate prior knowledge in science or experience in this level of education to be successful dealing with the level of independent research that is required with "pure" PBL. Regardless of this, she does use many of the operational components that define PBL.
Significance

In their efforts to improve the quality of their instruction, many instructors will try various types of inquiry-based methods, including PBL. Each instructor must take into account the various challenges to making changes and decide what their teaching/learning goals are for each particular class in which they want to facilitate PBL. That is, what do they want to accomplish by using PBL or a case study? Some instructors will have more support within their departments to make curriculum changes than others, so any short cuts to assessing their curricula for places to include PBL will be essential to save valuable planning time. One such short cut could be the PBL Classification Rubric designed as a result of this study (Figure 2). Like the proverbial picture that's worth a thousand words, a chart with easy-to-read labels will make it much easier for an instructor to use. The components of the rubric are broad enough to be applicable to many disciplines. The continuum levels of each component could easily be adjusted on an individual basis depending on discipline content and available instructional resources of the department.

A comparison chart called "Current Understanding of Inquiry-guided Learning" was constructed by North Carolina State University to provide guidance to instructor's wishing to integrate inquiry in their curriculum (Lee, et. al. 2004). It compares various cognitive skills and educational learning strategies with types of implementation an instructor might choose to use in the classroom (Figure 3). However, it is geared for use in professional administrative educational development and would be confusing to use without explicit instruction. Most instructors at college and university level are specialists in their disciplines, not in educational strategies or curriculum development. The PBL Classification Rubric is designed with easily identifiable terms that any instructor can understand.
The Innovation Configuration Checklist (IC Checklist) described by Hall (1992) was used as a tool to determine how classroom teachers use curriculum innovations. This tool closely resembles the PBL Classification Rubric designed as a result of this study (Figure 2) because the operational features or parts of the innovation are called components and within each component, several variations are possible. A recent revival of the IC Checklist is described by the president of Champion Training & Consulting (Figure 4), an organization that contracts with administrations of school districts around the country to measure usage of classroom innovations and train teachers to use IC checklists in their classrooms (Champion, 2003). However, the PBL Classification Rubric (Figure 2) is unique in that it focuses specifically on PBL and is designed for use by individual instructors without explicit instruction required.
High school initiative to increase student reading comprehension.

<table>
<thead>
<tr>
<th>Ideal</th>
<th>Some Progress Made</th>
<th>Unacceptable</th>
</tr>
</thead>
</table>

**Component 1: Reading focus in daily instruction in core classes**

| Every teacher of English, Social Studies, mathematics, & science incorporates a variety of comprehension strategies into daily instruction to help student strengthen their reading comprehension skills | Some teachers of English, Social Studies, mathematics, & science incorporate a variety of comprehension strategies into daily instruction | No teachers of English, Social Studies, mathematics, & science incorporate a variety of comprehension strategies into daily instruction |

**Component 2: Emphasis on vocabulary building in all classes.**

| Every teacher incorporates vocabulary building into daily instruction | Some teachers incorporate vocabulary building into daily instruction | No teachers incorporate vocabulary building into daily instruction |

Instructors can use the PBL Classification Rubric (Figure 2) as a personal tool or as a tool to guide them to obtain goals stipulated by their administration. As they score each unit of their curriculum they will see places where they are already doing a little or a lot of PBL and they will see places where they aren’t doing any PBL. As it stands the Rubric does not have stipulations for what is “good” or “bad”. There may be parts of any curriculum that will not be an easy fit for PBL. If an administrator is requiring that all instructors will move their curriculum towards “pure” PBL, then these parameters such as “Ideal”, “Some Progress Made” and “Unacceptable” could be added.
Few instructors enjoy teaching courses in which students are uninterested and possibly resentful of the time they spend there. Interesting and relevant problems or cases can be used as a "hook" to entice students to take ownership of their own learning process. If students become engaged in the problems and find the class material more meaningful, then it becomes a win-win situation for both the instructor and the student. Tools such as the PBL Classification Rubric can assist instructors in making a transition to PBL easier. Hopefully it will inspire other instructors to create their own versions of the tool and pass the information on to others. Anything we can do to make education more interesting and relevant will expand the desire for increased education that may help students as prospective employees and entrepreneurs survive and flourish in an increasingly complex world.

**Further research**

Some directions for future research at community college level include the use of the PBL Classification Rubric by more instructors and analysis of how each instructor’s specific curriculum fits into the PBL continuum. Each study should include classroom observations, student and instructor surveys and interviews, possible classroom videotaping, and follow-up surveys and interviews of student and instructor attitudes regarding PBL. Studies of this complexity would require funding from a grant or other outside source to facilitate faculty release time for curriculum development. By using the instrument of analysis designed for this study (Figure 2) in additional community college classrooms transferability of the current study could be established (Miles & Huberman, 1994). This means that techniques used in one study are easily adaptable to another study.
Limitations

Possible instructor variations in presentation of curriculum are what led to the continuum levels in the design of the PBL Classification Rubric (Figure 2). Although the physical content of the student notes packet stays the same, the order and complexity of presentation may change. At the beginning of each quarter the instructor asks pointed questions to determine the previous knowledge of the class as a whole. This information may change how she presents the curriculum, which would change the scoring variable of each component of the curriculum. The first three components (1a, b, & c in Figure 2) used in this study would be the most affected. This could change the outcome of the “ideal” measurements recorded in Tables 1 and 2 of this document. The recorded measurement of component 1a is already either (3) or (4) depending on what the instructor decides to do on a class-by-class basis. If she feels the students are not ready to understand an inquiry lab before they are given a certain amount of information about the topic, she will give a lecture first. This variability is hard to predict by just analyzing the student notes packet. Therefore, the instructor could also, on a class-by-class basis, vary the level of integration and the number of cognitive skills emphasized. This may not be done by the instructor in a conscious manner, but may lead to a certain amount of subjective bias in this study, which may be considered a limitation of this study.

A weakness in the PBL Classification Rubric may exist in the fact that it is trying to establish a continuum of PBL rather than a strict, easily measurable set of standards. In and of itself, a continuum suggests a blurring of the edges of the definitions of what is or is not PBL. That has been the problem with pinning down operational definitions. Also, it can be said that only component 1a: “Organization is around problems rather than disciplines” really sets the continuum for PBL, but according to the literature PBL is a type of inquiry-based learning and the other components must be included.
Another possible limitation of this study was the exclusion of the third area of differentiation that must be present for the distinction of PBL to be valid: Outcomes such as the development of skills and motivation, together with the development of the ability to be a lifelong learner. To include these components would require classroom observations, interviews with students, and follow-up surveys after a significant period of time. Since this study focused on analysis of established curriculum these components did not fit the scope of this study. These outcomes are also not specifically limited to PBL or inquiry learning.
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Appendix 1 - Sample of student packet: Part C - Tides (Newell, 2002)

MARINE BIOLOGY

PART C: TIDES

C-1. EXPLORATION

I. Tides

A. What are tides?
B. How are tides formed?
C. What is meant by a low tide?

C-2. TOPIC INTRODUCTION

I. Tides

A. Definition = _______________________

B. Caused by the

1. The moon, though smaller than the sun, exerts a stronger pull because it is so much closer to the Earth; i.e. sun has only 46% the amount of pull as the moon
2. The moon's force is more than _____ that of the sun
3. The gravitational attraction of the moon pulls ocean water nearest it away from the Earth and at the same time pulls the Earth away from the water farthest away and this results in two equal tidal bulges on opposite sides of the Earth
4. Tidal bulges caused by
   a. __________________________
   b. __________________________

C. Factors causing variation in the tides

1. Interaction of sun and moon
   a. Spring tides
      1) When the sun and moon are in line with the Earth, ______________________
         larger than normal tides result from their combined action and these
greater tides are known as Spring Tides
      2) Spring tides about 20% > average tidal range
   b. __________________________
      1) When the sun, Earth and moon are at right angles, ______________________
         Neap Tides result
      2) Neap tides 20% < average tidal range
   c. Two spring and two neap tides occur each month
   d. The sun’s effect is to ______________________, either to ↑
      the range of tides or to hold them back
e. Tides are ___ minutes later each day because the Earth has to "catch up" the distance the moon moves in its own orbit each day.

2. Effects of elliptical orbits
   a. Once each month the moon passes through points nearest and furthest from the Earth.
      1) Perigee = __________
      2) Apogee = __________
      3) Tide range ↑ when the moon passes through perigee
      4) Tide range ↓ when the moon passes through apogee
      5) Twice each month the moon is at perigee, its closest position to Earth and tides are greater; when at apogee, its furthest position from the earth, the moon's effect is least.
   b. As the Earth moves about the sun, a similar situation occurs - only yearly
      1) Perihelion = __________
      2) Aphelion = __________

3. Angular relationship
   a. Definition of declination =
   b. At maximum declination, the moon's attractive force is unevenly distributed with respect to equator
   c. Effect is to cause a difference in the heights of succeeding high waters and succeeding low waters in the same day
   d. Diurnal inequality (D.I.) = __________
   e. D.I. at maximum when maximum declination produces ______ tides.
   f. D.I. at minimum when minimum declination produces ______ tides.

4. Meteorological effects
   a. Wind can cause a mass of water to increase or decrease the height of a high or low tide depending if the winds onshore or offshore winds.
   b. Barometric pressure, ____ pressure raises water levels and ____ pressure lowers water levels.

D. Types of Tides
   1. If during a lunar day (_______), there occurs only _______
      a. Most pronounced during maximum declination; i.e. N Gulf of Mexico and SE Asia
   2. Characterized by _______
      a. Most common; i.e. East coast of U.S.
3. a. Characterized by

b. Diurnal inequality affects it by changing declination of moon; i.e. West coast of U.S., Alaska and Hawaii

E. Tidal Currents
1. Flood current, water flows _____ land
2. Ebb current, water flows _____ land

F. Oregon Tides
1. _____ tides are the type of tides in Oregon
   a. The moon’s orbit is offset from the Earth’s equator by 23.5° and therefore the Oregon coast experiences a procession of unequal tides spaced approximately _____ hours apart
   b. These tides move northward up the coast; i.e. Coos Bay has high and low tides approximately 20-30 minutes earlier than those on Columbia River
   c. Cycle each day as a higher high tide then a lowest low tide, then a lower high tide and finally a higher low tide before returning to another higher high tide

2. What is the range of tides in Oregon?
   a. Tide varies but less in south
   b. Range varies from +10 feet to -3 feet = a vertical displacement of 13 feet

3. When do Oregon’s highest and lowest tides occur?
   a. Largest diurnal inequality occurs in June (______) and July and in December (______) and January (summer solstice is when sun reaches northernmost point and winter solstice when sun reaches southern most point)
   b. Earth closest to sun during December, producing highest tides of year
   c. Lowest tides of the year generally occur in summer

4. Tides in estuaries and bays
   - Land masses _____ water movement and may delay the tide in different areas

C-3. APPLICATION

I. Lab/Movie/Project/Article
   A. Do lab labeled Tide Lab (20 points)
      a. Use the following dates for a spring tide and for a neap tide
      b. Do a graph for the above dates
      c. Answer all the questions on the tide lab
   B. Discuss newspaper or magazine articles (10 points/article)
   C. Do the review sheet
TIDE REVIEW SHEET

1. What is a tide? ____________________________

2. What causes the 2 tidal bulges?
   a. ____________________________
   b. ____________________________

3. Explain 2 differences between Spring tides and Neap tides.
   Spring Tides                                  Neap Tides
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

4. Tides are ____________________________.

5. Define:
   Apsides
   Apogee
   Perigee
   Apoapsis
   Periapsis
   Perihelion
   Apollonides
   Apogee
   Perigee
   Apoapsis
   Periapsis
   Perihelion

6. Name the 3 types of tides and draw a picture of each tide type that represents one day.
   a. ____________________________
   b. ____________________________
   c. ____________________________

7. What types of tide does the Oregon Coast experience? ____________________________

8. What is the tidal range along the Oregon coast? ____________________________

9. What do Oregon’s highest and lowest tides occur? ____________________________

10. What 6 factors, if multiplied together, would cause extremely low tides?
    a. ____________________________  €  ____________________________
    b. ____________________________  €  ____________________________
    c. ____________________________  €  ____________________________

11. What is meant by exposure? ____________________________

12. How do you raise tides, exposure and distribution of organisms? ____________________________
Phases of the Moon

The Two Tidal Bulges of the Earth

APOGEE and PERIGEE

Twice each month the moon is at perigee, its closest position to earth, and the tides are greatest. Twice each month the moon is at apogee, its farthest position from the earth, and the tides are least during this period.

Perihelion and Aphelion

Over per year the earth is at perihelion and the days are shortest and once each year the earth is at aphelion and the days are longest.
TIDE LAB

INTRODUCTION:

The shallow margins of the sea are strongly affected by the tides. On the coast of Oregon the vertical change in water level is as great as 13 feet. In some parts of the world, the Bay of Fundy for instance, the high tide mark is 50 feet above the low tide mark. Such large scale movements of water profoundly affect the seashore and its associated organisms. Strong seaward and shoreward currents accompany these tidal changes. The height of waves approaching the shore are altered. The very nature of the shore environment itself is changed.

Whether you plan to go clamming, tidepooling, picnicking or boating on the coast, a knowledge of the tides is essential, not only for your enjoyment but for your safety as well.

The easiest way to find out when it will be high tide or low tide is to consult a tide table. Most tide tables are similar in appearance but they may differ slightly in layout; they all list times and heights of the tides. The times listed indicate when the water will reach its highest point (high tide) and when it will reach its lowest point (low tide). Zero (0) is the average of the low times and the heights indicate how far above (+) or how far below (-) zero (0) the water will be. Most tide tables give the height in feet (f) and the time in hours (h) and minutes (m). Examine your tide table: it can be used to plan your own excursions to the coast.

When looking for intertidal organisms, you must know what is meant by the intertidal zone. The intertidal zone is the area from the highest high tide to the lowest low tide. The subtidal zone is the area below the lowest low tide - it is never exposed to air.

A. GRAPH OF TIDAL VARIATION

When you look at a tide table, it is difficult to visualize how it represents the rhythmic motion of the water on the shore. In this exercise we will use graphing to visualize two rhythmic patterns; the daily rhythms of high and low tides and the monthly rhythms of spring and neap tides. We will graph three days of spring tides and three days of neap tides. This will give you practice reading the tide table and a better understanding of how to interpret the numbers in the tide table.

Prepare your graph according to the following steps.

1. Use the special graph paper provided. The vertical axis should be labeled HEIGHT and the horizontal axis should be labeled TIME with hours written for a 24 hour clock avoiding the use of AM and PM designations. The two sets of three days worth of tides should be plotted on the same graph so that you may easily make comparisons of the daily and monthly rhythms.

2. Locate the days on the tide table. Now, make a point on the graph for each of the tides occurring on each day. Note: each point will represent either a high tide or a low tide. The point is placed on the graph in a position that is straight across from the tide's height value on the height scale and directly above the tide's time value on the time scale. If you are unfamiliar with graphing, ask for help, you will learn this quickly.

3. Next, connect each point with a line; the lines should be slightly rounded at the peaks and valleys.
4. Finally, crosshatch the area under the curved lines. The crosshatched area represents the water, showing the extent it covers the shore at different times. You now have a visual representation of tidal variation.

5. Repeat this process on the second half of the graph for three more days: ________________

QUESTIONS:

1. Is the zero tide mark the average of the high and low tides? Explain.
   (Read Introduction)

2. Will there be any days with fewer than 4 tides? Why?

3. What is the intertidal zone?

4. What is the subtidal zone?

5. What is the highest high tide and lowest low tide on your graph?

B. EXPOSURE TIME

Compared to the terrestrial environment, the oceans are remarkably stable. Temperatures in the ocean off Oregon may vary as little as 10 degrees throughout the year. The salt content, and thus the osmotic stress on marine life, shows almost no measurable variation. Other factors such as oxygen, acidity, and density are remarkably constant for any given spot in the ocean. However, in the shallow waters, the extremes experienced on land make themselves felt.

Nowhere is this more apparent than in the intertidal zone. Aquatic animals in the intertidal zone are subjected to the extreme conditions of the land environment during the ebbing of the tides. Most notably, winter temperatures may be low enough to freeze the intertidal organisms while summer temperatures may cook them. Osmotic conditions in the summer cause drying of the organism’s tissues (desiccation) while rain causes water to flood into the tissue, bursting the cells.

To survive in the intertidal zone, aquatic organisms must be equipped with adaptations for surviving exposure to extreme conditions; those creatures without these adaptations simply don’t survive. Thus, the structure of the intertidal ecosystem is partly determined by tidal rhythms that produce the variation in exposure.

To examine the variation in conditions stressful to aquatic life, we will compute exposure time for different intertidal levels. By exposure time, we mean exposure to terrestrial conditions. The steps listed below will lead you through the calculations.

1. On the graph you made of tidal variation, place your pencil on the 7 foot mark of the vertical axis. Draw a horizontal line from this point across your paper to the right hand margin of the graph.

2. Portions of the line you’ve just drawn pass through the crosshatched region that symbolizes water; the remainder of the line is ‘out of the water’. The lengths of the line segments ‘out of the water’ are proportional to exposure time (they run along the time axis). To calculate exposure time all you have to do is measure these line segments with a ruler. Here’s how:

   a. Measure each line segment across your graph at the 7 foot mark that is ‘out of water’ for the entire graph.

   b. Add the lengths of individual segments that are ‘out of water’ = (b) for the entire graph.
c. Measure the length of the entire line you’ve drawn at the 7 foot mark = (c) for the entire graph.

d. Now, divide the result in "b" by the result in "c" and then multiply by 100:

\[
\frac{b}{c} \times 100 = \% \text{ exposure}
\]

This calculation gives the percent of the total time that an organism living at the 7 foot mark would be exposed to terrestrial conditions (based upon our 6 day graph).

3. Record your result in the table below.

4. Now, calculate the exposure times for organisms living at the 4 foot mark and for those living at the 1 foot mark. Record these values in the table below.

5. Look at the 10, 8, -1, and -2 foot marks. You should be able to estimate the percent exposure at these heights without calculation. Record the estimates in the table below.

<table>
<thead>
<tr>
<th>TIDE LEVEL</th>
<th>-2</th>
<th>-1</th>
<th>1</th>
<th>4</th>
<th>7</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPOSURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Plot the data from the table above on the graph below and connect the points with a smooth curve:

QUESTIONS:
1. Explain how intertidal organisms differ from subtidal organisms.
2. Which tides represent the greatest hazard to intertidal life? Why?
3. What is exposure and what do organisms do to prevent dehydration?
4. How do intertidal organisms differ from land organisms?
OBJECTIVES & REFLECTIONS SHEET - PART C