

THE EFFECTS OF INQUIRY-BASED TEACHING ON ATTITUDES,  
SELF-EFFICACY, AND SCIENCE REASONING ABILITIES OF  
STUDENTS IN INTRODUCTORY BIOLOGY COURSES AT  
A RURAL, OPEN-ENROLLMENT COMMUNITY COLLEGE.

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## CHAPTER 1

### Introduction

Since the publication of such works as *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996), there has been interest in reforming the way science is taught in primary and secondary schools. More recently, with the publication of *Beyond Bio 101* (Olson, 2000), and *BIO 2010: Transforming Undergraduate Education for Future Research Biologists* (NRC, 2003), there has been interest among college science faculty to reform teaching of introductory biology courses in higher education institutions to improve scientific literacy and to better train K-12 teachers. While the number of studies investigating the effectiveness of various teaching methods has grown considerably in the last 10 years, few have focused on inquiry-based teaching at the community college level.

This study investigated whether an inquiry-based approach, either in lab alone or in lecture and lab, positively affect community college undergraduates' attitudes toward biology, their biological self-efficacy, and their scientific reasoning skills. These three measurements were chosen because others have found that these factors are positively associated with such outcomes as increased retention in the biological sciences, understanding of biological concepts, and skills necessary for biologists – characteristics of scientific literacy.



Unique to this study are: a) the combined use of three different instruments designed to measure three distinct variables that may influence students' progress toward scientific literacy; b) its focus on the community college level; and c) its comparison of teaching methodologies (traditional lab and lecture, traditional lecture and inquiry-based lab, and inquiry-based lab and lecture).

### ***Scientific Literacy***

With mounting evidence that a majority of United States citizens are not scientifically literate, the National Research Council (NRC) proposed the National Science Education Standards (NSES) in 1996. These standards, targeted for K-12 students, outlined goals that every school science program should achieve. They are used as criteria to judge quality science education (NRC, 1996). The goals for the NSES (NRC, 1996) include enabling students to: a) experience and understand the natural world; b) appropriately use scientific processes and principles when making personal decisions; c) intelligently engage in debate about scientific and technological matters that are public issues and d) increase their economic productivity through the use of their own knowledge, understanding, and skills of scientifically literate individuals. Similarly, the American Association for the Advancement of Science (AAAS) set standards for a scientifically literate individual (1990):

...[a] person...who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes.

The above goals define how the NRC and the AAAS characterize a scientifically literate society. More recently, similar goals have been defined for science literacy at the

college level with the publication of *College Pathways to the Science Education Standards* (NSTA, 2001). This publication brings the need to promote scientific literacy in our colleges and universities to center stage. Estimates of Americans that are scientifically illiterate are as high as 90% (Maienschein, 1998). The NSES (1996) defines scientific literacy as an individual with the “knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.” Similarly, Maienschein (1998) defines someone with *scientific* literacy as a productive member of society who can engage in scientific ways of knowing and thinking critically and creatively about the natural world. This is contrasted with Maienschein’s definition of someone with *science* literacy, which refers to being a productive member of society who possesses science skills and facts. Science literacy focuses primarily on gaining units of scientific or technical knowledge.

This distinction, although subtle, is significant. For example: a person with science literacy may know how to use a micropipette, other scientific equipment, know the chemical makeup of a cell membrane, or how to perform a given procedure such as gel electrophoresis. However, a person with scientific literacy would be able to identify and solve novel problems in situations encountered in the natural world: thinking as a scientist. Thus, science literacy and scientific literacy are not equivalent; their difference can be seen as the difference between knowing the facts and knowing how to use those facts within a context to answer a question or solve a problem.

Many educators today, especially those that continue to teach in the traditional manner, may be producing students who are more *science* literate, than *scientifically*

literate. Many believe that the methods of instruction that are currently used, along with current texts actually impede progress toward scientific literacy (AAAS, 1990).

Traditional practices emphasize the learning of answers not exploration of questions, memory at the expense of critical thought, and bits and pieces of information at the expense of understanding within a context (AAAS, 1990). Traditional practices also fail to encourage group work and the sharing of ideas and information (AAAS, 1990). In short, current curricula are “overstuffed and undernourished” (AAAS, 1990).

While Maienschein (1998) proposes that being proficient in both science and scientific literacy is going to produce the most effective individual, the NSES provides a framework for programs that produce a more scientifically literate society, and not just a society of science literate citizens. To achieve these goals, a major shift in how we teach science in our schools must take place. We must find what is essential to scientific literacy and teach that more effectively, not simply teach more content (AAAS, 1990).

### ***Call for Reform***

At a time when the field of biology has gone through many changes and rapid expansion (Hurd, 2001), we continue to educate future scientists in an ineffective manner (Wyckoff, 2001). A full 86% of faculty, in one study, reported lecture as their primary mode of instruction (NRC, 2003). Lectures persist because, not only are they traditional, but they appear to be cost-efficient and expedient (Wyckoff, 2001). Yet lectures may be one of the largest limiting factors in the quality of science education (Wyckoff, 2001). Despite the call for “science for all citizens” and increased scientific literacy for all Americans (NRC, 1996), there is general apathy for revitalizing the way we teach biology (Moore, 1993). In an age where science and technology are tightly intertwined

with findings and applications of science, we still find that only about 20 percent of United States' citizens have a grasp of many important scientific concepts (Holton, 1999), such as evolution. While there is high interest in scientific news and events, there is low understanding of scientific concepts by the general public (Holton, 1999). Such findings underscore the need for science education reform.

The call for changing the way we teach the sciences is not new. There has been an imperative for scientific understanding from antiquity, when Plato urged the study of mathematics (Holton, 1999), to Benjamin Franklin's attempt to improve the common stock of knowledge of citizens through the founding of the American Philosophical Society (Hurd, 2002). James Bryant Conant, then President of Harvard University, noted in *On Understanding Science* that every citizen should understand the "Tactics and Strategy of Science," best achieved by studying "examples of science in the making" (p. 13). In this view of scientific literacy, it is not knowing facts and laws, but understanding what it is that scientists really do that is important (Conant, 1947).

There have been many recent attempts at a national imperative for changing the way we teach science including: *Science for All Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993). These two works are a part of AAAS's Project 2061, a long-term initiative and set of tools to help in the reform of K-12 natural and social science, mathematics and technology education. The NSES (NRC, 1996), were designed to guide our nation's schools to produce a scientifically literate society, provide a framework of what a scientifically literate person should be, and a set of criteria for science education that will allow the fruition of this idea (NRC, 1996). The Howard Hughes Medical Institute's *Beyond Bio 101: The Transformation of Undergraduate*

*Biology Education* (Olson, 2003) is an assemblage of online documents of the experiences of many instructors at 220 colleges and universities. It chronicles what changes have already taken place in undergraduate education and their importance to creating a scientifically literate society. Finally, the NRC's: *Bio 2010*, (NRC, 2003) is a recent call to transform undergraduate biology education to actually focus on teaching all biology undergraduates as if they were all going into biomedical research. Teaching students in this manner will not only give students the facts, but the context behind those facts (NRC, 2003).

Does how we teach science affect our success in helping students become scientifically literate? There is concern and mounting evidence that teaching students in a traditional lecture-style format is an ineffective method for producing a scientifically literate citizenry (Wyckoff, 2001; Bishop, 2002). In one study, the teaching methods of four different instructors of chemistry were examined. The instructors ranged from inexperienced to seasoned, and from those faculty who were research-oriented to those whose primary focus was teaching. There were no significant differences in class grade point averages between the four chemistry classes. This suggests that differing lecture styles have no bearing on student success (Birk & Foster, 1993).

Furthermore, when a subset of these students was tracked into the second semester class, the student's performance in the first semester of general chemistry turned out to be the best indicator of success in the following semester, not which instructor they had previously. In addition, mean test scores did not correlate with attendance, further supporting the notion that lectures have little effect on student learning. Feynman (1963) after teaching physics in large lecture halls and lamenting on the low level of feedback

from students, concluded that, “It’s impossible to learn very much simply by sitting in a lecture, or even by simply doing the problems that are assigned.” However, other studies still find a correlation between attendance and success (Burdge & Daubenmire, 2001). Interestingly, Moore (2003) clearly showed a positive correlation between attendance and grades in an introductory science class; however, Moore did not rely on lecture, but on collaborative work, discussions and writings.

The NRC (2003) contends that the way students are taught and learn biology is as equally important as the content of the material. The NRC goes on to state that lectures often fail to keep the attention of some students. Even when they use ingenuity and an engaging lecture style, lecturers still find that only a few students are able to demonstrate an improvement in their scientific reasoning and literacy (Wyckoff, 2001). In short, lectures may be effective in the conveyance of facts, but do not foster critical and creative thinking – necessary characteristics of a scientifically literate society.

There are other reasons to change the way we teach science in our schools. While the problem of scientific illiteracy is a major concern, so too are attrition rates from science courses and scientific fields. Students, who start their academic careers as self-professed science majors, leave scientific fields at an alarming rate. Seymour & Hewitt (1997), found a 50% attrition rate for biology and the physical sciences regardless of student academic performance. They concluded that neither student motivation nor lack of preparedness determined which students left the sciences. The most common complaint as to why students lost interest in the sciences was poor teaching by science faculty.

Other faculty view introductory biology as a “weed-out” course to show students that *think* they want to be science majors just what it takes to be a scientist. In fact, many of these courses do not even touch on the idea of what it means to be a scientist. These courses instead tend to be expository in nature and overwhelm students with an impressive array of disjointed facts devoid of any meaningful context. These courses leave the wrong impression on students that would otherwise have been interested in the sciences. Students that stay in the sciences after these types of courses are simply better able to cope with poor pedagogy than those who leave (Seymour & Hewitt, 1997).

Introductory science courses are populated with students with a wide range of abilities, motivations, interests, and preparation. In open-enrollment institutions, there are many non-traditional students that have had a substantial break in their educational training. Instructors should be aware that these courses are perhaps a student’s first exposure to science courses, and possibly to a higher educational institution. Difficulties or failure at this early stage can have adverse effects on subsequent performance and on retention. Many students leave the sciences because of a negative experience (Brand, 1995). When asked why they left the sciences, students often cited that they were bored by all the memorization of jargon required and the lack of connections (Brand, 1995).

Other instructors think that introductory biology courses should show students what is interesting about science (Bierzychudek & Reiness, 1992). This attitude accompanies a different approach to teaching introductory biology. Instead of teaching a broad array of topics at a shallow depth, these courses cover a few topics at a depth that allows the instructor to emphasize the connections between biology and society (Bierzychudek & Reiness, 1992). These courses allow non-majors, as well as majors, to

discover why it is important to study and understand science. Science majors will have an opportunity to visit other topics in depth when they take upper-level courses (Bierzuchudek & Reiness, 1992).

There is also great concern that the pool of future scientists is decreasing (Hufford, 1990). The NRC (2003) also shows a gap between the number of jobs for biological and medical scientists and the numbers of students graduating with life science degrees. Hufford, (1990) suggests that the problems we face in science education are not based in the curriculum taught, but in students themselves and that it is impossible to make students scientifically literate if they see little benefit of or need for such knowledge. He recommends that we show students the benefits of being scientifically literate, and focus our attention on changing students' and the nation's attitudes, not only to the sciences, but to education in general, because only when we have educational receptivity, can we attempt to achieve scientific literacy.

### ***Teaching Models***

Teaching methods employed in science education can be partitioned into two broad categories: 1) the behaviorist-learning model, and 2) the constructivist-learning model.

The behaviorist model underlies traditional, teacher-centered, or lecture style classes. This model is teacher-centered - knowledge flows one-way, from the teacher to the student (Llewellyn, 2002). In the behaviorist model the teacher sees learning as observable changes in behavior (Llewellyn, 2002). In a behaviorist classroom, the instructor breaks the curriculum into smaller pieces of information, then evaluates the student based on how the student demonstrates understanding of the new knowledge



(Llewellyn, 2002). This learning model has dominated educational institutions for the past century. The behaviorist teacher sequences learning events from simple to more complex, in effect, the instructor believes that learning can be predicted and controlled. Typically the student's mind is seen as a blank slate, or empty vessel, ready for the teacher to fill. The assessments that instructors use with this style of teaching reward students when their level of knowledge becomes similar to the instructor's own (Leonard, 2000). The student is treated as a passive participant.

The constructivist-learning model is a cognitive one in which knowledge is not transferred on a one-way path from teacher to student. Instead, what is transmitted is communication; this in itself is not knowledge. Knowledge is, instead, constructed in the students' mind, based on prior experiences, conceptions, and understandings they bring to the lesson (Llewellyn, 2002), hence it is student-centered. When teaching is based on this model, it is most important to discover what students already know and teach them accordingly (Ausubel, 1968). Constructivist teachers provide experiences where students can work cooperatively with their peers to test their understanding of material. The student is an active participant in the learning process and searches for meaning by linking prior knowledge to new ideas and information (Llewellyn, 2002).

The constructivist theory is based on the notion that the student already has knowledge of the subject, based on their experiences, constructed into cognitive representations (Kelly, 1955; Piaget, 1970). These mental models allow the learner to actively interpret and assess phenomenon and incoming information (Piaget, 1970). Mental models are created in light of the ways an individual sees the world (Kelly, 1995) and the creation of a mental model is something done by an individual to fulfill their own

needs (Bodner, et al., 2001); the world does not create them for the individual. Therefore, a student's knowledge may be inconsistent with that of an instructor's (Osborne & Wittrock, 1983), as these mental models are often naïve, incomplete, and imprecise (Piaget, 1970). In other words, the student already has beliefs about the natural and technical world prior to being taught about them.

As individuals develop, they interact with the world around them, and develop understanding through observation, inquiry and discovery (Llewellyn, 2002). Students formulate their own understanding and interpretation of the world and then view the world through their own "personal lenses" (Llewellyn, 2002). When students encounter something novel or something that does not fit into their current mental model, the model may be reformed to fit this new knowledge. This new knowledge may be incomplete or a misconception. The general idea is to find out what the students think and challenge their misconceptions. It is only through doing this, that the student will construct new knowledge (Llewellyn, 2002) or revise a mental model (Kelly, 1955).

According to Piaget (1970), new learning occurs when a mental model is adapted. Adaptation occurs through a process of assimilation and accommodation. Assimilation involves using new information and transforming new knowledge to fit existing mental models. Accommodation involves modifying previous mental models to accept or fit the newly perceived knowledge. Adaptation happens when learners encounter phenomena contrary to their presently held understandings, and make adjustments in their mental model (Piaget, 1970). When learners experience new phenomena that do not fit neatly into their presently held mental models, disequilibrium occurs (Piaget, 1970). The learners will then go through the process of assimilation and accommodation to adapt

their mental models to bring about equilibrium, where all is well with the world. Piaget maintained that for conceptual change to occur, the learner must be faced with new conceptions that are inconsistent with present mental models.

*How People Learn: Brain, Mind, Experience, and School* (NRC, 1999) outlined these findings:

1. Students come to the classroom with perceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom.
2. To develop confidence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework and (c) organize knowledge in ways that facilitate retrieval and application.
3. A “metacognitive” approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

Metacognition is the process of thinking about thoughts, for example: being aware of how people think and learn. It can be thought of as a three-step process: developing a plan of action, monitoring the plan, and evaluating the plan.

Interestingly, students are very resistant to changing their ideas that have been challenged (Ausubel, 1968); they make conflicting data fit into their world view (Osborne & Wittrock, 1983) or simply by discarding the event (Llewellyn, 2002). Students will unknowingly misconstrue information they have been taught so it will fit into their current world view, and not conflict with previously held ideas (Osborne & Wittrock, 1983). Kelly (1955) noted that the entire process of building, using, and revising mental models has one primary goal: to help us predict, and therefore possibly control, future events. It is because of this goal, Kelly argues, that people hesitate to

revise their mental models. Revision may place people in ambiguous positions where they will no longer be able to predict and control future events. To summarize, under the constructivist theory, students come into the classroom with pre-existing knowledge about a given subject; instructors should identify what students know and build upon their prior knowledge; thus, help students construct new understandings as a result of new experiences (Leonard, 2000).

One of the key ideas of constructivism is that learning is both personally (reflection) and socially (testing one's model against peers) constructed (Llewellyn, 2002). Unlike the behaviorist approach, where knowledge flows from the instructor to the student in one-way fashion, the constructivist approach places the instructor on one corner of a triangle (Novak, 1981). The other two points are the students and knowledge. The entire triangle is placed within a social matrix (Novak, 1981). The idea here is that knowledge can flow through the instructor to the student, and also directly to the student without the intervention of the instructor, as the students construct their own knowledge. Students should be given ample opportunity to interact with their peers to test their new ideas: constructivist classrooms incorporate group, or cooperative activities. Students, then, are seen as active participants in the construction of their own knowledge (Osborne and Wittrock, 1983).

Under the constructivist model, the learner must reflect on information to construct new knowledge. The learner must then test his or her construct against those of peers. This testing of the construct is the social, cooperative piece of constructivism. The learner's construct is tested and continually revised.

The successful use of constructivist learning theory in classrooms has been widely demonstrated. One study looked at students' understanding of diffusion and osmosis when taught with traditional methods versus students taught in constructivist classrooms (Christianson & Fisher, 1999). Two instructors taught their students the concepts of diffusion and osmosis in the traditional large lecture/small lab setting. A third instructor taught the concepts using small discussion/lab groups. Students in this course were also expected to continue discussions outside of class, working in small groups to construct semantic networks of diffusion and osmosis using computer software (Christianson & Fisher, 1999). Students in the smaller, constructivist group showed a greater understanding of the material. The authors noted that because of many uncontrolled elements of their study, the findings are merely suggestive (Christianson & Fisher, 1999).

In other studies, constructivist teaching and learning enhanced performance on exams among chemistry (Kogut, 1997) and biology (Lord, 1997) students significantly over groups of students that did not learn in a constructivist classroom. Lord's (1997) findings prompted a listing of 101 benefits of constructivist learning, which include: increasing attitudes, stimulating thinking, elevating reading and writing skills, and modeling the real world (Lord, 2001). Other studies showed that university students performed better on unit tests and final exams when they were taught with a constructivist approach (Burrowes, 2003). The constructivist classes consisted of formal cooperative groups that continually interacted and were assessed daily. Burrowes (2003) also included pre- and post-attitude surveys in the classes and found student attitudes and interests toward biology also significantly increased in classes that were more student-centered.

While many instructors think that constructivist learning is beneficial, it must be used judiciously, and is not a cure-all to poor student performance (Kerns, 1996). Even in classes where student performance was enhanced through student-centered teaching, there were still students failing to attain high grades on tests. Means on given tests, and within classes may increase significantly, but may still be low, e.g. the increase in one study was from mean test scores of 58% to 65% (Burrowes, 2003). In Moore (2003), some students who attended class regularly still got poor grades. Moore (2003) attributes this to a lack of motivation. So, while we see improvement with student-centered methods, we must also keep in mind that some students may not put forth sufficient effort to improve their scores.

### ***Constructivist Teaching Methodologies***

Because constructivism is a student-centered theory of learning in which knowledge is constructed within the mind of the student and not received from the instructor, constructivist teaching must facilitate student's efforts to actively construct knowledge, (i.e. active learning). The *NSES* (NRC, 1996) calls for teaching high school students in an active manner. Unfortunately the NRC did not operationally define *active* (McManus et al., 2003). McManus et al. (2003) examined student success on achievement tests and the students' level of involvement with their own education. The treatments they chose, in order of low student involvement to high student involvement, were: a) traditional, teacher-centered instruction (or lecture), b) self-teaching using teacher-constructed instructional resources, and c) self-teaching using student-constructed instructional resources, (McManus et al., 2003). McManus (2003) reports that the highest achieving group consisted of students who were self-taught using student-constructed

instructional materials. The next highest achieving group was the self-taught students using teacher constructed instructional materials. The lowest achieving group was the traditionally taught one. Thus, students performed better on science achievement tests the more they were involved, or the more actively they participated in their own education (McManus et al., 2003).

The most popular way to teach in a constructivist manner is through a process called inquiry. Inquiry investigations usually involve (Llewellyn, 2002):

- 1) Generating a question or problem to be solved.
- 2) Choosing a course of action and carrying out procedures of an investigation.
- 3) Gathering and recording data through observation and instrumentation, and analyzing data to draw appropriate conclusions.

### ***Inquiry***

There are several definitions for inquiry. For this study, inquiry is defined as an instructional technique used to engage students in scientific thoughts and processes (Llewellyn, 2002). This technique helps students understand what it is that scientists do, and how questions can be answered in a scientific, logical manner. Students gain an understanding of the importance of the creative and logical processes of science. Students discover answers to questions rather than listen to answers. This process develops the students' critical thinking abilities and encourages them to become lifelong learners. Inquiry builds on previous knowledge and presents new knowledge in a context that allows the student to make meaningful connections between these two sets of knowledge.

There are also different levels of inquiry that an instructor can use. The levels depend on the amount of instructor direction and student involvement. In teacher-initiated inquiry (Llewellyn, 2002) the instructor poses a question and the students devise procedures to answer the question and formulate the results. Inquiry, then, can be more structured and directed by the instructor with guiding questions, while still allowing the students to develop their own methods to solve a problem. In student-initiated inquiry (Llewellyn, 2002), the students pose a question, plan the procedure, and formulate the results. This type of inquiry is more open-ended, where students start the process by bringing a question to the instructor; the students then devise methods to solve their problem, and finally formulate their results. This type of inquiry is often referred to as open-inquiry (Llewellyn, 2002).

Since the NRC did not strictly define what inquiry teaching should be, there has been much debate on how an instructor should teach using an inquiry method. The amount of debate on what inquiry teaching is, spawned a second publication by the NRC outlining how inquiry should be used, what it means to teach inquiry, and how to use inquiry to meet the *NSES* (NRC, 2000). The NRC outlined the essential features of what it means to teach inquiry in the classroom. Inquiry classrooms have five essential features (NRC, 2000):

1. Learners are engaged by scientifically oriented questions. The questions center on organisms or phenomenon of the natural world.
2. Students should give priority to evidence collected. This evidence will allow them to develop explanations that address the scientific phenomenon.
3. Students formulate explanations based on the evidence they collect.
4. Students should evaluate their explanations in light of alternative explanations and evidence.



5. Students should communicate their findings and justify their proposed explanations.

A common misconception is that “hands-on” activities are equivalent to inquiry teaching (NRC, 2000; Llewellyn, 2002). Hands-on activities do not necessarily engage students in inquiry learning. If the instructor provides instruction to the activity that tell the students what question to answer, provides materials or a materials list, charts to collect data on, and how to perform the experiment, it is not considered an inquiry exercise (Llewellyn, 2002). So clearly, not all hands-on means inquiry, and inquiry does not have to mean hands-on. To give students a genuine feel for the creative endeavors of scientists, we must move them away from the step-by-step mechanical tasks that are characteristic of laboratory technicians (Huber & Moore, 2001).

There are many examples of the inquiry method being used in classrooms and laboratories all across the United States. There are as many different styles of teaching in by inquiry as there are examples. The following examples range from teacher-initiated inquiry in the lab, to teacher-initiated inquiry in lecture, to student-initiated inquiry in the lab.

Many examples of inquiry in the laboratory are available from many disciplines that range from chemistry (Coppola & Lawton, 1995; Hinde & Kovac, 2001) to botany (Silvius & Stutzman, 1999) to exercise physiology (DiPasquale et al., 2003). Labs lend themselves quite easily to being taught in an inquiry style. Many instructors that have transformed labs to the inquiry-style rely on presenting the students with a particular problem. The students are then asked to solve that problem through collecting data,

analyzing results, drawing conclusions, and making and evaluating comparisons (Coppola & Lawton, 1995).

The move to inquiry-based labs gets students away from following a series of steps to a predetermined outcome. It allows the student to make mistakes and then improve upon them (Coppola & Lawton, 1995). It also allows students an opportunity to develop their abilities to think scientifically, to learn to deal with ambiguity, and to learn to use and evaluate the reliability of information (Marbach-Ad & Claassen, 2001). In inquiry-based labs, students often work collaboratively, rather than individually. Many instructors think that having students work in a collaborative setting actually promotes individual responsibility within the group, as the group could not complete the task without the contribution of each participant (Coppola & Lawton, 1995).

Using this type of teacher-directed approach in labs, students become successful at conducting research more rapidly than if they were conducting novel research (Wimmers, 2001). In novel research there are generally technical problems that must be overcome before meaningful data can be collected. Performing experiments that are based on published work helps students avoid these problems (Wimmers, 2001). Directing students in small research projects in the lab also allows the instructor to tie the lab experiences easily to content presented in lectures.

Inquiry teaching may also be conducted in the lecture portion of a class. Many inquiry methods even in large lecture halls include group learning (Klionsky, 2002). In these classes students are given problems and asked to work out solutions within groups (Lord, 1997). Students become responsible, not only for their own learning, but that of other members of their group (Lord, 1997). This gets students to become more active in

their own learning. In most constructivist, inquiry-based lectures, instructors spent about 15 to 20 minutes each session actually lecturing. The rest of the time students spent solving problems (Klionsky, 2002), and teaching difficult concepts to their peers (Libarkin & Mencke, 2002), or making sure everyone in the group understood the day's concepts to take the daily quiz (Lord, 1997).

The least structured method of inquiry is student-initiated, or open-inquiry. In this model, students are allowed to select what they wish to study. Instructors who use this model allow students to become fully immersed in the scientific method and scientific inquiry (Harker, 1999). Here the student identifies a problem rather than having a problem presented by the instructor to the students. This approach involves having the students engage in novel research, and all its frustrations. Some permutations of this model have gone so far as even to let the students design the course syllabus (Boersma et al., 2001). Many of these courses are not designed around specific content, but instead are concerned with the student meeting specific learning outcomes (Demers, 2003). What science is and how it is done is more important here than the specific factual elements of any particular discipline (Boersma et al., 2001).

Many of these courses, then, are not prerequisites for upper level courses, but are geared toward students fulfilling a lab science requirement, or for elementary education majors (Boersma et al., 2001). This type of approach may leave gaps in a student's understanding of relevant and basic concepts that may be needed to be able to ask meaningful questions (Goodman & Berntson, 2000). Other courses that use student-initiated inquiry may be upper division classes. Upper division courses generally do not

have to be concerned with meeting prerequisites, and students in these courses should already have most of the basic knowledge required.

### ***Inquiry Teaching Methods***

Four methods appear to be used most often, and while all four of these methods tend to overlap in some respects, there are distinctions among them.

#### ***1) Experimental Projects***

One way for students to understand how scientists think and work, and to acquire the skills and knowledge to think and act scientifically themselves is for them to engage in long-term experimental projects. In one study, an instructor replaced the ecology and environmental science unit with a five-week long class project (Petersen, 2000), during which students conducted an experiment and analyzed their results statistically. Students in these classes were required to perform all the tasks faced by contemporary scientists, including balancing a fictitious budget, and applying for collection permits. The subjects consisted of honors students and regular students. Both groups showed development and improvement in interdisciplinary skills related to science, and a greater understanding of scientific papers and data interpretation. Interestingly, the honors students gained more understanding and appreciation for science than did regular students.

Other experimental projects include semester-long projects of original research. In one study, the instructor assembled a research team consisting of high school students, college undergraduates (one non-major), and a graduate student engaged in an original research project (Oates, 2002). This mix of students was used as an example of how students from different backgrounds, educational levels, and interests can all learn from one another. There were no formal labs that showed the students how to use pipettes, or

colorimetric spectrophotometry, instead techniques were taught and used in context (Oates, 2002).

Having students engage in research allows the student to be more actively involved in their own learning and discovery. They also learn in context, which provides students a better mental framework in which to incorporate new knowledge (Seago, 1992). When engaged in open-ended research, the students also gain ownership of their own learning (Grant & Vatnick, 1998). Once students engage in protracted research, they begin to learn how science is done, and thus gain an appreciation for science. Students also get an opportunity to practice thinking biologically and scientifically, which is what one must do while conducting research (Seago, 1992).

## *2) Problem-Based Learning*

In problem-based learning (PBL) the instructor presents students with a problem, query, or puzzle that the learner wants to solve (Allen & Duch, 1998). What are presented to students are complex, real world problems that motivate students to identify and research concepts and principles they need to know to solve the problem. PBL was started in medical schools where students solved real patient problems through the use of case studies (Herreid, 2003). This model was subsequently modified and applied in undergraduate science courses (Herreid, 2003). The process of problem-based instruction (Boud & Feletti, 1991) is as follows:

A) Students are presented with a problem, and working in permanent groups, organize their ideas and previous knowledge related to the problem. The problem could be a case study, research paper, or videotape. Within their groups, the students attempt to define the broad nature of the problem. Problems are generally started with a brief

introductory lecture (Allen & Duch, 1998). Then each group is presented with the first part of a problem. Groups are then asked to start identifying the broad nature of the problem and the major factors or issues involved.

B) During an initial brainstorming session groups organize their thoughts about the problem and critically analyze their initial ideas and solutions to the problem. Throughout these steps, members within the group recognize issues and concepts that they do not understand; these “learning issues” are recorded. In their discussion, students pose questions about aspects of the problem that they do not understand. In this, students start to define what they know and, more importantly, what they don’t know. Learning issues are recorded by the group and help generate and direct discussion.

C) The group will reach a point where no further progress can be made until the group learns more about specific topics. Learning issues are prioritized, and the most effective ways of researching the learning issues are discussed. The first session ends and students are expected to return to the groups having investigated their learning issues. Before groups leave, learning issues are ranked in order of importance. Students then decide which questions the whole group, will follow up, and which issues can be assigned to individuals. Individuals who are assigned issues are expected to teach the rest of the group later. A discussion with the instructor outlines what resources are needed to research the learning issues and where they can be found.

D) The second session begins with group members communicating what they have learned. The learning issues can then be revisited from a perspective of deeper understanding, integrating new knowledge into the context of the problem. While students discuss in groups, they continue to define new learning issues as they progress

through the problem. During any of the above activities, the problem-solving process can temporarily be interrupted by short lectures, discussions, or group assignments to help clarify concepts. Once the instructor is satisfied that the student groups have arrived at a conclusion, the solution to the initial problem can be summarized in a wrap-up discussion. Students are also encouraged to summarize their knowledge and connect new concepts to old ones. For complex problems, additional stages may be added that require a more in-depth analysis, and the cycle of activities described above continues.

The PBL process fosters the ability to identify information that is needed for a particular application, where and how to seek information, how to organize information into a meaningful conceptual framework, and how to communicate that information to others (Allen & Duch, 1998). Students also begin to recognize that knowledge transcends artificial boundaries because problem-based instruction highlights interconnections among disciplines and the integration of concepts (Allen & Duch, 1998).

### *3) The Learning Cycle Method*

The learning cycle approach to teaching consists of three to five phases. In the three phase model, the first phase is the Exploration Phase, where students generally interact with each other to solve a problem or complete a task (Allard & Barman, 1994). The problem is open-ended to allow students to be creative yet directed in their problem solving. In other words, the problem does not have just one answer or one way of arriving at the answer; however, the instructor can narrow the field of possibilities. This phase also allows students to share ideas about something that is familiar to them, and try to relate the problem to different concepts (Beisenherz et al., 2001). For example: to

begin a unit on cells, students may investigate the differences between plant and animal cells by observing different specimens with a microscope, then draw and discuss observed differences (Allard & Barman, 1994).

During the second phase, concept introduction, students are introduced to the main concepts of the lesson, and any pertinent vocabulary. Here, students report findings accumulated during the exploration phase. The instructor then uses the information provided by the students as a springboard to discussions, for example: on the differences between plant and animal cells (Allard & Barman, 1994).

The final phase of the learning cycle is concept application. During this phase, students study additional examples of the main concepts. This may lead to a new task where students are asked to apply concepts they have learned to new situations, for instance: identifying unknown cell specimens (Allard & Barman, 1994).

In an example in plant nutrition (Lee, 2003), the instructor started the lesson with the open-ended question, “What do plants need to live?”. After a period of open discussion, the instructor started to guide students to think about the raw materials necessary for plant growth. The exploration phase could then begin with students setting up a host of experiments to determine what nutrients may be necessary for plants to live and grow. Students were expected to collect data for several weeks. After the experimental phase was complete, the instructor introduced reading assignments on nutrient effects on root and shoot growth. Applications from this point could vary widely from chemical testing in soils, to use of different types of fertilizers (Lee, 2003).

In the 5-E model, two more phases have been added to the learning cycle (Llewellyn, 2002). In the 5-E model, the first phase is Engagement. Here the teacher



sets the stage for the lesson, explains the objectives and focuses the students' attention. During the Engagement phase the instructor can also assess prior knowledge, and have students share their experiences, in true constructivist fashion (Llewellyn, 2002).

The second phase is the Exploration phase. Here students raise questions and develop hypotheses to test. The instructor is not directly involved with the students, while they gather evidence and data and share with other groups.

The third phase, Explanation, is more instructor-directed. Here the students are guided through data-processing techniques, and how their data relate to scientific concepts. The instructor may introduce more details and vocabulary to provide a common language for discussion of their results (Llewellyn, 2002).

The fourth phase is the Elaboration or Extension phase. The instructor reinforces concepts by applying gathered evidence and data to new and real-world situations. This places the new knowledge within the students' conceptual framework.

The final phase of the 5-E method is the Evaluation phase. During this phase the instructor and the students summarize the relationships among the variables in the experiment. In addition, the instructor poses questions to the students to get them to make judgments and analyze their own work (Llewellyn, 2002). The instructor can make comparisons between knowledge shared in the Engagement stage and new knowledge acquired throughout the lesson. This evaluation then may lead to another Engagement.

The most noticeable difference between the learning cycle and traditional teaching methods is that in the learning cycle the laboratory, or exploratory, experiences come first. In traditional lecture/lab situations, the labs are performed after the lecturer has discussed the topic and the laboratory is purely for verification and reinforcement. In

these traditional exercises students are rarely engaged mentally (Colburn & Clough, 1997), rather they are performing steps in a cookbook with a predetermined outcome.

#### 4) *Scientific Inquiry Method*

The NSES (NRC, 1996) describes inquiry as follows:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as, an understanding of how scientists study the natural world.

Inquiry is a multifaceted 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).

The AAAS (1990) defines scientific inquiry similarly:

Scientific inquiry is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientist always follow, no one path that leads them unerringly to scientific knowledge. There are, however, certain features of science that give it a distinctive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in every day life (p. 4).

Scientific inquiry learning can also be viewed as a cycle (Llewellyn, 2002):

- 1) Inquisition: The lesson starts with a question to be investigated.
- 2) Acquisition: Students brainstorm possible solutions to the problem.
- 3) Supposition: Students select which solution to test.
- 4) Implementation: Students design and carry out an experiment.
- 5) Summation: Upon collecting evidence, students draw conclusions.
- 6) Exhibition: Students communicate their findings to other students.

During the exhibition phase, students may discover more questions to be answered, and thus start back at the inquisition phase.

One difference from the learning cycle is that during the learning cycle, the second step is devoted to learning the terminology and the main concepts. This is absent in the scientific inquiry method and could be done before, during, or after the inquiry process. The scientific inquiry method more closely models the scientific method and that which scientists do everyday (Windschitl & Buttemer, 2000), than does the learning cycle. The scientific inquiry method develops science process skills; this is an intellectual ability (Basaga et al., 1994). These process skills, once learned, can then be used to formulate responses to questions, justify points of view, interpret data, and explain events and procedures (Basaga et al., 1994). The scientific inquiry method is more flexible than the learning cycle, and is more representative of how scientists engage in problem solving. While some instructors may use the structured steps, as outlined above, others may wish to leave the process more flexible.

To be sure, the differences between the four outlined methods are subtle, yet may be outlined as follows: The experimental projects method involves more long-term projects that may have research teams and even fictitious budgets. Problem-based learning generally employs case studies. The learning cycle is a structured method that may give inexperienced students a better idea of the process of science. Finally, the scientific inquiry method is somewhere in between these methods. It allows for the flexibility of short and long-term projects, it may follow defined steps, or allow students the freedom to jump around within the process, and it may start off with a case study.

### ***Impact of Reform***

Since the writing of the *NSES*, many educators have examined the effect of teaching students in a more active, inquiry-based style. When comparing constructivist and traditional classrooms, Lord (1997) found significant gains in student understanding of the material. Students under the constructivist model performed better on questions that required more than rote memorization. These questions required students to think critically, or utilize knowledge in a novel, practical situation. Lord (1997) also reported that constructivist-taught students responded to survey questions with more positive comments, indicating that the students enjoyed the constructivist class more. Meanwhile students in a traditional class complained that many of the questions on the test, the practical application questions, were unfair, as they were not covered in lecture. Lord (1997) notes that comments such as these demonstrate a fundamental misunderstanding by students of what really constitutes knowledge.

Another study looked at the value of replacing traditional biochemistry labs with labs that are more inquiry-based (Basaga et al., 1994). One class performed the traditional cookbook labs, where laboratory sheets gave detailed explanations of the problem, apparatus, and how to measure and collect data. In these traditional labs students were following a procedure to verify previously known results. Results were expressed graphically or in tables. In the inquiry lab, students were given a laboratory sheet presenting a problem, and a diagram of the apparatus to be used. Students were then asked to formulate an experiment that would provide them with a solution to the proposed problem, and asked to generate hypotheses on related topics. Data were recorded and then represented graphically and as tables and the students then drew

conclusions based on their results and made further generalizations. Interestingly, the inquiry lab group's experiments took only about 35 minutes more than the group performing cookbook labs. Students in the inquiry labs scored higher on a Biochemistry Achievement Test and on a Science Process Skill Test than those in traditional labs (Basaga et al., 1994). In this study, the Biochemistry Achievement Test was developed by the investigators and was tested to have an  $\alpha$  reliability coefficient of 0.84. The Science Process Skill Test was developed by Okey, Wise and Burns at the University of Georgia, Department of Education and was found to have a reliability coefficient of 0.85 (Basaga et al., 1994).

While study after study has demonstrated the value of reforming science education, there are still sizable barriers to changing how we teach. One perceived disadvantage to teaching students with inquiry instruction is that the amount of content taught must decrease. Since teaching and learning by inquiry may allow students to drive the learning process, the whole process slows, and there is less time to cover all the content. Students taught by inquiry may then be at a disadvantage when they are faced with large-scale achievement tests.

To address this concern, students in a project-based science (PBS) program, which used extensive student-directed inquiry supported by technology and collaboration, were tracked as they took a national, standardized achievement exam (Schneider et al., 2002). When compared to students at a national level, students in the PBS program scored significantly higher on more than half of the questions on the test, and most PBS students scored at the 70<sup>th</sup>-percentile. Most PBS students scored better on questions that required an extended response and on questions that involved scientific investigations.

While these students may not have covered the same amount of content as other students, the PBS format encouraged students to extend their thinking. Interestingly, the PBS students did out-perform the national sample on scientific investigation questions, but only as well as the national sample on practical reasoning questions. In the practical reasoning items, students were asked to apply their knowledge to novel, real-world situations. The PBS students demonstrated that they still need help in transferring their science understanding to novel situations. However, although these PBS students did not surpass the national average in this area, the PBS students used in this sample were 10<sup>th</sup> graders while the national sample was made up of 12<sup>th</sup> graders (Schneider et al., 2002), thus the PBS students did just as well as their older counterparts.

### ***Student Attitudes and Self-Efficacy***

While the goals of the NSES are to create a more scientifically literate society, we still have to be concerned with society's receptiveness to education (Hufford, 1990). In other words, we have to change attitudes toward education before we can be successful educators. Attitudes appear to have a great influence on how successful students will be in a given subject (Cote & Levine, 2000). One study found that a student's IQ is a poor indicator of student success, while the attitude and motivation of that student to learn was a much better indicator of higher outcomes (Cote & Levine, 2000). Other studies have also indicated that attitudes influence achievement in the sciences (Schibeci & Riley, 1986). Attitudes are an opinion or general feeling about a subject. In the case of this study, attitudes toward biology were measured. Attitudes affect how a student uses or does not use (or even forgets) knowledge about a particular subject (Mager, 1968). Attitudes can be closely tied to motivation within a subject, and typically correlate to

achievement. Generally, the more positive a student's attitude, the higher the achievement of that student (Russell & Hollander, 1975).

Another aspect to consider in our attempts to create a more scientifically literate society is student self-efficacy toward a subject. Self-efficacy is defined as a person's beliefs about their capabilities to produce effects (Bandura, 1994). Self-efficacy is more than just confidence, as one can be confident about failing a particular endeavor.

Personal self-efficacy refers to the belief that an individual can organize and successfully execute courses of action (Bandura, 1994). Self-efficacy beliefs can provide a foundation for motivation and personal accomplishment (Pajares, 2002). If individuals believe that their actions will produce an outcome they desire, they are more likely to persevere in the face of resistance (Pajares, 2002). High self-efficacy reflects how well knowledge and skill are acquired in the first place (Pajares, 2002).

An experience in which an individual successfully masters a concept is the most effective method for developing a strong sense of self-efficacy. Failure undermines a sense of self-efficacy, especially if the failure occurs before a strong sense of efficacy is established (Bandura, 1994). Interestingly, individuals that experience easy and quick success are more easily discouraged by failure. Therefore, some setbacks and obstacles appear to prove useful in teaching that success requires sustained effort (Bandura, 1994).

Self-efficacy appears to be influenced by four types of experiences (Bandura, 1977):

- 1) Mastery experiences, where an individual successfully completes a given task.

By successfully completing a task, the individual should feel more efficacious to successfully complete other tasks of a similar nature.

- 2) Verbal persuasion, involves positive written or auditory feedback from a knowledgeable person, such as an instructor. Positive support from an instructor may instill a higher sense of self-efficacy about the current task, and perhaps about future tasks.
- 3) Vicarious learning, or peer observation. Watching someone else successfully perform a given task may increase the self-efficacy of the watcher. The watcher may then feel able to perform the task because of a higher sense of self-efficacy.
- 4) Affective states may also be a factor in an individual's sense of self-efficacy. For example, if students do not eat before taking exams, their physical state may cloud their minds and lower their sense of self-efficacy. Moods, emotions, and physical states can all affect one's sense of self-efficacy about a given task.

Self-efficacy is also an important determinant of a student's attitude toward a given subject, and both self-efficacy and attitude reflect on how successful a student will be in a given subject.

### ***Scientific Reasoning***

Scientific reasoning can be defined as: "consistent logical thought patterns which are employed during the process of scientific inquiry that enable individuals to propose relationships between observed phenomena; to design experiments which test hypotheses concerning the proposed relationships; to determine all possible alternatives and outcomes; to consider probabilities of occurrences; to predict logical consequences; to



weigh evidence, or proof; and to use a number of instances to justify a particular conclusion” (Steussy, 1984).

In previous studies, attitudes, self-efficacy, or standardized tests were used to examine the effectiveness of inquiry instruction in making students scientifically literate. Studies that have used standardized tests as part of their design, while showing that students do not necessarily lose content while learning by inquiry, have not really shown students becoming more scientifically literate (knowledgeable of the nature and process of doing science and capable of scientific reasoning) than the general population (Schneider et al., 2002).

Since expository instruction focuses primarily on facts and concepts, a standardized test would be a satisfactory measure of achievement. Tests on scientific reasoning ability are a better measure of student improvement in courses taught by inquiry instruction. Studies on scientific reasoning have shown that a student’s prior level of scientific reasoning is a good predictor of achievement in science classes (Johnson & Lawson, 1998). Scientific reasoning also greatly increases when students learn under inquiry instruction (Johnson & Lawson, 1998), and when students take multiple science courses (Rifkin & Georgakakos, 1996). Students were also found more likely to develop scientific thinking abilities in open-inquiry biology classes, than when taught in traditional science classes (Shepardson, 1997).

### ***Community College Studies on Inquiry Instruction***

Many studies have been conducted on inquiry teaching and learning and its effectiveness; however, few studies have been conducted at the community college level. One study examined inquiry labs and their effectiveness at the community college

(Lunsford, 2003). The study only encompassed 12 students over one semester, and generally is a report on how inquiry worked for this instructor and is a model for others to use. While this study was mostly a qualitative account of one instructor's experience with a semester-long project, it does show that community college students respond well to inquiry in the lab.

Another study on using inquiry-based learning in the mathematics curriculum is again a report on their program to date (Narayan et al., 2003). Johnson and Lawson (1998) reported on the effectiveness of using reasoning ability and prior knowledge to predict the achievement of students in biology classes at a community college. They found that significant improvements in science reasoning did occur in students in the inquiry (learning cycle) classes, and not in the expository classes (Johnson & Lawson, 1998).

### ***Definition of Terms***

*Attitude:* A student's opinions or feelings toward biology. Attitudes are tied to motivation within biology and student achievement.

*Self-efficacy:* A student's belief in their ability to produce a positive outcome when presented with a given task within biology. The student believes that they would be able to successfully organize and execute courses of action within the field of biology.

*Scientific Reasoning:* A student's ability to use logical thought patterns to produce a valid test of hypotheses when presented a novel situation or problem. The student should also be able to test and analyze results and draw conclusions from collected data.

*Scientific Inquiry:* A constructivist method of teaching and learning that is student-centered. Scientific inquiry falls under the larger umbrella of inquiry-based teaching where students are active learners, and with the guidance of the instructor, construct their own knowledge about a subject.

### ***Research Questions***

This study examined attitudes, self-efficacy, and science reasoning of students in a rural, open enrollment community college. Assessing these three parameters should allow a picture of how community college students respond to inquiry instruction. Discovering how community college students respond to inquiry-based instruction provides knowledge on which to base decisions about how to alter teaching methods. Community colleges are an important link in many students' academic careers and this may be the only time that many of these students are exposed to a science course.

I compared three groups of students: students taught in traditional lectures and traditional labs (TT), students taught in traditional lectures and inquiry labs (TI), and students taught in inquiry lectures and inquiry labs (II). The teaching methods used in each situation are described below. This study did not focus on gender, racial, ethnic or similar issues within the sciences and teaching strategies, so no demographic data are reported. Acquisition of content by students was not a focus of this study either. Demographic data related to ACT and GPA was not used as part of this study.

This study addressed the following questions:

1) Does switching from traditional, teacher-centered instruction (TT) to inquiry-based labs (TI) result in increased positive attitudes, self-efficacy, and science reasoning in community college students?

2) Are attitudes, self-efficacy, and science reasoning increased to a greater degree in community college students if traditional instruction (TT) is modified to include inquiry-based labs and lectures (II)?

3) Are attitudes, self-efficacy, and science reasoning increased to a greater degree in community college students that are taught with inquiry-based instruction in lecture and lab (II) over students taught with only inquiry-based labs (TI)?

4) Are attitudes, self-efficacy, and scientific reasoning increased to an even greater degree if students in inquiry-based lectures and labs (II) are exposed to increased amounts of inquiry-based instruction (II+)?

5) Are there correlations among positive attitude, self-efficacy, and science reasoning in community college students?

These questions can be formulated in terms of the following statistical hypotheses all based on mean difference scores:

*Student Attitudes*

1.  $H_0$ : The switch to inquiry-based labs and lecture did not affect student attitudes toward biology ( $II = TT$ ).

$H_1$ : The switch to inquiry-based labs and lectures affected student attitudes toward biology ( $II \neq TT$ ).

2.  $H_0$ : The switch to inquiry-based labs did not affect student attitudes toward biology ( $TI = TT$ ).

$H_1$ : The switch to inquiry-based labs affected student attitudes toward biology ( $TI \neq TT$ ).

3.  $H_0$ : Inquiry-based lecture in addition to inquiry-based lab did not affect student attitudes toward biology ( $II = TI$ ).  
 $H_1$ : Inquiry-based lecture in addition to inquiry-based labs affected student attitudes toward biology ( $II \neq TI$ ).
4.  $H_0$ : Adding more inquiry-based activities to the lecture did not affect student attitudes toward biology ( $II+ = II$ ).  
 $H_1$ : Adding more inquiry-based activities to the lectures affected student attitudes toward biology ( $II+ \neq II$ ).

*Student Self-Efficacy*

5.  $H_0$ : The switch to inquiry-based labs and lecture did not affect students' overall self-efficacy ( $II = TT$ ).  
 $H_1$ : The switch to inquiry-based labs and lectures affected students' overall self-efficacy ( $II \neq TT$ ).
6.  $H_0$ : The switch to inquiry-based labs did not affect students' overall self-efficacy ( $TI = TT$ ).  
 $H_1$ : The switch to inquiry-based labs affected students' overall self-efficacy ( $TI \neq TT$ ).
7.  $H_0$ : Inquiry-based lecture in addition to inquiry-based lab did not affect students' overall self-efficacy ( $II = TI$ ).  
 $H_1$ : Inquiry-based lecture in addition to inquiry-based lab affected students' overall self-efficacy ( $II \neq TI$ ).
8.  $H_0$ : Adding more inquiry-based activities to the lecture did not affect students' overall self-efficacy ( $II+ = II$ ).

H<sub>1</sub>: Adding more inquiry-based activities to the lectures affected students' overall self-efficacy ( $\Pi+ \neq \Pi$ ).

*Student Scientific Reasoning*

9. H<sub>0</sub>: The switch to inquiry-based labs and lecture did not affect students' scientific reasoning abilities ( $\Pi = TT$ ).

H<sub>1</sub>: The switch to inquiry-based labs and lectures affected students' scientific reasoning abilities ( $\Pi \neq TT$ ).

10. H<sub>0</sub>: The switch to inquiry-based labs did not affect students' scientific reasoning abilities ( $TI = TT$ ).

H<sub>1</sub>: The switch to inquiry-based labs affected students' scientific reasoning abilities ( $TI \neq TT$ ).

11. H<sub>0</sub>: Inquiry-based lecture in addition to inquiry-based labs did not affect students' scientific reasoning abilities ( $\Pi = TI$ ).

H<sub>1</sub>: Inquiry-based lecture in addition to inquiry-based labs affected students' scientific reasoning abilities ( $\Pi \neq TI$ ).

12. H<sub>0</sub>: Adding more inquiry-based activities to the lecture did not affect students' scientific reasoning abilities ( $\Pi+ = \Pi$ ).

H<sub>1</sub>: Adding more inquiry-based activities to the lectures affected students' scientific reasoning abilities ( $\Pi+ \neq \Pi$ ).

*Correlations*

13. H<sub>0</sub>: There are no correlations between student attitudes toward biology and student's self-efficacy in biology.

$H_1$ : There are positive correlations between student attitudes toward biology and student's self-efficacy in biology.

14.  $H_0$ : There are no correlations between student attitudes toward biology and science reasoning ability.

$H_1$ : There are positive correlations between student attitudes toward biology and science reasoning ability.

15.  $H_0$ : There are no correlations between student's self-efficacy and science reasoning ability.

$H_1$ : There are positive correlations between student' self-efficacy and science reasoning ability.

## CHAPTER 2

### Materials and Methods

#### *Courses and Sample Population*

This study encompassed two separate classes, including 213 students, at Eastern Wyoming College (EWC). The BIOL 1000 course is recommended for non-biology majors, including education majors. Biology 1000 considers fundamental principles of ecology, evolution, cell biology, and genetics, as well as, their relevance to contemporary society. The BIOL 1010 course is intended for majors in the life and health sciences. Discussions of fundamental concepts are considered in BIOL 1010, including basic chemistry of living systems, cell structures and functions, energy relations, genetics, molecular biology, ecology, population dynamics, and evolutionary theory. Syllabi for both of these courses can be found in Appendix A.

The data for these two courses were combined as this study did not focus on the differences between majors and non-majors, but instead on the effect different types of instruction have on students in biology. The first year of the study also coincided with the first year of the division into majors/non-majors courses. At that stage, advisors were unclear as to where to place their advisees, and there were non-majors in the major's course for a number of reasons, including uncertainty, mistakes, and time conflicts. Thus, the majors/non-majors division was fairly arbitrary during the years of this study; therefore, the data were pooled. The same labs for both classes were converted to



inquiry-based labs and the same units in lecture were also converted in those classes that were targeted for inquiry-based lecture and lab.

Eastern Wyoming College is a small open-enrollment, community college in southeast Wyoming, that serves a rural community and offers A.A., A.S. and A.A.S. degrees and certificates in welding, cosmetology, business office technology, and network technology, to over 1,600 students. The service area of the college covers six rural counties that span almost 16,000 square miles. The Science and Math Division consist of 16 full-time faculty. It offers A.S. degrees in Biology, Mathematics, various Pre-Medical Fields, Statistics, and Wildlife & Fisheries Biology. The Division also offers an A.A.S. in Veterinary Technology. Other degrees requiring lab sciences at the college include all of the A.S. and A.A. transfer degrees, such as Business Administration and Agriculture.

***Baseline Data (Control: TT)***

During the first year of this study (2001 - 2002), baseline data were collected on all biology classes (TT; n = 58) using the pre- and post-tests that are outlined below. All data collection methods were approved by the Institutional Review Board of Oklahoma State University (approval number: AS0218). Classes were conducted as “traditional,” meaning that both classes used the same formats that had been used previously. The lecture was expository, leaving minimal room for student input or questioning. The laboratory used a “cookbook” format where students performed experiments to verify ideas presented during the lecture. The labs had a predetermined outcome, a “correct answer,” the students were supposed to obtain.

### ***Lab Design (Experimental Group A: TI)***

In the second year (2002 – 2003), the labs were changed as follows: During the summer after the “traditional” year of the study, both instructors determined exactly how the “cookbook” labs were to be converted to inquiry-based labs. Three labs were revised in both classes: 1) Cell Structure and Function 2) Natural Selection and Evolution, and 3) Population Ecology. In the Biology 1010 course, a Small Animal Respiration Lab was also revised to an inquiry-based lab. Some of these inquiry-based labs were modeled after inquiry-based labs already in use at Oklahoma State University (French, 2000). These labs are included in Appendix B.

During the 2002-2003 school year, all students in both experimental groups (II; n = 109 and TI; n = 46) participated in the new lab format. This format consisted of three newly modified inquiry-based labs for the Biology 1000 students and four new inquiry-based labs in the Biology 1010 course. The remaining labs continued to be taught in the traditional “cookbook” format. Students were asked to form into lab groups of three to four students. During inquiry-based labs, students were presented a scenario that contained a question or a problem to which the students were to find a solution. It was left to the students to formulate hypotheses and procedures to test their hypotheses.

In the inquiry-based labs, students wrote their own procedure, gathered their data accordingly, then drew their own conclusions (in light of the given scenario) and made note of any shortcomings in their procedure. Students were encouraged to write their hypotheses in a hypothetico-deductive style (Lawson, 2000), but were not limited to this style. A hypothetico-deductive style of hypothesis generally contains IF...AND...THEN, as key components to the statement. An example is: IF two students fall asleep in

biology class because they sit in the back of the classroom, AND student A moves to the front while student B remains in the back, THEN student A will stay awake during class. This type of statement presents the hypothesis to be examined as the “IF”, the experiment to be conducted as the “AND”, and the prediction of the outcome as the “THEN.” This type of hypothetico-deductive style may have facilitated student understanding of the process of science in those students that were unfamiliar with generating hypotheses. If students were already comfortable with generating hypotheses, they were encouraged to use whatever style with which they were most comfortable.

Students had to have their design approved before they started their investigation. They were then left to collect whatever data they thought was appropriate in some inquiry labs, while in others they were guided to collect certain data, but could collect more, or other data if they thought it was appropriate. The practice of guided data collection may have helped students unfamiliar with this process.

Once students ran their experiments, they reported and discussed their results in a formal lab report. The lab reports consisted of an Introduction, Procedures (Materials and Methods), Results, Discussion, and Literature Cited sections. The lab report’s format basically followed that of an article in a scientific journal. Students were encouraged to point out how their research was relevant to society and themselves, and where their research could be expanded.

### ***Lecture Transition (Experimental Group B: II)***

During year 2 (2002 – 2003) lecture units that correspond to the inquiry-based labs in both the 1010 and 1000 classes were also converted to an inquiry-based style. However, only one of the instructors taught lectures and lab in an inquiry-based style

(Instructor II). The other instructor continued to teach lectures in the traditional, expository style, but taught inquiry-based labs (Instructor TI). The Biology 1010 and 1000 classes were split between these instructors, so that no one instructor taught all of the 1010 or 1000 sections.

The reason for this split was two-fold. First, one instructor was not comfortable teaching content in an inquiry format. Second, and more importantly, I wanted to test whether restricting the inquiry-based format to labs is as effective in improving student attitudes, self-efficacy and biology/science reasoning as teaching both lecture and lab via an inquiry-based format.

Instructor II changed 2 of 4 lecture units that corresponded to the revised inquiry-based labs to an inquiry-based style of instruction. Only two units were changed, as the new inquiry labs fell within those two units. During these units, the teaching style was less didactic, teacher-centered instruction. The instructor solicited more input from students and asked more thought provoking questions. For example: the traditional lecturer told students the contents of a eukaryotic cell and the functions of the organelles. The II instructor asked the students to think about what a human body needs to do everyday to survive. The instructor then gave the class time to brainstorm individually and in groups to list systems or organs the body uses. The instructor then asked the students to equate their list of human organ systems to a single cell. During this discussion, the instructor equated the organelles of a cell and their functions, to organs and organ systems of humans. Toward the end of this subunit, the instructor asked students to equate a cell to anything else, other than a human body, list how their object was like a cell, and justify their choices. For instance a student might have equated a cell

to a car and explained that the engine is like a cell's mitochondria: both are powerhouses. This type of instruction is more constructivist, drawing on the students' past experiences and building on their prior knowledge. Other details of converted lectures are in Appendix C.

### ***Further Transition (Experimental Group C: II+)***

During the final semester (Spring 2003) of the project, Instructor II took the transition of inquiry-based lectures one step further. In addition to previous changes in lecture format, the instructor added four problem-based learning (PBL) exercises from Allen and Duch (1998), and an in-depth analysis of two primary literature papers. Both the PBL exercises and the papers were added into units that were previously changed to an inquiry-based format. The idea behind this further transition of the inquiry-based lectures was to determine if practice in problem solving, and analyzing research papers, facilitated a deeper understanding of how science is done. This deeper understanding of how science is done may lead to even higher attitudes, higher self-efficacy, and better science reasoning skills. This "step up" in inquiry-based teaching may also give insight to the increasing effectiveness of instructors that continue to practice inquiry-based instruction. Other research has demonstrated the effectiveness of using a combination of both a laboratory component (hands-on) and a recitation component (minds-on) to improve student retention and learning

The first PBL exercise focused on hypothesis generation and testing. A second PBL exercise fit into the cell unit and emphasized diffusion and osmosis, active transport, cell membranes and osmoregulation. The first paper also fit into the cell unit and emphasized plant cell growth (Wymer et al., 1996). Another PBL exercise fit into the

population ecology unit and emphasized factors influencing population size and r- and K-selection. The final PBL exercise fit into the ecology unit and emphasized global warming and the Greenhouse Effect, global carbon dioxide cycles and photosynthesis. The final paper fit into the evolution unit and emphasized evolution and natural selection in guppies (Endler, 1980). The students were given a series of questions when assigned a primary literature paper to help facilitate an in-depth analysis and discussion. The PBL exercises were preceded by a mini-lecture and accompanied by handouts. The PBL exercises are from Allen and Duch (1998).

### ***Survey Instruments***

Three survey instruments were administered as pre- and post-test in each class for the four semesters of the study, during the second and the last week of the semester. While all instruments were combined into a single survey, each instrument maintained its integrity by keeping each individual survey's questions within its own grouping, i.e. the 14 questions from the attitude survey were grouped together, the 23 questions from the self-efficacy survey were grouped together, and the science reasoning question was in its own section. Wording and organization of the questions were not changed. Every student within the study was given the same survey.

I used Prism 4 statistical package from GraphPad to perform Analysis of Variance (ANOVA), two-tailed t-tests, and correlation analyses. If the ANOVA showed a mean was significantly different, a Newman-Keuls multiple comparisons test was performed post-hoc to determine which means were significantly different.

To retain student's anonymity, yet allow repeated-measure sampling, each student was assigned an eight-digit code that they placed on all answer sheets. The code was

made so the year, semester, and section could easily be determined. As an example a code might be: 01010359. The last three digits were random and unique to a particular student.

To measure 1) attitude, 2) self-efficacy, and 3) science reasoning, three survey instruments were chosen based on their validity and appropriateness for this study.

1) The Biology Attitude Survey (Russell, 1975) is a 14 question Likert-type survey, that is a valid and reliable measure of students' attitudes toward biology (Chronbach's  $\alpha=0.90$ ). The instrument consists of seven positive questions and seven negative questions. Students were asked to respond to both a pre- and post-test. Responses were assigned a score of 1 to 5, with 5 always assigned to the strongly favorable attitude and 1 assigned to the strongly unfavorable attitude (Russell & Hollander, 1975). The scores for the pre-test and the post-test for each student were each summed, and then treated parametrically. A copy of this survey is in Appendix D.

2) A Biology Self-Efficacy Survey (Baldwin *et al.*, 1999) was used to measure students' self-reported confidence about their own comprehension of biology and its transferability to their everyday lives. This survey, which consists of 23 Likert-type questions, addresses three areas identified in the literature as influential on a student's biological literacy. These areas are: "methods of biology" (Chronbach's  $\alpha=0.88$ ); "generalization to other biology/science classes and analyzing data" (Chronbach's  $\alpha=0.88$ ); and "application of biological concepts and skills" (Chronbach's  $\alpha=0.89$ ) (Baldwin *et al.*, 1999). Each answer was assigned a score of 1 to 5; with 5 assigned to the "Totally Confident" response and 1 assigned to the "Not At All Confident" response. Students were asked to respond to both a pre- and post-test. The scores for the pre-test

and the post-test for each student were summed, then treated parametrically. A copy of this survey is in Appendix D.

3) A Science Reasoning Test (Weld & Stier, 2002) was used to determine students' understanding of the process of science. This test was determined to have a reliability of over 0.9 when subjected to the Holsti method (Holsti, 1969). This simple, one question test was used instead of exam grades as a measure of any potential gains in the understanding of the process of science. The science reasoning test has a minimum score of 0 and a maximum score of 10. Students were asked to respond to both a pre- and post-test. Each pre-test and post-test was scored by the primary investigator according to the rubric supplied with the reasoning test, and then treated parametrically. A copy of this survey and the scoring rubric is in Appendix D.



## CHAPTER 3

### Results

#### *Pre-test Analysis*

To determine if the starting points (pre-tests) were the same for each year and each treatment, I performed a one-way ANOVA among the pre-test scores for all groups (TT, TI, II, II+). The differences between the means for pre-test attitude scores were not significantly different ( $F = 1.93$ ;  $p = 0.126$ ; Figure 1). I found no significant difference between means for pre-test self-efficacy scores ( $F = 1.52$ ;  $p = 0.210$ ; Figure 2). There were also no significant differences between means for pre-test science reasoning scores ( $F = 1.17$ ;  $p = 0.322$ ; Figure 3).

#### *Summary of Survey Results*

Analysis of the three surveys yielded the following results: attitudes in TT decreased, TI increased, II and II+ did not change. Self-efficacy in all four groups increased. Scientific reasoning in the TI and II groups did not change, while scientific reasoning in the II and II+ groups increased (Table 1).

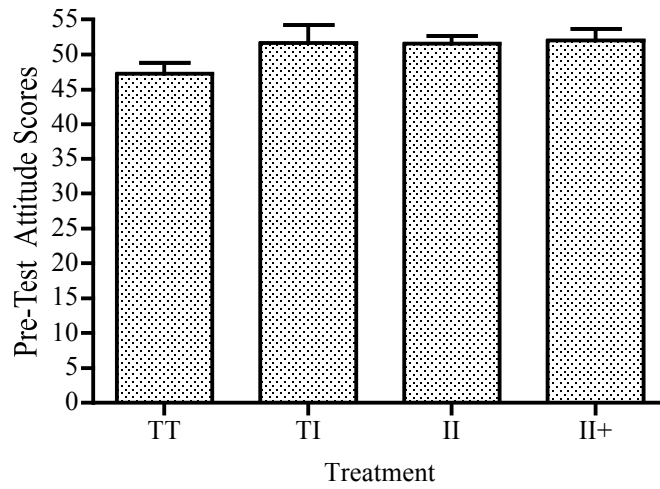


Figure 1. Attitude pre-test scores for the four groups. TT n=58; TI n=46; II n=76; II+ n=33. Note: bar height denotes the mean and the whisker is the 95% confidence interval.

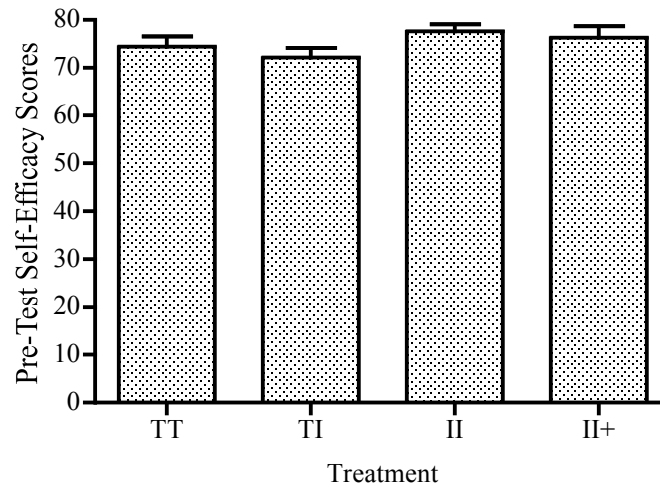


Figure 2. Self-efficacy pre-test scores for the four groups. Sample size and legend are the same as in Figure 1.

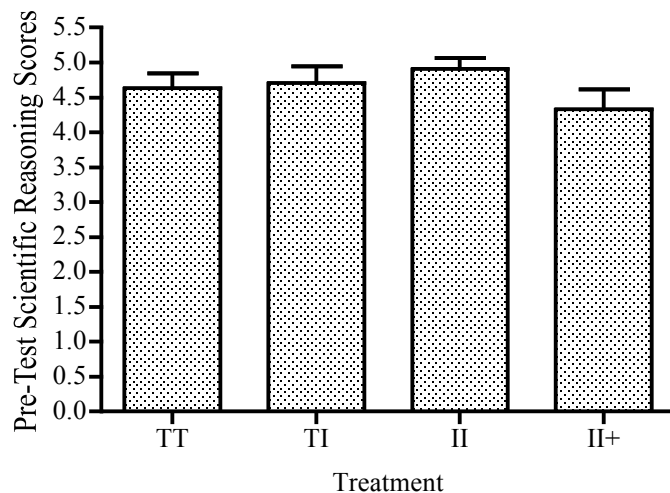


Figure 3. Science reasoning pre-test scores for the four groups. Mean and 95% confidence interval are shown.

TABLE 1. SUMMARY OF THE STUDENT SURVEY DATA. Arrows indicate significant change and the direction of that change. Bars indicate no change.

	TT	TI	II	II+
Attitude	↓	↑	—	—
Self-Efficacy	↑	↑	↑	↑
Science Reasoning	—	—	↑	↑

### *Student Attitudes Analysis*

I analyzed the mean changes in attitude score using a two-tailed t-test to compare the means to the null hypothesis of no change in student attitudes. The mean attitude score of students in the TT group was significantly different from a hypothesized mean of zero ( $p = 0.025$ ; Table 2). The mean change was -2.138, indicating that the attitudes of students in this treatment decreased. The attitudes of students in the TI treatment

increased significantly ( $p = 0.005$ ; Table 2). The attitudes of students in the II group did not change significantly ( $p = 0.343$ ; Table 2). I analyzed the II+ group separately to determine if conducting more inquiry activities affected this group's attitudes toward biology. The attitudes of the II+ group did not change significantly ( $p = 0.803$ ; Table 2), nor did that of the II group when analyzed separately from that of the II+ group ( $p = .0271$ ; Table 2)

An ANOVA was performed on the change in attitude scores to determine if there were differences among groups (TT, TI, II, II+). Significant differences were found among the groups ( $F = 7.60$ ;  $p = 0.0037$ ; Figure 4); the TI group was significantly different from the TT group when analyzed using Newman-Keuls ( $p < 0.01$ ; Figure 4).

TABLE 2. DATA SUMMARY OF THE MEAN CHANGE OF STUDENT ATTITUDES. \*Data of the II treatment without the II+ group.

Group	N	Mean Difference	p-value from t-test
TT	58	-2.138	0.025
TI	46	4.304	0.005
II	109	0.762	0.343
II*	76	0.485	0.803
II+	33	0.882	0.271

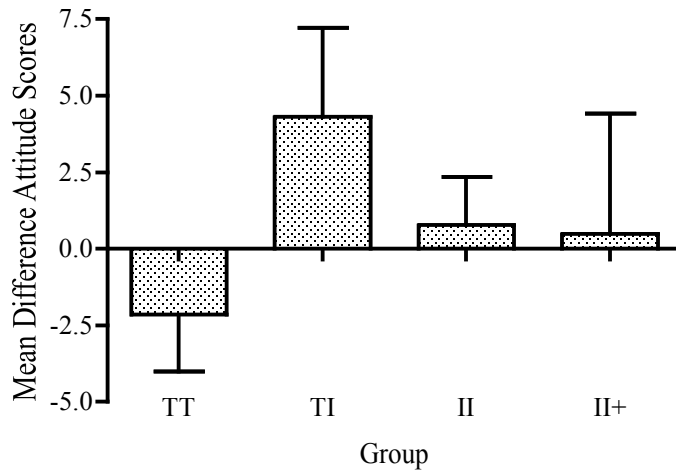


Figure 4. Mean change in attitude scores for the four groups. TT is significantly different from TI ( $p < 0.01$ ). Other groups are not significantly different from each other. Means and 95% confidence intervals are shown.

In addressing the statistical hypotheses presented in the introduction, we cannot reject the  $H_0$  of hypotheses 1, so the switch to inquiry-based labs and lecture did not affect student attitudes toward biology ( $II = TT$ ). We can reject the  $H_0$  of hypothesis 2 and accept the  $H_1$ . Therefore, switching to inquiry-based labs positively affected student attitudes toward biology ( $TI \neq TT$ ). Since the analysis with Newman-Keuls did not show a difference between the mean difference in attitude scores between the TI, II, and II+ groups, the  $H_0$  of hypothesis 3 and 4 cannot be rejected; inquiry-based lecture in addition to inquiry-based lab did not affect student attitudes toward biology ( $II = TI$ ); furthermore, adding more inquiry activities to the lecture did not affect student attitudes ( $II+ = II$ ).

### ***Student Self-Efficacy Analysis***

I analyzed the means in self-efficacy differences using a two-tailed t-test to compare each mean to the null hypothesis of no change in student self-efficacy. The self-

efficacy of students in the TT group, the TI group, the II group and the II+ group increased significantly ( $p = 0.036$ ,  $p = 0.0001$ ,  $p = 0.0001$ ,  $p = 0.0187$ , respectively; Table 3). When the II group was analyzed separately, without the II+ group they showed a significant increase in self-efficacy ( $n = 76$ ;  $p = 0.0011$ ; Table 3).

I also performed an ANOVA and found a significant difference in the mean change in student self- efficacy among groups ( $F = 4.68$ ;  $p = 0.010$ ; Figure 5). When each pair of means was analyzed with Newman-Keuls and the TI treatment was found to be significantly different from the TT treatment ( $p < 0.05$ ) and the II treatment ( $p < 0.05$ ). However, the TT, II and II+ groups were not significantly different from each other ( $p > 0.05$ ; Figure 5).

TABLE 3. DATA SUMMARY OF THE MEAN CHANGE OF STUDENT SELF-EFFICACY. \*Data of the II treatment without the II+ group.

Group	N	Mean Difference	p-value from t-test
TT	58	3.345	0.036
TI	46	10.70	0.0001
II	109	5.000	0.0001
II*	76	4.632	0.0011
II+	33	5.848	0.0187

The  $H_0$  of hypothesis 5: The switch to inquiry-based lectures and labs did not affect students' overall sense of self-efficacy level, cannot be rejected. While students in all groups gained in self-efficacy, the II group did not see a greater gain in self-efficacy than did the TT students. However, the switch to inquiry-based labs alone (TI) did appear to positively affect student's self-efficacy. So, the  $H_0$  of hypothesis 6 may be rejected and the  $H_1$  accepted ( $TI \neq TT$ ). The analysis of the TI and II groups showed that these means were significantly different from each other ( $p < 0.05$ ); therefore, the  $H_0$  of

hypothesis 7 can be rejected. However, the  $H_1$ , that inquiry-based lecture in addition to inquiry-based lab positively affected students' overall self-efficacy cannot be accepted, as the TI group's mean is significantly higher than the II group's mean. In this case, the  $H_1$  of hypothesis 7 is accepted; however, inquiry-based lecture in addition to inquiry-based lab negatively affected students' overall self-efficacy ( $II \neq TI$ ). The Newman-Keuls analysis did not detect a difference between the II group and the II+ group; therefore, the  $H_0$  of hypothesis 8 is not rejected ( $II+ = II$ ).

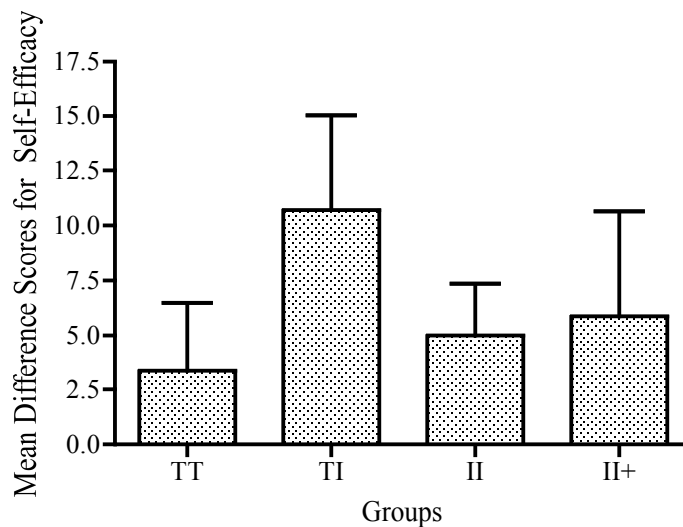


Figure 5. Mean change in self-efficacy scores for the four groups. Sample size and legend is the same as in previous figures. TI is significantly different from TT and II ( $p < 0.05$ ).

### ***Scientific Reasoning Analysis***

I analyzed the changes in scientific reasoning using a two-tailed t-test to compare the means to the null hypothesis of no change in student scientific reasoning. Scientific reasoning of students taught in the TT format did not change ( $p = 0.952$ ; Table 4), nor did scientific reasoning in the TI group ( $p = 0.853$ ; Table 4). Scientific reasoning of students

in the II group showed a significant positive gain ( $p = 0.0001$ ). Within this group the II+ group was analyzed separately. The increase in mean scientific reasoning scores of the II+ group was significant ( $p = 0.0103$ ; Table 4). Without the II+ group, the remaining II students ( $n=76$ ) also showed a significant increase in scientific reasoning ( $p = 0.0042$ ; Table 4)

Using an ANOVA, I determined a significant difference in the mean change in science reasoning scores ( $F = 3.295$ ;  $p = 0.039$ ; Figure 6), among the four groups. When analyzed post-hoc with Newman-Keuls, the II and II+ groups were found to be significantly different from the TT group ( $p = 0.021$ ) and marginally significant from the TI group ( $p = 0.061$ ). The TT and TI groups, and the II and II+ groups were not significantly different ( $p > 0.05$ ; Figure 6).

TABLE 4. DATA SUMMARY OF THE MEAN CHANGE OF STUDENT SCIENCE REASONING ABILITY. \* Data of the II treatment without the II+ group.

Group	N	Difference	p-value from t-test
TT	58	-0.017	0.952
TI	46	0.065	0.853
II	109	0.771	0.0001
II*	76	0.671	0.004
II+	33	1.000	0.010



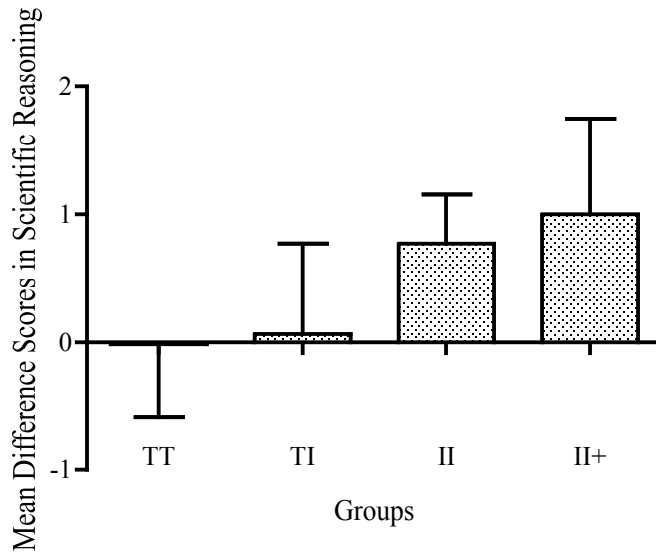


Figure 6. Mean change in scientific reasoning scores between groups. Sample size and legend is the same as in previous figures. II & II+ are significantly different from TT ( $p = 0.021$ ) and marginally significant from TI ( $p = 0.06$ ).

In addressing the statistical hypotheses presented in the introduction, the  $H_0$  of hypotheses 9 is rejected and the  $H_1$  is accepted; therefore, switching to inquiry-based labs and lecture positively affected students' scientific reasoning ( $II \neq TT$ ). The  $H_0$  of hypothesis 10 cannot be rejected ( $TT = TI$ ). Switching to inquiry-based labs alone did not affect students' scientific reasoning abilities positively. The  $H_0$  of hypothesis 11 is rejected as switching to inquiry-based lecture, in addition to inquiry-based labs, did significantly affect students' scientific reasoning abilities ( $II \neq TI$ ). Finally, the  $H_0$  of hypothesis 12 cannot be rejected. Adding more inquiry-based activities to the lecture did not affect students' scientific reasoning abilities ( $II+ = II$ ). The lack of significance may be a function of the small sample size of the II+ group, this group showed the largest overall change in science reasoning abilities.

### ***Correlations***

I performed pair-wise correlations within each group, within the two groups that had inquiry-based teaching (TI and II) and among all groups. Results of the correlation analysis show a strong positive correlation between students' attitudes and self-efficacy within each group (Table 5, 6, 7). Only the II group showed other significant, positive correlations between self-efficacy and scientific reasoning, and scientific reasoning and attitudes (Table 5).

Within the groups that had at least some inquiry-based teaching, attitudes and self-efficacy were significantly and positively correlated. Scientific reasoning and attitudes and self-efficacy were not correlated (Table 8). The same correlations are seen when all treatments are analyzed, however scientific reasoning and self-efficacy appear to be marginally significant (Table 9).

In the II and II+ groups, the  $H_0$  of hypotheses 13, 14, and 15 may be rejected and the  $H_1$  of each of these hypotheses accepted. There are positive correlations between attitudes and self-efficacy; attitudes and science reasoning; and self-efficacy and science reasoning. In all other groups (TI and TT) only the  $H_0$  of hypothesis 13 may be rejected. In these two groups, only attitudes and self-efficacy are positively correlated. The remaining surveys show no correlations.

**TABLE 5. PAIR-WISE CORRELATIONS OF EACH SURVEY RESULT WITHIN THE II TREATMENT.**

Correlation Variables	Correlation	N	p-value
Attitude/Self-Efficacy	0.3644	109	0.0001
Scientific Reasoning/Self-Efficacy	0.2702	109	0.0045
Scientific Reasoning/Attitude	0.1970	109	0.0401

TABLE 6. PAIR-WISE CORRELATIONS OF EACH SURVEY RESULT WITHIN THE TI TREATMENT.

Correlation Variables	Correlation	N	p-value
Attitude/Self-Efficacy	0.5524	46	0.0001
Scientific Reasoning/Self-Efficacy	-0.0908	46	0.5482
Scientific Reasoning/Attitude	-0.0563	46	0.7101

TABLE 7. PAIR-WISE CORRELATIONS OF EACH SURVEY RESULT WITHIN THE TT TREATMENT.

Correlation Variables	Correlation	N	p-value
Attitude/Self-Efficacy	0.5429	58	<0.0001
Scientific Reasoning/Self-Efficacy	0.1549	58	0.2456
Scientific Reasoning/Attitude	0.1459	58	0.3596

TABLE 8. PAIR-WISE CORRELATIONS OF EACH SURVEY RESULT BETWEEN THE II AND TI TREATMENTS.

Correlation Variables	Correlation	N	p-value
Attitude/Self-Efficacy	0.4427	155	<0.0001
Scientific Reasoning/Self-Efficacy	0.1043	155	0.1967
Scientific Reasoning/Attitude	0.0741	155	0.3596

TABLE 9. PAIR-WISE CORRELATIONS OF EACH SURVEY RESULT AMONG ALL TREATMENTS.

Correlation Variables	Correlation	N	p-value
Attitude/Self-Efficacy	0.3961	213	<0.0001
Scientific Reasoning/Self-Efficacy	0.1290	213	0.0603
Scientific Reasoning/Attitude	0.0514	213	0.4551

## **CHAPTER 4**

### **Discussion**

The focus of this study was to determine if switching from traditional, teacher-centered instruction to a more student-centered mode of instruction changed attitudes, self-efficacy, and science reasoning in community college students; specifically a positive change in these attributes. Few studies on inquiry-based teaching have been conducted at the community college level (Johnson & Lawson, 1998; Lunsford, 2003; Narayan et al., 2003); none were found that combined the three parameters that this study examined.

This study also examined levels of inquiry-based learning. The first level of inquiry-based teaching included classes that were taught with expository lectures and inquiry-based labs (TI). The second level of inquiry-based classes included those taught with inquiry-based sections within the lecture portion of the class and inquiry-based labs that corresponded to the inquiry-based lectures (II). In the final level of inquiry-based classes, the instructor included additional inquiry-based activities, such as PBL activities and reading and discussing primary literature articles (II+). The idea behind increasing inquiry-based activities in the last treatment was that I wanted to determine if students' attitudes, self-efficacy, and science reasoning were positively affected to a greater extent when presented with more, and different, inquiry-based activities.

As many instructors know, there are many different ways in which students learn and, as pointed out in previous studies (Burrowes, 2003; Kerns, 1996; Moore, 2003), student-centered methods are not a cure-all, but must be used judiciously. The idea behind adding different inquiry-based activities was to reach more students. One of the reasons for the shift toward inquiry-based teaching and learning is to present and teach science in the way that science is done. In this regard, we are hoping to create a more scientifically literate society.

I chose to use the scientific inquiry method, as outlined in the introduction, as a starting point for converting lecture activities in the II group. I chose this method, as I believe it is the most flexible in design and closely resembles the scientific process. While the experimental projects also closely model the scientific process, I decided that for the students in my courses needed more guidance than is seen in the experimental projects method. With the II+ group, I also used the scientific inquiry method and added PBL exercises to the lecture and other exercises in which students read and analyzed primary literature. Many studies have shown that reading and analyzing primary literature is an effective way to show students how science is done (Chrisman, 1998; Fortner, 1999; Herman, 1999; Levine, 2001), and to increase their scientific literacy.

### ***Pre-test Analysis***

As expected, no difference was found between pre-test scores for attitude, self-efficacy and science reasoning, between the four groups. Because these groups showed no significant difference in the pre-test scores for each survey instrument, it was assumed that the four groups were similar in starting points for this study.

### *Student Attitudes*

Attitudes are an important indicator of whether a student may use or forget knowledge they acquire from a course (Mager, 1968). Students with positive attitudes in a course are more likely to succeed and remember what they have been taught. Not surprisingly, student attitudes in the traditional, teacher-centered course, decreased. Studies have shown that subject-oriented courses are not an effective means of transferring knowledge to the student, even if that student is a self-professed biology major (Seymour & Hewitt, 1997).

Teacher-centered, didactic courses or seminars are most effective when two principals are met. First, the audience and the lecturer share a common background upon which the lecture builds. Second, and perhaps more important, that the members of the audience share an interest in the subject (Weld, 2003). In most undergraduate courses, it would be safe to assume that both of these conditions are rarely met. Even when renowned physicist David Feynman revised his freshman physics course and developed a highly innovative approach to teaching physics, only the same few students developed a deep grasp of the material (Wyckoff, 2001). It seems reasonable that if students find lectures boring, their attitudes toward the subject will suffer. Then, as student's attitudes suffer, so will their success (Cote & Levine, 2000; Schibeci & Riley, 1986).

Student attitudes in the traditional lecture and inquiry labs course (TI) increased significantly. It would appear, as other studies have shown (Sundberg & Dini, 1993; French & Russell, in press), that engaging students in an inquiry-based laboratory positively affects their attitudes toward biology. Interestingly, students in the inquiry-based lecture and laboratory courses (II) did not show a positive gain in attitudes toward

biology. This lack of positive change in attitudes differs from other experiments on inquiry-based learning in post-secondary settings (Ebert-May *et al.*, 1997; French & Russell, in press). It would be expected that students in the II courses would have had an even greater increase in their attitudes toward biology. When broken out, even the II+ group did not show a positive gain in attitude.

The lack of change in attitude in the II and II+ courses, while not expected, is not completely surprising. Inquiry-based courses can be more difficult, not only from the instructor's perspective but, more importantly, from the student's. The insignificant change in the II groups may be an artifact of artificially inflated attitude scores on the pre-test. In casual conversations with students I found that many students had an "easy" time in previous biology courses. This "ease" may translate into high attitudes toward biology. When the student is then presented with a more difficult biology course, attitudes may change very little because their attitudes started out high. Most of these students are also probably ego-oriented. Ego-oriented students gauge their performance based on the performance of others and attribute their success or failure to ability (Ward & Bodner, 1993). Task-oriented students are interested in learning a subject for its own sake. Task-oriented students evaluate their performance on an internal basis, are more likely to be satisfied with school and learning, and are more likely to sustain interest in a topic even after showing poor performance (Ward & Bodner, 1993).

Ward & Bodner (1993) suggest that because most students (99%) are ego-oriented, instructors undermine their motivation in classes, and need to shift these students toward task-orientation. Pushing instruction and testing away from rote memorization and toward the students' ability to justify and explain what they know is

one step toward making our students more task-oriented. This is exactly what inquiry-based instruction is trying to achieve.

While calling for this change Ward & Bodner (1993) also note that these changes will take time. If most students are ego-oriented, the modest gains in attitude in the II courses maybe more of a success than initially thought. Many of these students are getting their first experience with a scientifically oriented course and it is difficult for them. Because it is difficult, their attitudes toward the subject wane.

There also seem to be certain groups of students that may not be as positively affected by changes in pedagogy as others. French & Russell (in press) found that women with low ACT scores did not show significant increases in attitude after the course was converted to a more student-centered orientation. Eastern Wyoming College is an open-enrollment community college. As with many other open-enrollment colleges, the student body is quite different from one found at a university or four-year college. Up to half the students in the courses that were part of this study may not have the ACT scores to meet minimum requirements at a liberal arts college or major university.

Perhaps lower student achievement at an open-enrollment institution is also a possible reason for the lower attitude scores. Since many of these students are under-prepared, they may need more experience in student-centered teaching experiences to gain the proper “toolbox” so that they may learn effectively in this type of course. Up to 60% of students that enroll at EWC need some form of a developmental course in either English or math. One could infer that the expectations of these students are low and it could be that these students are more content to be passive. Since this was the first time



that both the instructor and students were exposed to inquiry-based teaching practices, in particular PBL, it could also be that more time was needed for adjustment.

### ***Student Self-Efficacy***

Self-efficacy, again, is defined as a person's beliefs about their capabilities to produce positive effects, and refers to the belief that an individual can organize and successfully execute courses of action (Bandura, 1994). Self-efficacy beliefs can provide a foundation for motivation and personal accomplishment (Pajares, 2002), and relate to a person's belief that they can affect an outcome. Self-efficacy is an important determinant of a student's attitude toward a given subject, and both efficacy (Brannick *et al.*, 2005) and attitude (Cote & Levine, 2000) reflect how successful a student may be in a given subject.

All groups (TT, TI, II and II+) experienced a significant, positive gain in self-efficacy. Thus the students are more likely to believe that they can organize and successfully execute courses of action within the field of biology. This study corroborates other studies that found student-centered pedagogy techniques raise a student's self-efficacy (Wilke, 2003). However, that the traditional group also experienced a significant gain in self-efficacy does not fit with previous studies. It would seem that in this study that any exposure to biology increases the student's self-efficacy toward the subject. This positive gain across the board may be due to the type of student found in an open-enrollment community college. Since these students are typically lower achieving students, their self-efficacy in a given subject may be lower than a typical college or university student. Exposing them to the subject has a greater positive effect. When these students were "graded" on their overall self-efficacy, all groups scored an

average below 68%. To grade these students' overall self-efficacy, their mean difference in self-efficacy score was divided by the total points possible for the self-efficacy survey. The students in this study scored themselves quite low to start off with; therefore, the rise in overall self-efficacy across the board does not seem unreasonable.

Interestingly, the group with the largest gain in self-efficacy was the TI treatment. This group had a traditional lecture and some inquiry-based labs. The II group gained in self-efficacy, but did not attain large gains in self-efficacy as expected. Again, this may be attributed to the perceived difficulty and newness of the II course. While the TI course had new components added into the laboratory section, most of the course was left unchanged and was closer to student expectations of what constitutes a college course; expository lecture. To most students, the II course was a radically different way to learn a subject, and one that made many students uncomfortable. To take this one step further, the II+ treatment did not show a significant gain in self-efficacy, while the II treatment alone did show a significant gain in self-efficacy. In increasing the amount of inquiry, I had hoped to increase student self-efficacy in biology to an even greater degree. It would appear that adding different inquiry experiences had did not have the desired effect. This may be attributed to changing experiences and changing student attitudes over the course of this study.

Experiences where an individual masters a concept are the best way in which to increase one's self-efficacy, while failure may undermine an individual's self-efficacy (Bandura, 1994). If students are coming to college after a relatively "easy" high school science curriculum, they may have an inflated sense of self-efficacy. Then, when challenged, their self-efficacy may be undermined. They may realize that they had not

mastered a subject as they had thought. This drop in self-efficacy is not unusual regarding other self-efficacy studies. In many studies, self-efficacy is seen to rise during the study then decrease to pre-test levels when the subjects are given a challenge. Self-efficacy has been found to rise during pre-service teacher training and then decrease when those teachers start student teaching (Wagler, 2003). Student teachers may find that the sudden immersion into student teaching is detrimental to their self-efficacy, perhaps because they are overly optimistic (Woolfolk et al., 1990) and have underestimated the complexity of the task (Weinstein, 1998). Other studies on pre-service teachers have shown a subsequent drop in self-efficacy that may have been a realization of shortcomings in their own teaching abilities, and a lack of reinforcement of their related self-efficacy (Moseley et al., 2000).

This “blow” to one’s self-efficacy may be explained thusly: The student feels confident that they can create positive results within biology when they start the course. Once into the course, the student’s self-efficacy is shaken as they realize that their perceived ability to produce positive outcomes is not completely correct. As they progress through the course, many students recover their self-efficacy. Perhaps by the end of the course, they may be more reserved as to how they answer questions of self-efficacy. This setback may compel some students to quit, or drop the course. Bandura (1994) notes that some individuals may be quickly discouraged by failures if they had experienced quick and easy success.

More importantly, setbacks and obstacles appear to be useful in training students that success requires a sustained effort (Bandura, 1994). So, in essence, the students that persisted through a more challenging course and gained self-efficacy may have a much

stronger sense of self-efficacy than they had before. It would be interesting to test these students' self-efficacy more than twice to determine at what point during the course did their self-efficacy drop. It may also be beneficial to test a cohort of students well after the course to monitor changes in self-efficacy.

Within the II+ treatment an element of cooperative learning was also introduced with the addition of the PBL exercises. Students were given a real world problem and expected to work together to find a solution. The gains in self-efficacy in the II+ group corroborate other studies that found gains in self-efficacy after the introduction of cooperative learning (Sadler, 2002).

What is interesting in this study is that the II and TT students gained in self-efficacy about equally. If self-efficacy were the only parameter measured in this study, a difference between these two groups would not have been seen. However, because this study used multiple survey instruments (see below for more discussion), a more complete picture of the effectiveness of inquiry-based pedagogy could be drawn.

### ***Scientific Reasoning***

The third part of this study was to determine if scientific reasoning abilities were positively affected by inquiry-based instruction. One of the main outcomes promoted by the *NSES* and *Benchmarks*, is that students learn how to “think like scientists”. When presented with a problem, students should be able to use scientific reasoning to logically arrive at an answer. We should be training students to become scientists so that they may use scientific reasoning and logic to solve everyday problems and engage in intelligent debate over public policy. This study used a scientific reasoning test and not a

standardized exam to indicate if students gain in scientific literacy (knowing how to do science) rather than science literacy (knowing terms and instruments).

The starting points for scientific reasoning were almost identical. The pre-test means for the II and TI groups were both 4.73 while the TT group had a pre-test mean of 4.64. The II and the II+ groups were the only groups that made significant gains in their scientific reasoning abilities, while the TI and TT showed no gains in scientific reasoning abilities. From this I conclude that changing some labs to inquiry-based instruction is not sufficient in increasing scientific reasoning skills. The more a student is exposed to scientific ways of thinking, the better his or her grasp on how to scientifically reason, and the more effective they will be in solving scientific problems.

### ***TT Conclusions***

It has been reported repeatedly that expository teaching is perhaps the least effective method of teaching students (Weld, 2003; Wyckoff, 2001). This study corroborates previous studies that show students lose interest in biology when it is taught as a broad array of disconnected facts (Bierzychudek & Reiness, 1992; Brand, 1995; Dougherty, 1995; Seymour & Hewitt, 1997). Students taught by the traditional, expository method had a significant decrease in their attitudes toward biology. They also experienced no gain in self-efficacy, and a slight loss in scientific reasoning. They don't like biology, they don't feel confident about the subject, and they still can't effectively answer a question in a scientific manner. They may understand more terminology within the field, or a few interesting facts, but that is not the goal of the NSES and AAAS Benchmarks.

### ***TI, II and II+ Conclusions***

In this section, unless otherwise stated, the use of the term II includes both the II and II+ groups. In looking at the results for the inquiry-based groups, some immediate questions come to mind: 1) If inquiry teaching is as effective as claimed, why do TI students not show an increase in scientific reasoning, while their attitudes and self-efficacy increase? 2) Why don't the attitudes of the II students increase more? There are possible explanations for these seemingly discrepant results.

The TI group showed the largest gains in attitudes toward biology and self-efficacy in biology, yet did not gain in scientific reasoning. This finding is counter to other studies that show a positive relationship to academic performance and self-efficacy (Pajares, 1996; Chemers *et al.*, 2001; Brannick *et al.*, 2005). Perhaps the style of teaching used in the TI course was not challenging to students in the TI courses; the students found this course to be easy. When students find a course to be easier than expected, their attitudes toward the subject and their feelings of self-efficacy within the subject may increase "artificially." Then, when the scientific reasoning abilities of these students are tested, they do not perform as well as they think they should; they are overly confident.

Another explanation may be related to the instructor. The TI instructor did not feel comfortable teaching the lecture portion of a course with an inquiry component. As an artifact of this arrangement of teaching duties, some idiosyncrasies may appear in the data. On at least one occasion during the labs that were designated as inquiry-based labs, I observed the TI instructor giving students more instruction than necessary. During the population and competition labs, students were asked to design their own competition

experiments using *Paramecium* after running a computerized competition simulation.

Students should have been able to use their own experiences learned, during the computer simulation, to design their own experiments. Before beginning any experiments, students were encouraged to check with the instructor to see if their hypotheses were testable and their experiments could answer their questions. However, the TI instructor told students how many test tubes to use and what to put in each test tube. This effectively made an inquiry-based lab a cookbook lab, and discouraged student inquisitiveness and creativity. It is unclear how many labs were re-converted to cookbook labs, so it is impossible to determine how this affected the results in these classes.

When the II students were left to design their own experiments, I found that many student groups not only did the minimum number of test tubes to perform and control the experiment effectively, they set up more test tubes to examine multiple hypotheses. The II students acted inquisitive and creative. The TI group appeared to be undermined. This may have contributed to these students' inflated attitudes and self-efficacies within biology, yet did not allow them to develop or practice their scientific reasoning abilities.

Just as perplexing, the students in the II courses did not experience positive gains in attitudes toward biology, but gained in self-efficacy and in scientific reasoning abilities. In this case, the II students' ideas about a science course were challenged, and they discovered that, as one student put it, "biology isn't as fun as it was in high school." However, by the end of the course, they showed more self-efficacy and were better able to answer questions scientifically.

The students in the II+ course also did not show a positive gain in attitudes. The II+ course included problem-based learning activities and reading and interpreting

primary literature articles. While the articles picked were great demonstrations of the scientific process, they were a difficult assignment for most students. Once the class as a whole summarized the articles and their methods, many students admitted understanding. A few even remarked, “why didn’t anyone ever show it [the subject] to us like this before?” That these students’ attitudes toward biology did not decrease, and their self-efficacy and scientific reasoning increased, perhaps demonstrates the beginning shift of students from ego-orientation to task-orientation within biology.

Students may still be accustomed to receiving all pertinent course information from the instructor. In one study, 20% of students surveyed gave negative responses after participating in a course that emphasized reading the primary scientific literature (Levine, 2001). Perhaps students who are less motivated or are already struggling, receive less benefit from reading technically oriented literature (Levine, 2001).

When a class is presented in a wholly new format, many students find it disconcerting. Students develop an expectation about courses before they get to college. That expectation is: sit in class, take notes, study those notes, and take the exam. An inquiry, student-centered lecture does not fit their expectations and may push many students out their comfort zones. When pushed out of this comfort zone, they may perform poorly and thus lose interest and self-efficacy in the subject. With continued coaching, students may recover, and while attitudes may still suffer a minor set back, these students show marked increases in self-efficacy and scientific reasoning. These students may have learned that success comes after a sustained effort.

Changes to instructional design may affect the educational experiences of the students and their expectations (Harrison *et al.*, 2001; Russell & French, 2002; Luckie *et*



*al.*, 2004). Other studies have shown that while students see the benefit of inquiry-based laboratories, they may express negative comments about the organization of the lab and quality of teaching (Casem, 2006). While initial student response to change may be low, it improves over time as organization and teaching effectiveness changes (Casem, 2006). So, it is not surprising that the attitudes of students in the II and II+ course did not increase as expected; however, it is evident that students derived benefit of these changes to the instructional design as they are reflected in the scientific reasoning portion of the surveys.

### ***Correlations***

Pairwise correlations of each survey instrument within the II treatment showed that each instrument was positively correlated. So, as attitudes increase, so will self-efficacy and scientific reasoning, and et cetera. That attitudes and self-efficacy are positively correlated is not a surprise. As students gain greater self-efficacy about a subject, and feel more comfortable with that subject, their attitudes should also improve. Using an inquiry approach also ties students' scientific reasoning skills to their attitudes and self-efficacy. This corroborates other experiments that show that student attitudes are more important than their aptitude in predicting success in science courses (Cote & Levine, 2000). Within the other treatments (TI and TT) the only significant, positive correlation was between changes in attitudes and self-efficacy.

The positive correlation of attitudes and self-efficacy holds true when the II and TI group are added together and also when all three treatments are added together. So, there appears to be a positive correlation between attitudes and self-efficacy. The better

students' attitudes toward biology, the more they feel that they can produce positive results.

Interestingly, the TI group had the largest positive change in attitude; however their attitude and science reasoning results did not correlate. Neither did their self-efficacy and scientific reasoning. This may again be explained by the TI group's false sense of self-efficacy and attitude. If this group's attitudes, self-efficacy and science reasoning were undermined as explained earlier, it would stand to reason that their gains in self-efficacy and attitude would not correlate to gains in scientific reasoning, as this group did not show significant gains in scientific reasoning.

### ***Using Multiple Survey Instruments***

This study is unique in its use of multiple survey instruments and focus on the community college level. Using multiple survey instruments allows better interpretation of the data and a fuller picture of the effect that inquiry-based teaching has on students at the community college. While many of these survey instruments are considered positively correlated, and the present study corroborates this idea, there may be times where one survey instrument may give a researcher a skewed view. For instance, using only the self-efficacy survey, one might conclude that TI and II instruction are equally effective at raising student self-efficacy in biology. However, after using all three instruments it appears that the TI students may have a false sense of self-efficacy built on quick and easy success. Such self-efficacy may not persist in the face of resistance or obstacles.

Using only the attitude survey as a measure of student success in biology would also present a skewed picture of the II treatment. While this group showed no significant

improvement in attitudes, they were the only group to show improvement in their scientific reasoning abilities. The results of the attitude survey would certainly be disheartening if not viewed with the more positive results of the self-efficacy and scientific reasoning surveys.

Using multiple surveys also allows an investigator to determine if there are shortcomings within the research design or its implementation. Clearly one problem with this study is the unbalanced manner in which the TI and II classes were divided between instructors. One of the major hurdles to better teaching through student-centered instruction is getting instructors comfortable with the methods and amenable to change. Many instructors are aware that expository teaching is ineffective, but are unwilling to change to an “untested” method, just for the sake of changing. For this reason, among others, continued research along these lines within higher education institutions is essential to bringing about this desired and needed change. Change in teaching styles is needed at the top, as it is the higher education faculty who train new teachers. If we really teach the way we were taught, then we need to retrain current faculty to teach in a manner that is more in line with current calls for teaching reform.

### ***Conclusions***

This study corroborates previous experiments that show that student-centered, inquiry-based teaching is more effective at increasing student scientific literacy. Students taught with an inquiry-based curriculum are better able to use scientific ways of thinking to answer questions. Students also show increased attitudes toward biology and a greater self-efficacy within the subject of biology when taught with inquiry-based methods.

A fuller, more complete picture of the effectiveness of inquiry-based teaching is reached when multiple surveys are used. There are interesting interactions that would have been missed if only one survey instrument were used. Perhaps an even fuller picture would be revealed if students also participated in a standardized pre- and post-test that focused on content knowledge. Part of the AAAS standards for a scientifically literate individual include being familiar with the natural world and being able to use scientific knowledge, as well as, scientific thought. While this study assumed that being able to reason scientifically is a good measure of a scientifically literate individual, there are instructors that are reluctant to give up on expository teaching, as they believe they would be sacrificing content. More studies are emerging that show active learning, such as inquiry-based methodologies, leads to an improvement in students' content achievement (Wilke, 2003). Other studies have reported that students taught in cooperative learning groups did not appear to gain less content knowledge than students taught by direct lecture (Sadler, 2002). If instructors can make deeper, more meaningful connections then it becomes easier for students to access that knowledge when asked. It is much harder to remember seemingly unrelated and disconnected facts.

As a personal anecdote, I was amazed at the students' level of involvement and willingness to participate once they realized that this "new" teaching style was not threatening, and was inherently more interesting than "just taking notes." Many students rose to the challenge of devising an experiment with the scientific or hypothetico-deductive method. Once they were comfortable with the process, they found it logical and easy to accomplish. Obviously, this can be quickly undermined if an instructor

peremptorily decides that the students won't be successful and gives them the answer, whether on purpose or sub-consciously.

One of the largest obstacles for instructors to overcome is our own apprehension at letting students struggle for a while and to become frustrated. As Bandura (1994) notes, we need to let students have set backs and struggles for them to learn that success comes with perseverance. This is the way that the student will gain self-efficacy within a subject. It is very easy for an instructor to give away answers to students to help, or even to keep the students from becoming frustrated. However, this does not serve the students and only sets them up for future hardship. It seems to over-inflate their self-efficacy and attitude toward the subject, without giving them the knowledge or experience necessary to critically think within the subject. Given the chance, students will rise to the occasion and even surprise you with their own ingenuity. The gut reaction for many students is to say, "I don't get it." The reaction from the instructor must be to re-challenge the student, not simply give the answer. When most students understand that the instructor won't just give them the answer, they try harder; they become more task-oriented.

Some instructors may question the importance of attitudes and self-efficacy in students. If we can increase the scientific reasoning abilities of our students, isn't that enough? Although improving only scientific reasoning appears to embody the goals of the NSES and AAAS, focusing in on this one measure may be shortsighted. While demonstrating that students are able to reason scientifically, we may not be creating a society that feels that they can effectively use scientific reasoning, or even care that they can. To create a scientifically literate society we need to focus, not only on increasing scientific reasoning abilities, but also on students' attitudes toward science. Much of the

concern within the sciences in recent years is the alarming rate at which students leave the sciences or our failure to entice students (especially women) to choose science as a potential career (Tobias, 1990; Seymour & Hewitt, 1997). Focusing on attitudes and self-efficacy, as well as, scientific reasoning may help reverse this trend. This is especially important as our society relies more heavily on science and technology.

In striving to reach the goals of the *NSES, Benchmarks, BIO 2010* and *Beyond BIO 101*, it is imperative that we get the fullest picture possible so that we may make informed decisions as to what works and what needs to be re-thought. It is clear from this study and countless others that the way we teach undergraduate biology must change. There are a myriad of changes that each instructor could make. Which will be effective? That is a question that can only be answered with further and complete research.

### ***Recommendations for Future Research***

There are many areas that may be more closely examined in future studies. This study did not elucidate differences in demographic data. The sample size of this study was too small to examine possible effects of gender, educational background (ACT scores) and ethnicity on these parameters. Many studies have looked at how differences in these demographic variables are impacted by inquiry-based teaching (Steussy, 1984; Russell, 1999; French & Russell, in press). These types of studies should also be extended to the community colleges.

During this study, I believe we are seeing a rebound effect in overall student self-efficacy. I believe that many of the students in the II groups had their self-efficacy shaken and were in the process of rebuilding their self-efficacy when the post-test was given, and this is a possible reason why these students did not gain a higher self-efficacy,

than the TI group, as expected. It would be interesting to give community college students, who score themselves low in self-efficacy, a series of self-efficacy post-tests throughout the semester to observe possible drops and rebounds in self-efficacy throughout the semester. This periodic self-efficacy testing would allow an examiner to map out the effect of challenges and obstacles to student self-efficacy.

This study was also limited in the number of labs that were converted to inquiry-based labs. This study converted four cookbook labs to inquiry-based labs; some of the inquiry-based labs ran for several weeks. An interesting study could be to add additional inquiry-based labs one at a time. This would allow the examiner to determine if more inquiry-based labs, without inquiry-based lectures, would be as effective in positively affecting student attitudes, self-efficacy and scientific reasoning, as adding in inquiry-based lecture exercises. For instructors wary of adding inquiry-based lecture exercises, this type of study may be useful.

This study was also conducted while I, as the TI instructor, was also discovering how to teach in an inquiry-based style. While I chose to teach with what I would consider as the scientific inquiry method, others may not. The reason I chose this method was that I thought it afforded the most flexibility in design. While I thought I followed a valid inquiry-based teaching style, there is no doubt that any instructor would continue to refine and perfect their style over several years. This study was limited to two years, at the onset of learning to teach in a new fashion. It would be beneficial to study instructors over a number of years to determine how much of an instructor effect, or learning curve for teachers, there may be.

### ***Implications of the Study***

Because many community colleges are growing rapidly across the United States, the implications of this study may be far reaching. Many students use community colleges as their springboard to liberal arts colleges and universities. These students may take their first, and perhaps only science course at these colleges. Community colleges then, are quickly becoming a clearinghouse for introductory science courses. If we are to meet the goals of the *NSES* and others, much more reform and research needs to be done at the community colleges across the nation. We need to make sure that this growing number of students is exposed to the scientific field in our community colleges to insure that we are making the proper strides toward a scientifically literate society.

Many of these students that choose to attend their introductory science courses at community colleges may also continue their education at a college or university as an Elementary Education major. Again, if we are to meet the goals of the *NSES*, it is important that we break the cycle of teaching how we were taught. If reform in science teaching does not reach the community colleges, we will have a much tougher time in breaking this cycle.

Research at the community colleges is also important, if the student body is vastly different than those found at other colleges and universities. Students at community colleges may be less motivated due to poorer attitudes, have lower self-efficacy and poorer scientific reasoning skills than other students. Since most community colleges are open-enrollment, the student body at these institutions may be quite different from those at more selective institutions. Because of this potential difference in student



demographics, it is important to examine these differences and determine if inquiry-based teaching methods are proper or effective for these students.

To be sure, community colleges are becoming important in preparing, not only scientifically literate citizens, but also future teachers that can take inquiry-based teaching to the elementary schools. To that end, community colleges, liberal arts colleges and universities need to make sure that they collaborate in reforming and researching the best type of teaching methods needed for each type of student.

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APPENDIX A

SYLLABI FOR THE II, TI AND II+ CLASSES



**Resources:**

- a) Textbook -- Biology, Raven and Johnson (6th ed.)
- b) Laboratory Manual (2nd ed.)
- c) Other Instructional Material -- videotapes, slides, internet resources, overhead transparencies, microscope slides, plant and animal specimens, and handouts given in class.

**Course Outline -- Tentative Lecture Schedule**

<u>Date</u>	<u>Topic</u>
9/3	Intro: Why Study Biology? Asking ?'s
9/5	Science and the Scientific Method Chemical Bonds and Water

**Lab: No Lab This Week**

9/8	Macromolecules and Carbon
9/10	Proteins & Nucleic Acids
9/12	Lipids & Carbohydrates

**Lab: Scientific Method (Lab 1) & Microscopy (Lab 2)**

9/15	Catch-Up/Review
9/17	Cell Theory & Structure <i>Read pp. 75-76; Virtual Lab Online</i>
9/19	<b>Exam 1 (1,2,3)</b>

**Lab: Can cell types and function be determined by identifying cell structures? (Lab 4)**

9/22	Discussion of Virtual Lab/Cell Structure
9/24	Cell Structure/Cell Analogies
9/26	Membrane Structure

**Lab: Can cell types and function be determined by identifying cell structures? (Lab 4)**

9/29	Diffusion/Osmosis
10/1	Osmosis/Transport <i>Read pp. 141-142; Virtual Lab Online</i>
10/3	Discuss Virtual Lab/Energy

**Lab: Diffusion and Osmosis (Lab 5)**

10/6	Energy & Enzymes
10/8	Respiration
10/10	Respiration

**Lab: Enzymes (Lab 3)**

10/13 Photosynthesis  
 10/15 Photosynthesis/Review  
 10/17 **Exam 2 (5,6,8,9,10)**  
**Lab: What factors influence metabolic rates? (Lab 6)**

10/20 Mitosis  
 10/22 Meiosis  
 10/24 **Fall Break - No Class**  
**Lab: Mitosis and Meiosis (Lab 7)**

10/27 **Fall Break - No Class**  
 10/29 Inheritance  
 10/31 Inheritance/Multiple Alleles  
**Lab: Observing human phenotypes and population variation (Lab 8)**

11/3 Multiple Alleles; Sex Linkage  
 11/5 Human Chromosomes  
 11/7 DNA  
**Lab: Introduction to DNA Fingerprinting (Lab 9)**

11/10 Replication, Transcription  
 11/12 Transcription, Translation  
 11/14 Catch-Up/Review  
**Lab: Introduction to DNA Fingerprinting (Lab 9)**

11/17 **Exam 3 (11,12,13,14,15)**  
*Read pp. 419-420; Virtual Lab Online*  
 11/19 Discuss Virtual Lab/Genes In Populations  
 11/21 Genes in Populations/Evolution  
**Lab: Natural Selection: Are albino individuals more easily captured by predators? (Lab 10)**

11/24 Evolution/Darwin  
 11/26 **Thanksgiving - No Class**  
 11/28 **Thanksgiving - No Class**  
**Lab: No Lab**

12/1 Origin of Species  
*Read pp. 493-494; Virtual Lab Online*  
 12/3 Discuss Virtual Lab Online/Population Ecology  
 12/5 Population Ecology

**Lab: Does competition affect population growth rates? (Lab 11)**

12/8 Population Ecology  
 12/10 Community Ecology  
 12/12 Community Ecology

**Lab: Does competition affect population growth rates? (Lab 11)**

12/15 Putting It All Together/Review  
 12/19 Final Exam (Comprehensive & 1,20,21,22,24,25)  
 10:00-11:45 am

**Course Requirements:**

- a) **Lecture Exams** -- Three one-hour lecture exams will be given. Lecture exams are worth 100 points each. The final exam will be *comprehensive* and worth 200 points.
- b) **Lecture Quizzes** -- Approximately 11 quizzes will be given, usually at the beginning of a lecture session. Each quiz will be worth 10 points. The lowest quiz will be thrown out for a total of 100 points.
- c) **Lecture Discussions** - We will discuss four primary literature articles, these discussions will be worth 10 points each.
- d) **Lecture Questions** - Throughout the semester you will be asked to answer questions and respond with a remote. These questions will give you two points for a correct answer and one point for answering incorrectly. You may accumulate a maximum of 60 points towards your grade.
- e) **Lab Reports** -- Four lab reports will be required and will be worth 20 points each. See the lab manual for further information.
- f) **Lab Assignments** -- Lab assignments will total 80 points.
- g) **Lab Participation** -- You are expected to participate in lab. 40 points will be given at the instructor's discretion.
- h) **Attendance** -- See below.

**Evaluation Criteria:**

Final grades will be determined with the following total points:

Lecture	Lab	
Exam 1.....100	Lab Reports.....80	900-1000 (90-100%)=A
Exam 2.....100	Lab Assignments..110	800-899 (80-89%) =B
Exam 3.....100	Planning Forms....40	700-799 (70-79%) =C
Final Exam.200	Participation..... <u>70</u>	600-699 (60-69%) =D
Quizzes....100	300	≤599 (≤59%) =F
Discussions.40		
Questions... <u>60</u> (Max)		
700		

**Late Assignments**

Assignments are considered late if they are not turned in on the designated due date and time as specified by the instructor. Any assignment turned in within 24 hours of the due date and time will receive an automatic 10% reduction in grade. No assignments will be accepted after this period. For instance, if an assignment is due at the beginning of lab, and you turn it in at the end of lab, it will receive an automatic 10% reduction in grade.



### **Attendance and Withdrawal Policy**

Regular attendance is essential to success in this course. Therefore, you are expected to attend all lecture and lab sessions. Should it be necessary for you to miss a lecture or lab session due to an extenuating circumstance or participation in an approved school function, it is your responsibility to make up the work missed. Contact the instructor before missing a session when possible. All labs must be made up during the week in which they are conducted, or you will lose your participation points. Contact a classmate for assignments, handouts and notes missed during lecture sessions.

- Assignments will not be accepted from missed labs.
- Missing more than one lab will result in failure of the class.

You may withdraw from the course with a grade of “W” (withdrawal); however, the decision must be made and the procedure accomplished **on or before** the last official day to drop a class. Otherwise you will receive a grade of “F”. This is your responsibility. Also consistent with Eastern Wyoming College policy, the instructor may withdraw you from this course on or before the last day to drop a class:

- i) your absences exceed 20% of the scheduled class sessions for the semester,
- ii) you are absent six consecutive class hours.

Exceptions that do not count as absences:

1. Prolonged illness (hospital, etc.)
2. Death in the immediate family.
3. School activities and trips (team sports, class field trips, etc.) Student must tell instructor before absence.
4. Snowy highways -- out of town students.

Note: the instructor reserves the right to verify extenuating circumstances.

Tardiness: Coming in late to class or lab is extremely disruptive. However, there are extenuating circumstances when students are late to class. Therefore, a student may be late to class two times for the grading period. After that, two (2) points will be deducted for each tardy. Excessive tardiness (3 or more) may result in a lowered grade.

Additional comments:

1. Sleeping in class - 2 points will be deducted.
2. Working on other assignments - 2 points will be deducted.

### **Make-up Policy**

Make-up exams are only given due to extenuating circumstances or participation in an approved school function, and with great reluctance. The student must contact the instructor prior to the exam date, either by leaving a message, or by talking to the instructor. In most cases you will be asked to take the exam early. If this is not possible, you may take an essay make-up exam within one week of the original test date. If the instructor is not contacted before the exam date, no make-up exam will be possible. **No**

**make-up exams are possible for the final exam. There are no make up opportunities for lab.** In other words, attend your lab every week.

### **Academic Honesty**

Any form of academic dishonesty will not be tolerated. This includes both using additional materials on exams (cheating) and plagiarism. Plagiarism is copying or using the ideas of another individual without giving proper credit through the use of quotation marks or other acceptable forms of citation. Cheating includes using notes or crib sheets on tests and copying from fellow students, or submitting work that was done by someone else. While you will work with others in lab, you are still expected to answer questions for assignments on your own. If it is obvious that a student has violated any of the above, all students involved will receive zero credit for the assignment or exam. The matter may also be turned over to the Dean of Students for any further action. In short -- don't even think about it.

### **Classroom Expectations for Students**

1. You are expected to attend all classes and labs.
2. You are expected to complete all required work and exams within the dates of the semester (September 4-December 19)
3. You are expected to read the textbook and all assigned readings, and complete all other assignments as given by the instructor.
4. You are expected to take all exams on the dates and times scheduled.
5. You are expected to take notes during lecture and study them.
6. You are expected to seek additional help as necessary. Make an appointment with me for assistance if you are attending class regularly, taking notes, reading your text, and are using your study guides but are still not performing well on tests. In addition to your instructor, tutors and peer study groups are an excellent resource.
7. You are expected to be fully prepared to participate in activities and discussions in each lecture and laboratory session.
8. You are expected to observe proper classroom etiquette (i.e. showing respect for others by not talking when others are talking, being prompt to class, and cooperating with your instructor in your educational experience.)
9. You are expected to clean up your lab station at the end of each lab. Failure to do so will result in a loss of participation points.

### **Safety Rules**

1. If you have personal health problems or limitations of which the instructor should be aware, please advise him of these personally, as soon as possible after the first class meeting.
2. In case of fire, evacuate the classroom and building. Exit the classroom in an orderly manner, following the exit plan near the door of the classroom.
3. In the event of a tornado, you will hear a siren sounding steadily. Move to an interior wall of the room, away from windows. Place your head between your knees. Do not leave the building. Remain in the safe shelter until an all-clear signal is given.

4. In the event of an earthquake, evacuate the building if this can be done safely. If the building cannot be evacuated, stay away from windows, and get under desks or next to a load-bearing wall.
5. In case of severe winter weather, classes may be dismissed. An announcement will be made throughout the campus, or the message will be broadcast over the radio stations KGOS and KERM in Torrington. Off-campus students should use discretion in attempting to reach campus during severe weather.

**Americans with Disabilities**

Eastern Wyoming College is committed to providing reasonable accommodations for qualified individuals with disabilities. If a student has a disability and desires reasonable accommodation for such disability, the student should contact Mr. Tom McDowell or Ms. Marilyn Cotant as soon as possible, so that arrangements may be made.

**Disclaimer**

Information contained in this syllabus is, to the best knowledge of the instructor, considered correct and complete. However, this syllabus should not be considered a contract between Eastern Wyoming College and the student. The instructor reserves the right, acting within the policies and procedures of EWC, to make changes in course content or instructional technique without notice or obligation.

**Fall Semester 2002**

Eastern Wyoming College  
Biology Department

Course Information

**Principles of Biology (Biol 1000-03)**

Biol 1000 Lab (Biol L004-01, L004-02, or L004-03)

Biol 1000-02 lecture meets TTh from 10:30 - 11:55 am.

Labs meet once a week; T, W, or Th from 2:00 to 4:55 pm.

4.0 credit hours.

**Instructor Information**

Nick Roster, M.S.

Office #218

Office Phone: 532-8294

E-mail: [nroster@ewc.wy.edu](mailto:nroster@ewc.wy.edu)

Office hours: MTW 1-2

M 2-4

Other times by appointment.

**Course Content Information**

Catalog description: Primarily for the non-major. Considers fundamental principles of ecology, evolution, cell biology, and genetics, as well as their relevance to contemporary society. Emphasizes critical thinking and problem-solving abilities. Laboratory is required. (This course is not equivalent to BIOL 1010 and credit cannot be earned for both courses.)

Rationale: As an informed citizen in a democracy, you have a great deal to say about the solutions to problems. In a democracy it is assumed that the public is informed enough to make intelligent decisions. This is why an understanding of biological concepts is so important for any person regardless of his or her vocation. Biology 1000 will fulfill the general education category of Lab Science for the Associate of Arts and Associate of Science Degree.

**Course objectives:**

- I. To develop an understanding of the scientific method and its relationship to life processes.
- II. To develop an understanding of ecosystem organization, and community types.

- III. To become familiar with modes of inheritance, species diversity, and natural selection.
- IV. To develop an understanding of the basic chemistry, anatomy, energetics, and reproduction of living cells.
- V. To become familiar with various laboratory applications and techniques.
- VI. To develop an appreciation of social problems and current issues, which affect the science of biology.

**Resources:**

- a) Textbook -- Basic Concepts in Biology, Starr (5th ed.)
- b) Laboratory Manual (1st ed.)
- c) Other Instructional Material -- videotapes, slides, internet resources, overhead transparencies, microscope slides, plant and animal specimens, and handouts given in class.

**Course Outline -- Tentative Lecture Schedule**

<u>Date</u>	<u>Reading Assignment</u>	<u>Topic</u>
Sept5	Ch. 1	Intro: Why Study Biology? Asking ?'s Science and the Scientific Method

**Lab: No Lab This Week**

10	Ch. 20	Bacteria, Viruses, Protozoans and Algae
12*	Ch. 21	Fungi, Mold, Lichens
	Ch. 22	Bryophytes, Seedless Vascular Plants

**Lab: Scientific Method & Microscopy**

17	Ch. 22	Seed Vascular Plants
19*	Ch. 23	Sponges, Worms, Mollusks
	Ch. 23	Arthropods and Insects

**Lab: Gymnosperms and Angiosperms**

24*	Ch. 24	Vertebrates/Review
26		<b>Exam 1 (1, 20-24)</b>
	Ch. 27	Population Dynamics

**Lab: Echinoderms and Vertebrates**

1	Ch. 28/29	Social/Community Interactions
Oct 3*	Ch. 29/30	Communities/Ecosystems
	Ch. 31	Temperate and Arctic Biomes

**Lab: Population Simulation (Part 1)**

8 Ch. 31 Aquatic Biomes  
 10\* Ch. 32 Human Population Growth/Impacts

**Lab: Population Simulation (Part 2)**

15 Ch. 32 Environmental Impacts/Review

17 **Exam 2 (27-32)**

**Lab: Identification of an Unknown Chemical**

22 Ch. 2 Atoms and Bonds

24\* Ch. 2 Water, Acids, Bases, Salts

Ch. 3 Carbohydrates and Proteins

**Lab: Cell Structure (Part 1)**

29 Ch. 3 Proteins, Nucleic Acids

31\* Ch. 4 Cells

Ch. 4 Cell Structure

**Lab: Cell Structure (Part 2)**

Nov 5 Ch. 8,9 Mitosis& Meiosis/Review

7 **Exam 3 (2-4, 8, 9)**

**Lab: Mitosis and Meiosis**

12 Ch. 10 Inheritance

14\* Ch. 11 Chromosomes

Ch. 12 DNA

**Lab: Observing Human Phenotypes**

19 Ch. 13 Transcription/Translation

21\* Ch. 14 Gene Expression

Ch. 15 Genetic Engineering/Ethical Issues

**Lab: DNA Fingerprinting (Part 1)**

26 **Exam 4 (10-15)**

28 **No Class - Thanksgiving**

**No Class - Thanksgiving**

**Lab: No Lab This Week**

Dec 3 Ch. 16 Darwin's Theory

5\* Ch. 17 Origin of Species

Ch. 18 Macroevolution

**Lab: DNA Fingerprinting (Part 2)**

10	Ch. 18	Human Evolution
12*	Ch. 19	Origins of Life
	Ch. 19	Origins of Life

**Lab: Natural Selection**

Final Exam (Comprehensive)

Biol 1000-01 Wednesday, December 17, 2002 10:00-11:45 am

**Course Expectations****Course Requirements:**

- Lecture Exams** -- Four one-hour lecture exams will be given. Lecture exams are worth 100 points each. The final exam will be *comprehensive* and worth 200 points.
- Lecture Quizzes** -- Approximately 11 quizzes will be given, usually at the beginning of a lecture session. Each quiz will be worth 10 points. The lowest quiz will be thrown out for a total of 100 points.
- Lab Reports** -- Three lab reports will be required and will be worth 20 points each. See the lab manual for further information.
- Lab Assignments** -- Lab assignments will total 80 points.
- Lab Participation** -- You are expected to participate in lab. 40 points will be given at the instructor's discretion.
- Attendance** -- See below.

**Evaluation Criteria:**

Final grades will be determined with the following total points:

<u>Lecture</u>	<u>Lab</u>	
Exam 1.....100	Lab Reports.....60	792-880 (90-100%)=A
Exam 2.....100	Lab Assignments....80	704-791 (80-89%) =B
Exam 3.....100	Participation.....40	616-703 (70-79%) =C
Exam 4.....100	180	528-615 (60-69%) =D
Final Exam.200		≤527 (≤59%) =F
Quizzes....100		
700		

**Late Assignments**

Assignments are considered late if they are not turned in on the designated due date and time as specified by the instructor. Any assignment turned in within 24 hours of the due date and time will receive an automatic 10% reduction in grade. No assignments will be accepted after this period. For instance, if an assignment is due at the beginning of lab, and you turn it in at the end of lab, it will receive an automatic 10% reduction in grade.

**Attendance and Withdrawal Policy**

Regular attendance is essential to success in this course. Therefore, you are expected to attend all lecture and lab sessions. Should it be necessary for you to miss a lecture or lab session due to an extenuating circumstance or participation in an approved school function, it is your responsibility to make up the work missed. Contact the instructor

before missing a session when possible. All labs must be made up during the week in which they are conducted, or you will lose your participation points. Contact a classmate for assignments, handouts and notes missed during lecture sessions.

- Assignments will not be accepted from missed labs.
- Missing more than one lab will result in failure of the class.

You may withdraw from the course with a grade of “W” (withdrawal); however, the decision must be made and the procedure accomplished **on or before** the last official day to drop a class (November 8, 2002). Otherwise you will receive a grade of “F”. This is your responsibility.

Also consistent with Eastern Wyoming College policy, the instructor may withdraw you from this course on or before the last day to drop a class:

- i) your absences exceed 20% of the scheduled class sessions for the semester,
- ii) you are absent six consecutive class hours.

Exceptions that do not count as absences:

1. Prolonged illness (hospital, etc.)
2. Death in the immediate family.
3. School activities and trips (team sports, class field trips, etc.) Student must tell instructor before absence.
4. Snowy highways -- out of town students.

Note: the instructor reserves the right to verify extenuating circumstances.

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Additional comments:

1. Sleeping in class - 2 points will be deducted.
2. Working on other assignments - 2 points will be deducted.

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Make-up exams are only given due to extenuating circumstances or participation in an approved school function, and with great reluctance. The student must contact the instructor prior to the exam date, either by leaving a message, or by talking to the instructor. In most cases you will be asked to take the exam early. If this is not possible, you may take an essay make-up exam within one week of the original test date. If the instructor is not contacted before the exam date, no make-up exam will be possible. **No make-up exams are possible for the final exam.**



### **Academic Honesty**

Any form of academic dishonesty will not be tolerated. This includes both using additional materials on exams (cheating) and plagiarism. Plagiarism is copying or using the ideas of another individual without giving proper credit through the use of quotation marks or other acceptable forms of citation. Cheating includes using notes or crib sheets on tests and copying from fellow students, or submitting work that was done by someone else. While you will work with others in lab, you are still expected to answer questions for assignments on your own. If it is obvious that a student has violated any of the above, all students involved will receive zero credit for the assignment or exam. The matter may also be turned over to the Dean of Students for any further action. In short -- don't even think about it.

### **Classroom Expectations for Students**

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2. You are expected to complete all required work and exams within the dates of the semester (September 4 - December 20)
3. You are expected to read the textbook and all assigned readings, and complete all other assignments as given by the instructor.
4. You are expected to take all exams on the dates and times scheduled.
5. You are expected to take notes during lecture and study them.
6. You are expected to seek additional help as necessary. Make an appointment with me for assistance if you are attending class regularly, taking notes, reading your text, and are using your study guides but are still not performing well on tests. In addition to your instructor, tutors and peer study groups are an excellent resource.
7. You are expected to be fully prepared to participate in activities and discussions in each lecture and laboratory session.
8. You are expected to observe proper classroom etiquette (i.e. showing respect for others by not talking when others are talking, being prompt to class, and cooperating with your instructor in your educational experience.)
9. You are expected to clean up your lab station at the end of each lab. Failure to do so will result in a loss of participation points.

### **Safety Rules**

1. If you have personal health problems or limitations of which the instructor should be aware, please advise him of these personally, as soon as possible after the first class meeting.

2. In case of fire, evacuate the classroom and building. Exit the classroom in an orderly manner, following the exit plan near the door of the classroom.
3. In the event of a tornado, you will hear a siren sounding steadily. Move to an interior wall of the room, away from windows. Place your head between your knees. Do not leave the building. Remain in the safe shelter until an all-clear signal is given.
4. In the event of an earthquake, evacuate the building if this can be done safely. If the building cannot be evacuated, stay away from windows, and get under desks or next to a load-bearing wall.
5. In case of severe winter weather, classes may be dismissed. An announcement will be made throughout the campus, or the message will be broadcast over the radio stations KGOS and KERM in Torrington. Off-campus students should use discretion in attempting to reach campus during severe weather.

**Americans with Disabilities**

Eastern Wyoming College is committed to providing reasonable accommodations for qualified individuals with disabilities. If a student has a disability and desires reasonable accommodation for such disability, the student should contact Ms. Lynnea Bartlett or Ms. Marilyn Cotant as soon as possible, so that arrangements may be made.

**Disclaimer**

Information contained in this syllabus is, to the best knowledge of the instructor, considered correct and complete. However, this syllabus should not be considered a contract between Eastern Wyoming College and the student. The instructor reserves the right, acting within the policies and procedures of EWC, to make changes in course content or instructional technique without notice or obligation.

**Biology 1010 – Eastern Wyoming College – (II+ Syllabus)**

This course will use a problem-based learning format. Students in groups will work through real world problems with the goal of learning how to apply and synthesize biological concepts and principles, find and evaluate biological information, and communicate ideas and information about biology to others. Discussions led by the course instructor, plus supplementary lectures, help give the problems a context and conceptual framework, and otherwise guide efforts to learn to "think biologically."

**Instructor Information**

Nick Roster

Office: Tebbett 218

Office Phone: 532-8294

E-mail: [nroster@ewc.wy.edu](mailto:nroster@ewc.wy.edu)

Office hours: MTWTh: 1-2:00 M: 2-3

Other times by appointment. You may want to call or e-mail me to see if I will be in my office before you drop by.

**Course Content**

A survey of the basic principles of biology. Units are included on the scientific method, the cell, genetics, evolution and diversity, and ecology.

Resources:

- a) Textbook -- "Explore Life", Postlethwait and Hopson
- b) Textbook -- "Thinking Towards Solutions: PBL Activities for General Biology", Allen and Duch
- c) Lab Manual -- Biology 1010 Lab Manual
- d) Other Instructional Material -- anything presented in class and lab including: internet resources, microscope slides, plant and animal specimens, and handouts.

**Course Objectives**

The problem-based learning format, integrated with other class activities such as demonstrations, mini-lectures, and concept-mapping will provide the opportunity to develop the basic skills and understanding of content in the areas further described below. Exams, group and individual assignments related to each problem, oral presentations, and group evaluations will provide the opportunity for you to demonstrate the progress you have made in meeting both the content and skills objectives.

## Content Objectives

The emphasis in this course will be the unity and diversity of life, and seeing biological principles within a context so that you can learn to apply these concepts to novel situations. There are several common themes or principles that are important enough to repeat in various contexts, and include (by no means is this list all inclusive):

Scientific Method or your ability to state hypotheses, design experiments and interpret data.

Gradients – living things create, maintain, or respond to differences in concentration of an amount of a substance over an area. You will need to know how gradients are created, and what occurs when a gradient is present.

Protein structure and function and their use in membranes. You need to understand the effect changing a protein's shape has on the protein and the biochemical system in which it is found. You need to know what function proteins serve and how these functions are achieved.

Natural Selection. You need to understand how this process leads to adaptations. You need to understand its action and result in scenarios, and how fitness is involved. You need to understand the trade-offs in costs and benefits that exist in every adaptation, structure or function.

Homeostasis. You need to recognize what happens when a living system is thrown out of balance, and how a living thing returns to a balanced state, in regards to its internal environment.

Metabolism. Chemical and energy transformations are an essential characteristic of all living things. You need to know the metabolic processes we discuss and how they apply to particular scenarios.

Laws of Thermodynamics. Tied to metabolism are thermodynamics. You need to know how the laws of thermodynamics apply to energy acquisition and transfer. You need to understand how these laws help shape our understanding of how chemical reactions can be related.

In addition to these, various activities in the class will be designed to introduce you to ways of taking this understanding several steps further - i.e., towards applying concepts you have learned to new situations, synthesizing concepts to build a new (higher level of) understanding, and using your knowledge and understanding of biology to build reasoned arguments for a particular point of view.

## **Skills Objectives**

In addition to learning concepts and principles in biology, the PBL format also allows you to practice the following skills, which should not only be applicable to other areas of study, but also to future jobs:

- Reason critically and creatively
- Make reasoned decisions in unfamiliar situations
- Ask questions that guide self-directed learning
- Identify, find, and analyze information that is needed for a particular project or task
- Piece together information into a coherent and cohesive framework
- Communicate ideas and concepts
- Collaborate productively in teams toward accomplishment of shared goals
- Gain understanding of the other person's point of view
- Give and accept constructive criticism gracefully

## Course Methods

### **Course Philosophy**

Introductory Biology (BIOL 1010 and BIOL 2020) is intended to be a survey course which introduces students to the breadth of biological sciences and prepares them for higher level courses in biology or other sciences. Therefore a broad-based understanding of content is important. Although the lecture format of teaching has the potential to deliver content, there is no assurance that a student will develop the skills mentioned above, since listening to lecture is a very passive activity. Furthermore, studies suggest that collaborative learning improves productivity, professional self-esteem, problem-solving skills, and positive social relationships. Therefore, this course will include some lecturing, but will also have an active student-centered component of group learning.

### **Course Structure**

Half or more of "lecture" meetings will be devoted to traditional lecturing. The rest will be devoted to problem-based group learning. Class activities are roughly apportioned in the following way: there will be a lecture on the material; then you will work with your group on an activity (usually a problem) which applies to the topic of the week.

Lectures: It is your responsibility to do the readings and come prepared to listen to a lecture. Lectures will be given using Power Point. Copies of slides for each lecture will be posted (usually the day before the lecture), and can be accessed from WebCT. You may be able to better follow the lecture if you bring along these Power Point notes. Also posted on WebCT will be suggested readings, questions and learning objective for each major topic within the course. It is your responsibility to do the readings and come prepared to class.

**Problems:** Problems will be real-world scenarios which you will have to analyze in the context of a biological foundation. Working with other members of your group, you will address a series of questions which will require resources (text, notes, internet resources) to answer. Therefore bring your text; most times it will be extremely difficult to work through the problem without a text. These problems should reinforce your understanding of the content material, help you develop some analytical skills, hone your ability to work with others, and give you experience in addressing real issues. You may be asked to do some research ahead of time, or you may be asked to preview the problem on line. If so, it can be accessed from WebCT. There will usually be a group "product" from your problem session due at the end of the period (usually answers to questions, or opinions). These will be read, graded, and returned in the next class, with some relevant discussion. Common class misconceptions can be read and corrected here.

**Exams & Quizzes:** Quizzes will be given during the semester - their purpose is to keep you up to date in your studying. They will consist of 10-15 multiple choice questions and will be available on WebCT. There will generally be a quiz every week (excluding exam weeks) it will be YOUR responsibility to complete these quizzes on WebCT even if your scatter-brained instructor forgets to mention them. In addition to the quizzes, there will be 4 exams. You will need a #2 pencil to take exams. Three of them are hourly exams, given during regular class time, and the fourth exam is a final exam, scheduled during Finals Week. They will be similar in format to the quizzes, but with a more extensive synthesis of the material (use learning guides, class notes, and problems to prepare). Exam questions will typically require interpretation of data and application of concepts to novel situations rather than rote memory. All class activities (including lab) and assigned readings are fair game for exams.

### **Formation and Functioning of Groups**

Groups of 4 people each will be assigned by me by the second class period. They will be listed in the "Group" link on WebCT. Except for minor changes that may have to be made because of late dropping or adding of the course, these groups will be permanent for the whole semester. I will try to make these groups similar to your lab groups.

An early group activity will be to formulate ground rules, or operating rules of conduct that each member agrees to abide by. These will be in writing, signed by each group member, and handed in to me. Each group will be assigned a folder in which attendance will be recorded and quizzes and problems can be stored. An explanation of the peer evaluation process will also be in the folder. It is extremely important for group functioning that you attend each group session and that you be punctual. Lateness and absenteeism can result in a poor peer evaluation score and a grade deduction. If absence is unavoidable due to one of the reasons listed below (see Attendance section), you **MUST** notify your group members and me.

**Rotating Roles.** There are two roles that are important to each group getting its work done, including the group's ability to contribute well to whole class discussions. These include the role of "recorder" and "reporter." Because these roles are so important, they

will be rotated (approximately weekly) to ensure that each member of the group has a chance to perform in these roles.

**Recorder** - Writes down the group's learning issues and their priority, and who is responsible for researching each learning issue. Takes notes on discussions for the group's contribution to whole class discussions for use by the reporter. Keeps track of who performed the recorder and reporter roles. Keeps ongoing written record (including drafts and final version) of any group assignments, and prints the necessary forms from WebCT as needed by the group.

**Reporter** - Offers group contribution to whole class discussions. Hands in group assignments to instructor by due date and time.

Date	Lecture Topic	Chapter	Lab
1/14	Introduction to Course/What is Life and Science?	1	No Lab
1/17 1/19 1/21	Life characteristics Problem #1 - A Birdsong Trilogy Populations & Ecology	124	Accessing EBSCOLab 1 - Scientific Method Lab 2 - Microscopy
1/24 1/26 1/28	Problem #2 - Camping with Caterpillars Interactions of Populations Global Warming and Butterflies	2425	Competition (11)
1/31 2/2 2/4	Energy Flow Materials in Nutrient Cycles Biomes	25	Finish Competition
2/7 2/9 2/11	"Review/Catch-Up Exam #1 - Chapters 1,24,25 No Class"	25	Diffusion and Osmosis (5)
2/14 2/16 2/18	Inorganic Chemistry Problem #3 Don Tries to Culture Fish Cells Cell Function/Lactose Intolerance	2	Enzymes (3)
2/21 2/23 2/25	Particle Movement How Organisms Get Energy	23	Cells (4)

2/28 3/2 3/4	Aerobic and Anaerobic Exercise Problem #5 The Geritol Solution Photosynthesis	3	Cells (4)
3/7 3/9 3/11	"Review/Catch-up Exam #2 - Chapters 2,3 Cell Division"	4	Metabolism (6)
3/14 3/16 3/18	Inheritance Inheritance	5	Mitosis and Meiosis (7)
3/30 4/1	Inheritance DNA Replication	56	Phenotypes and Variation (8)
4/4 4/6 4/8	DNA Replication How Genes Work	67	DNA Profiling (9)
4/11 4/13 4/15	Transcription Translation	7	DNA Profiling (9)
4/18 4/20 4/22	"Exam #3 - Chapters 4,5,6,7 Guppies in the Rainforest Natural Selection	9	Natural Selection (10)
4/25 4/27 4/29	Evolution	9	TBA
5/2 5/4	Review and Catch-Up Final Exam (10:00)	All	No Lab

### Grading

Your final grade is a reflection of your effort in both the classroom (lecture) and laboratory. Lecture will constitute 70% of the final grade, lab 30%. Your grade in lecture will be based on three criteria: Individual Performance, Group Performance, and Peer Evaluation.

1. Individual Performance (quizzes, exams, other assignments): 75% of lecture grade
2. Group performance (problems): 25% of lecture grade
3. Instructor/Peer Evaluation (modifies the group performance grade). The peer evaluation system is described after grading.

A more detailed breakdown of the individual and group components of the lecture grade is shown below:



<b>Individual Component</b>	-	<b>75%</b>
-	<b>% of Lecture Grade</b>	-
Quiz Average	10%	-
Hourly Exams	35%	-
Final Exams	20%	-
Other Assignments	10%	-
<b>Group Component</b>	-	<b>25%*</b>
-	<b>% of Lecture Grade</b>	-
Problem Average	25%	-
-	<b>*Modified by Peer Evaluation Score</b>	<b>100%</b>

The total grade for lecture will be multiplied by 70%

Your grade in Lab will be based on Lab Assignments (including Reports), Lab Exams, and Peer Evaluation. Peer evaluation in lab will modify your participation grade. A more detailed breakdown of the lab grade is shown below in the grade calculation example

Example of grade calculation:

If for example, your semester's grades were the following, you could calculate your expected grade for the course:

Lecture Peer Evaluation 9.5 out of 10, or 95.0%

#### Individual Component

Component	Grade Ave	Weighting Factor	Total
Quiz Ave	90	10%	9%
Exam Ave	80	35%	28%
Final Exam	83	20%	16.6%
Other Assign	92	10%	9.2%
Total	-	75%	<b>62.8%</b>

#### Group Component

Component	Grade Ave	Weighting Factor	Total
Problems*	90	25%	22.5%
X Peer Evaluation		<b>95%</b>	<b>21.4%</b>

\*Each Problem is graded on a 10-point scale. The average is then multiplied by 10.

Lab Peer Evaluation 9.0 out of 10, or 90%. You automatically get a 100 average, your peer evaluations in lab will modify this.

### Lab Component

Component	Grade Ave	Weighting Factor	Total
Assign Ave	90	30%	27%
Reports Ave	86	40%	34.4%
Lab Exams	89	20%	17.8%
Participation	90	10%	9%
-	-	100%	<b>88.2%</b>

Lecture =  $(62.8 + 21.4\%) \times 70\% = 58.9\%$

Lab Work =  $88.2\% \times 30\% = 26.5\%$

Final Grade =  $58.9\% + 26.5\% = 85.4\%$

### Grading Scale

A	88-100
B	77-87.9
C	66-76.9
D	55-65.9
F	Below 55

This absolute grading scale (rather than one based on class average) means that your success in this course won't hinge on someone else's lack thereof.

### Attendance

Attendance in lecture is EXPECTED and will be checked - this may be used for "extra credit" where grades are borderline. Announcements will be made, or activities started, at the beginning of class, so promptness is important. If you miss a lecture, notes must be obtained from another student. Power point slides for each lecture are available through a link for each class topic (see the class schedule). Even if you do not anticipate absence, you may still want to access the power point notes for each lecture. They will usually be available the day before each lecture. These slides are not all-inclusive. I will supplement them during lecture, so attendance is extremely important -nothing substitutes for coming to lecture. If you are not present in lecture when graded work is taking place, credit for that work will not be received. Exceptions are the following:

1. documented illness - must be document by a physician
2. documented personal tragedy (documented by Dean of Instruction or Dean of Students)
3. documented official College business (documented by faculty sponsoring the event)

Students who know they will miss an exam for an excusable reason must inform me before or on the day of the exam through phone or e-mail; otherwise, absence will be considered unexcused and a zero will be given.

Absence from your group on a group problem day is excusable for the above reasons only. The activity may then be made up by getting the instructions from me and handing the "product" in to me before I return your group's graded product in class. One of the benefits of analyzing a problem is to evaluate the opinions of other people; therefore you may only resort to doing a problem on your own if one of the above circumstances makes it impossible for you to be in class. There will be NO EXCEPTIONS to this.

Attendance in laboratory is MANDATORY. We place high importance on the laboratory experience. Therefore unexcused laboratory absences will result in a grade reduction for the whole course. One absence will reduce your grade by 5 points; two unexcused absences will result in a failure of the whole course. Excused absences fall into the categories listed above and can be made up by attending a lab at another time during the same week. Responsibility for arranging this lies with the student. However, the student MUST see me first, and I will determine if the reason for absence is valid. Make up during a later week cannot be accommodated.

You may withdraw from the course with a grade of "W"; however, the decision must be made and the procedure accomplished on or before the last official day to drop a class (see the Academic Calendar). Otherwise you will receive a grade of "F".

Also consistent with Eastern Wyoming College Policy, the instructor may withdraw you from this course on or before the last day to drop a class:

- i) your absences exceed 20% of the scheduled class session for the semester,
- ii) you are absent for six consecutive class hours.

Tardiness is extremely disruptive. However, there are extenuating circumstances when students are late to class. Therefore, a student may be late to class two times for the grading period. After that, two (2) points will be deducted for each tardy.

### **Make Ups, Late Assignments and Academic Honesty**

#### **Make-up Policy**

Make-up exams are only given due to extenuating circumstances or participation in an approved school function, and with great reluctance. The student must contact the instructor prior to the exam date, either by leaving a message, or by talking to the instructor. In most cases you will be asked to take the exam early. If this is not possible, you may take an essay make-up exam within one week of the original test date. If the instructor is not contacted before the exam date, no make-up exam will be possible. No make-up exams are possible for the final exam.

**Late Assignments**

Assignments are considered late if they are not turned in on the designated due date and time as specified by the instructor. Any assignment turned in within 24 hours of the due date and time will receive an automatic 10% reduction in grade. No assignments will be accepted after this period. For instance, if an assignment is due at the beginning of lab, and you turn it in at the end of lab, it will receive an automatic 10% reduction in grade.

**Academic Honesty**

Any form of academic dishonesty will not be tolerated. This includes both using additional materials on exams (cheating) and plagiarism. Plagiarism is copying or using the ideas of another individual without giving proper credit through the use of quotation marks or other acceptable forms of citation. Cheating includes using notes or crib sheets on tests and copying from fellow students, or submitting work that was done by someone else. While you will work with others in lab, you are still expected to answer questions for assignments on your own. Since quizzes will be done on WebCT over an extended period of time, there will be opportunity to consult with your classmates, do not do it. Quizzes are to be done on your own. If it is obvious that a student has violated any of the above, all students involved will receive zero credit for the assignment, quiz or exam. The matter may also be turned over to the Dean of Students for any further action. In short -- don't even think about it.

**Communication**

You will need access the web throughout the semester and WebCT. You can access most things in this course from home through WebCT, or from computers on campus. You will also have to activate your WebCT account, you will be given directions on how to do this, if you don't already know how. I will use email within WebCT to communicate with the whole class, and with individuals. Often, announcements will be made by email within WebCT. The web page should be checked frequently for changes or additions, and will need to be accessed weekly for problem previews or Power Point notes. In laboratory, data will be shared and transmitted through WebCT, which will be explained in lab. Lab reports must be typed; graphs can be hand-done (on graph paper) or done in Excel.

**Evaluations**

For group problems, all members of a group receive the same grade. The expectation is that everyone made equal contributions and expended equal effort. However, in reality, that may not be true - some may work very hard, while others may "coast". To acknowledge differences in effort among group members, you will have a chance to evaluate one another with respect to attitude, participation and contributions by doing peer evaluations. These peer evaluations will be done in a quantitative way at the end of the semester, and will be used to advise me in determining how, or whether, to modify a person's group performance score. You will evaluate your peers both in lecture and in lab.

Peer evaluation scores will be given by assigning 0-10 points to fellow group members. A score of 10 indicates that a person is a fully functional group member (comes to class

on time, comes prepared to work, contributes to group) - in other words, he/she merits 100% for group effort. If a group is not functioning well because of one or more weak members, or some other dysfunction, this should be brought to my attention as early as possible in the semester, so that the situation can be corrected, and low evaluation scores can be avoided at the end of the term.

After averaging your peer evaluation scores from other group members, your score will be used to modify your group grade in the following way. If for example, you receive scores of 9.5, 10, and 9 from your other group members, your average is 9.5 pts. This means you will receive 95% of your group performance score. If your average is 8.5pts., you will receive 85% of the group performance score. I will also take attendance into account. It is expected that everyone will attend every class.

### **Guidelines for Success**

- \*COME TO CLASS. On time. Your group will depend on you, especially on days with group functions.
- \*Come to class prepared.
- \*Hand in assignments on time.
- \*Participate in group discussions and group tasks.
- \*Carry out your responsibilities assigned by the group.
- \*Listen to and show respect for others' opinions (but, this doesn't mean you have to agree!)
- \*Assist your group in planning how it can work better next time.
- \*Take advantage of office hours, or ask questions by e-mail. Stay in touch
- \*Write up laboratory reports as soon as possible after the lab is completed. It will be easier to do it immediately, rather than several days later.
- \* Take responsibility for your own education and get involved. You will learn more and have more fun if you are active in your education - guaranteed!

For lab and lecture, be familiar with the college policy on Academic Dishonesty. All work submitted for grading in lab and lecture, except the group work, must be the original work of each individual.

### **Miscellaneous**

Americans with Disabilities

Eastern Wyoming College is committed to providing reasonable accommodations for qualified individuals with disabilities. If a student has a disability and desires reasonable accommodation for such disability, the student should contact Ms. Marilyn Cotant or Mr. Tom McDowell as soon as possible, so that arrangements may be made.

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APPENDIX B

LABS MODIFIED FOR INQUIRY INSTRUCTION.

## Can cell types and function be determined by identifying cell structures?

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### Introduction

The local Game Warden has been investigating the mysterious disappearance of several pronghorn antelope from an established herd in the area. Local ranchers are also concerned as these antelope have been seen in and around their own livestock. What the Game Warden has found so far is that each time an antelope disappears some cellular residue that he cannot identify is left behind. You have been assigned the task of determining the identity of the components of this cellular residue. To accurately determine the components of this residue, you must first familiarize yourself with cell types and functions.

You will need to develop a system of cellular identification to determine what is in this mysterious cellular residue. This may help determine what is happening to the antelope.

---

### Lab Activities

After completing these activities, you should be able to:

- describe relationships between cell function and their components (organelles)
- identify cellular structures on an electron photomicrograph
- identify cell types based on their components

To determine the contents of the cellular residue, it is important that you become familiar with the organelles of cells and their functions. As determining the identity of cells may be related to the assimilation of organelles within the cell, it would also be helpful to be able to identify cellular organelles from photomicrographs. The following activities will give you experience in identifying cellular components before you are asked to identify the unknown cells in the cellular residue.

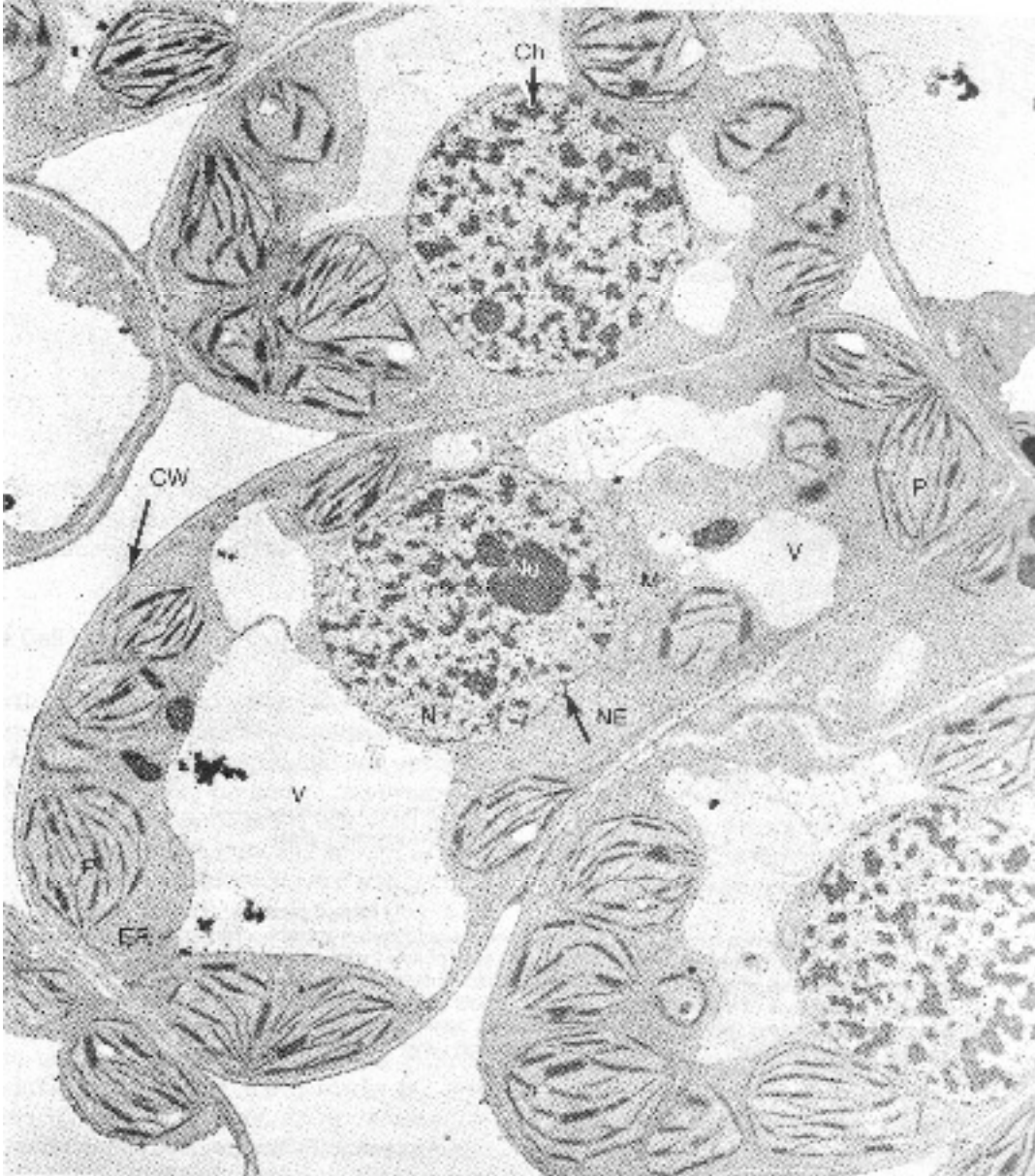
A. Below is a list of cell components. To be able to identify an unknown cell, it will be helpful to understand the functions of the cellular components. This table will allow you to summarize the not only the functions of the cellular components, but in which kingdom each component is found. This will allow you to more quickly identify the unknown cells. You may wish to use your textbook, lecture notes, or web links to help you fill in this table. Be sure to enter your descriptions in your own words, as this will give you a chance to develop a better understanding of the functions and appearance of these components.

**Cell Component Identification Summary**

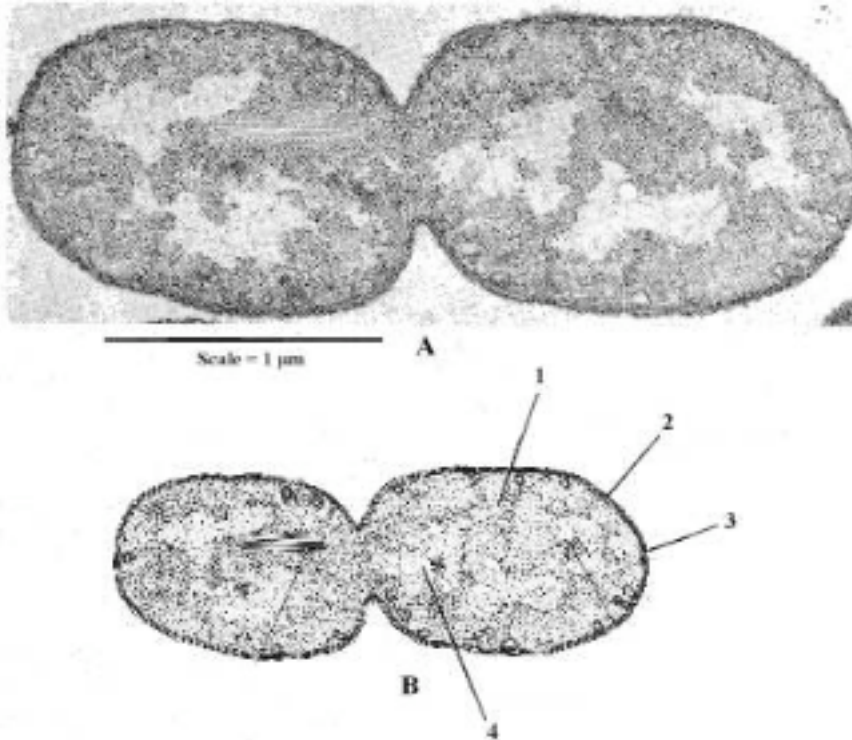
<b>Cell Structure</b>	<b>Function(s) and Appearance</b>	<b>Monera</b>	<b>Protista</b>	<b>Fungi</b>	<b>Plantae</b>	<b>Animalia</b>
Cell Membrane						
Nucleus						
Nucleolus						
Golgi Body						
Smooth Endoplasmic Reticulum						
Rough Endoplasmic Reticulum						
Ribosomes						
Mitochondria						
Chloroplast						
Vesicle						
Cytoplasm						
Cilia						
Flagella						
Cell Wall						
Plastid						
Vacuole						



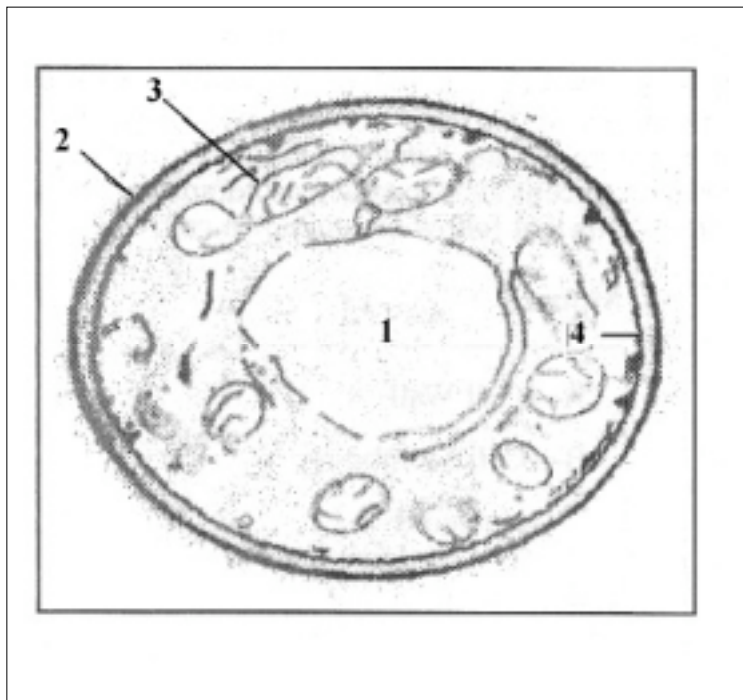
B. Use the following photomicrographs and diagrams to practice identifying cells and cell components. Note the scale on each diagram. The last two cells are unknown. Identify their components and the Kingdom to which they belong.



**Figure 2.** Plant cell structure. Ch, chromatin; CW, cell wall; ER, endoplasmic reticulum; M, mitochondria; N, nucleus; NE, nuclear envelope; Nu, nucleolus; P, plastids; V, vacuole.

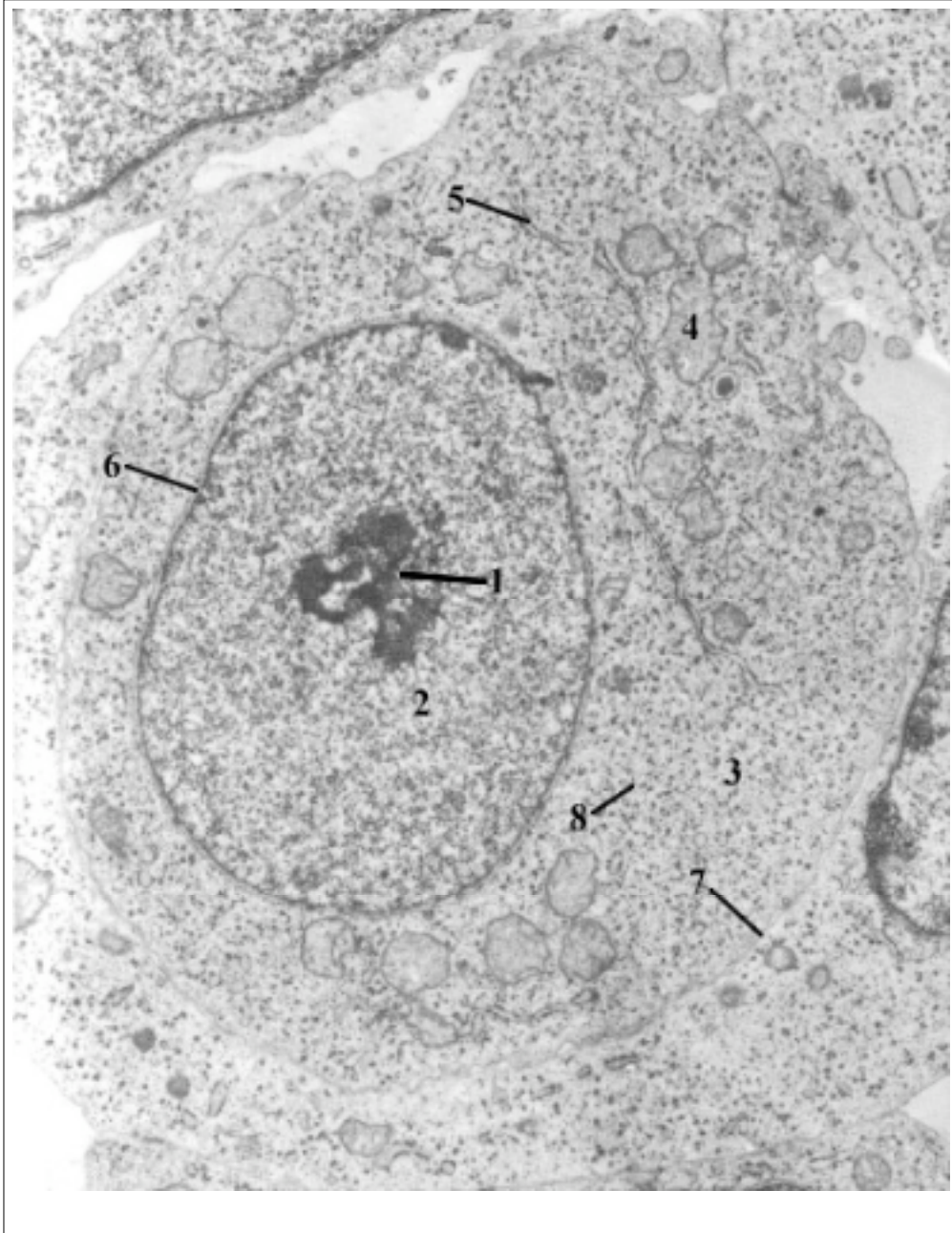


**Figure 3.** A. Transmission electron micrograph of bacterial cell. Note scale. B. Drawing of above TEM. 1, ribosomes; 2, cell membrane; 3, cell wall; 4, nucleoid region. Also note that at the time of the TEM the bacterium is in the process of division.



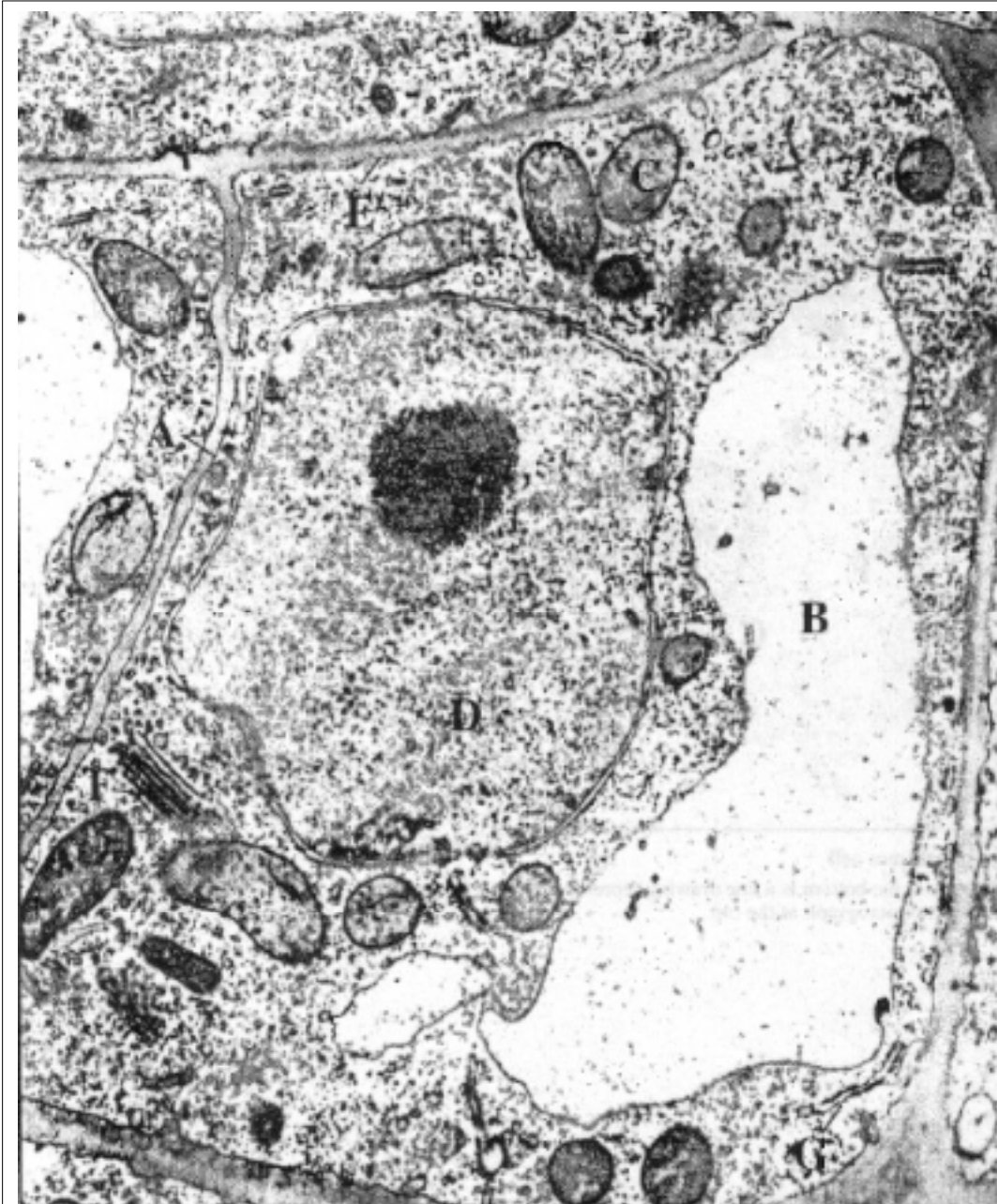
**Figure 4.** Fungal cell (yeast).

- 1 - Nucleus
- 2 - Cell wall
- 3 - Mitochondria
- 4 - Cell membrane



**Figure 5.** Animal cell. 1, nucleolus; 2, nucleus; 3, cytoplasm; 4, mitochondria; 5, endoplasmic reticulum; 6, nuclear membrane; 7, cell membrane; 8, ribosomes.

Figure 6. Unknown Cell #1



A -

E -

B -

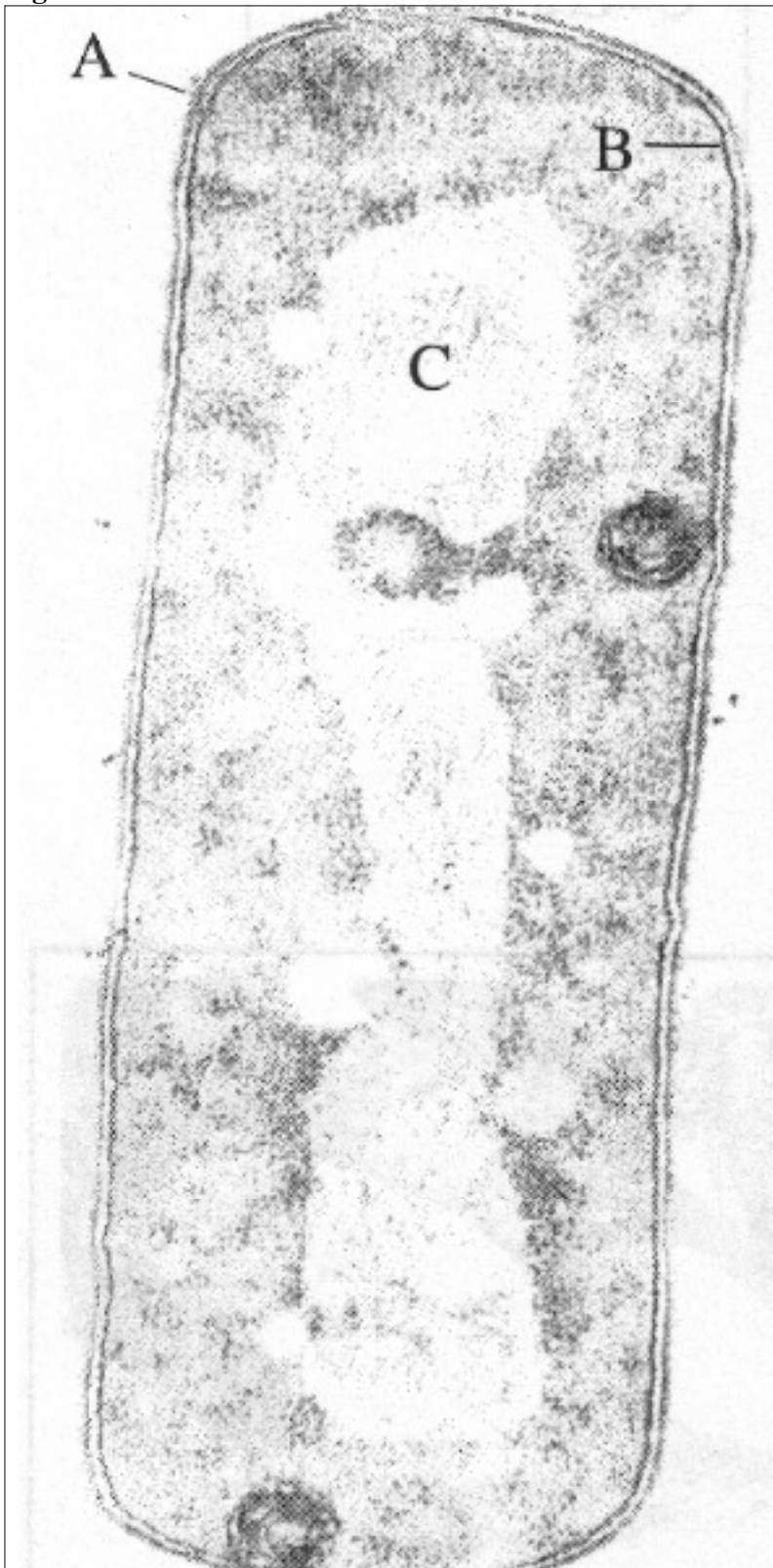
F -

C -

G -

D -

Figure 7. Unknown Cell #2



- A-
- B-
- C-

Answer the following questions based on what you see in the photomicrograph/diagram of Unknown Cell #1 and #2.

a. What kind of cell is it (kingdom)?

1-

2-

b. How did you identify the cell types?

There are terms or concepts that you may wish to use in your lab report. They include the following:

Prokaryote	Eukaryote
Organelle	All cell components in the previous table
Photomicrograph	Taxonomy
Kingdom (the Hierarchical Classification System)	

You will use the following tables to help you identify the unknown cells in the cellular residue. Mark off organelles that are present, and make additional notes that will assist you in correctly identifying the unknown cells.

Since your resources on site are limited, you only have a 1000x light microscope. It is certainly not powerful enough to discern the smaller organelles, so some samples of the cellular residue were sent to the State Crime Lab for further analysis. You will be given a report of their findings.

Examine the slides of the five unknowns and begin to fill in the tables. From this preliminary examination, you may be able to determine the Kingdom, and thus narrow the possible number of cell types. However, you should use the State Crime Lab report to finalize and confirm your findings. Using the State Crime Lab report, you may even be able to determine the function of the cells and their location.

Finally, your report should not only identify the mysterious cellular residues, but it should also contain a guide. This guide will help other criminologists in the identification of cells based on their structure and contents. So, you will need to develop a system for the identification of each type of cell.

**Unknown Cell One**

<b>Cell Structure</b>	<b>Present</b>	<b>Absent</b>	<b>Other Notes</b>
Cell Membrane			
Nucleus			
Nucleolus			
Golgi Body			
Smooth Endoplasmic Reticulum			
Rough Endoplasmic Reticulum			
Ribosomes			
Mitochondria			
Chloroplast			
Vesicle			
Cytoplasm			
Cilia			
Flagella			
Cell Wall			
Plastid			
Vacuole			
Unidentified Structures			

**Unknown Cell Two**

<b>Cell Structure</b>	<b>Present</b>	<b>Absent</b>	<b>Other Notes</b>
Cell Membrane			
Nucleus			
Nucleolus			
Golgi Body			
Smooth Endoplasmic Reticulum			
Rough Endoplasmic Reticulum			
Ribosomes			
Mitochondria			
Chloroplast			
Vesicle			
Cytoplasm			
Cilia			
Flagella			
Cell Wall			
Plastid			
Vacuole			
Unidentified Structures			



**Unknown Cell Three**

<b>Cell Structure</b>	<b>Present</b>	<b>Absent</b>	<b>Other Notes</b>
Cell Membrane			
Nucleus			
Nucleolus			
Golgi Body			
Smooth Endoplasmic Reticulum			
Rough Endoplasmic Reticulum			
Ribosomes			
Mitochondria			
Chloroplast			
Vesicle			
Cytoplasm			
Cilia			
Flagella			
Cell Wall			
Plastid			
Vacuole			
Unidentified Structures			

**Unknown Cell Four**

<b>Cell Structure</b>	<b>Present</b>	<b>Absent</b>	<b>Other Notes</b>
Cell Membrane			
Nucleus			
Nucleolus			
Golgi Body			
Smooth Endoplasmic Reticulum			
Rough Endoplasmic Reticulum			
Ribosomes			
Mitochondria			
Chloroplast			
Vesicle			
Cytoplasm			
Cilia			
Flagella			
Cell Wall			
Plastid			
Vacuole			
Unidentified Structures			

**Unknown Cell Five**

<b>Cell Structure</b>	<b>Present</b>	<b>Absent</b>	<b>Other Notes</b>
Cell Membrane			
Nucleus			
Nucleolus			
Golgi Body			
Smooth Endoplasmic Reticulum			
Rough Endoplasmic Reticulum			
Ribosomes			
Mitochondria			
Chloroplast			
Vesicle			
Cytoplasm			
Cilia			
Flagella			
Cell Wall			
Plastid			
Vacuole			
Unidentified Structures			

**Planning Form**

Name \_\_\_\_\_ Date \_\_\_\_\_

Describe the **observation** in the background material that led to the **question** under investigation:

What **hypothesis** (casual explanation) are you proposing to explain the observations and answer the question?

Outline of your **Experiment**:

- A. How will you treat your **experimental group(s)**?
  
- B. What will serve as your control **groups(s)**?
  
- C. How will you **collect** your data (equipment, interval, method, and duration of sampling)?
  
- D. How will you **analyze** your results and compare them to those predicted from your hypothesis?

What are your **Prediction(s)**?

A. IF my hypothesis is SUPPORTED, then I predict that the results of my experiment will be that.....

B. IF my hypothesis is UNSUPPORTED, then I predict that the results of my experiment will be that....

References (textbook, library articles, WWW, other)

**Lab Notes**

Hypothesis to be tested:

Alternative hypothesis(es):

Justification for hypothesis:

**Experimental Design**

Independent (manipulated) variable:

Dependent (measured) variable:

Any modifications of laboratory manual procedures:

Observations during experiments:

How do your observations support or not support your hypothesis?

How do your observations relate to your references?

## What factors influence metabolic rate?

---

### Introduction

The zookeepers at the Scottsbluff Zoo are responsible for the care and feeding of all the animals. They must also keep careful records on when each animal eats and how much they eat. When looking over their records, they notice that many animals eat different amounts of food at different times of the year. They also notice that as the animals grow they also eat different amounts. They all remember from their introductory biology courses that energy is required for all the chemical reactions in the body (metabolism). The energy that is needed is derived from the food we eat. They can also recall that oxygen is needed and carbon dioxide is given off as a byproduct. Concerned that some animals may not be getting enough food while others are getting too much, they decide to investigate. They decide that using small rodents would be best at answering this question, as they have plenty of them. Unfortunately, they can't break free from their zoo keeping duties to work on this problem. They call you. Are their thoughts valid? Do some animals eat more at different times of the year? Should they buy more food for all the animals or just some of them?



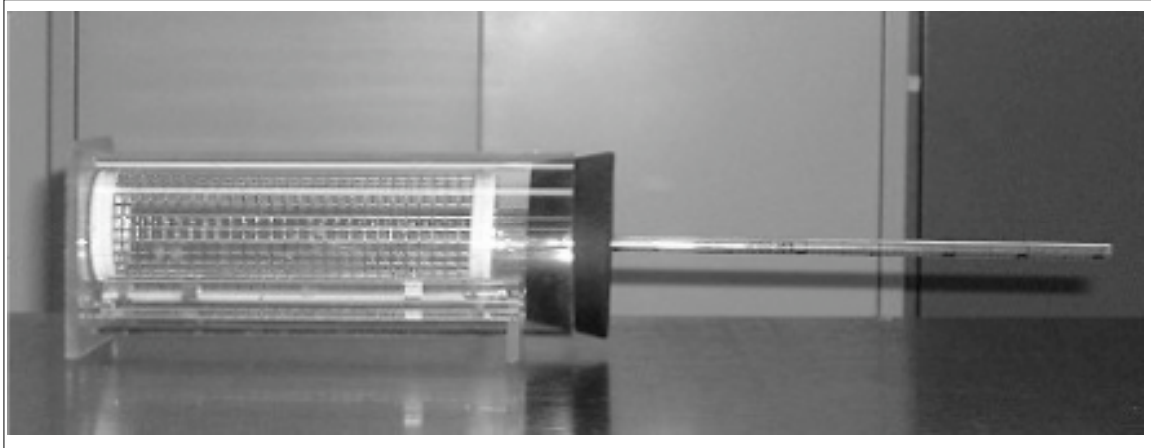
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### Lab Activities

After completing these activities you should be able to:

- determine rate from a graph
- compare rates from many experimental trials
- use a metabolic chamber and explain how it works
- explain the relationship between O<sub>2</sub> consumed and metabolic rate
- be able to use Excel to manipulate numbers and create graphs

Before planning your experiment, view the respiration chamber Figure 9 and in the lab. In the bottom of the chamber, you place soda lime. What does soda lime do? Why do you need it? Again, think about the process of metabolism. Think about how a respiration chamber, such as the one in lab, might work.



**Figure 9.** Small animal respiration chamber.

--What might you measure to help you calculate an organism's metabolic rate? There are two things you might measure.

Terms and concepts you might use in your lab report:

Endothermic	Homeotherm	Metabolic Rate
Ectothermic	Poikilotherm	

Special equipment for this lab.

Water baths (hot and cold)	Triple-beam balances
Metabolic chambers	Soda Lime (caustic)
Gerbils	

Special Instructions

Animal handling

You will be using live animals in this lab. They need to be handled with the utmost care and respect. For your protection, you should wear gloves when handling any of the animals in this lab. General instructions:

1. These animals *will* try to escape. If an animal escapes, try to quickly and quietly recapture it without squashing it.
2. They are going to get tired. Give them breaks between trials. Open the chamber and give them fresh air. Only handle them as much as necessary. As they get tired they may become less willing to be handled.
3. These are live animals - they will perform the usual bodily functions. Be prepared, and clean up after them.
4. The animals should never be placed directly in ice or hot water baths.
5. Do not adjust temperatures on the water baths.

6. While the animals and chambers are acclimating to temperatures, leave the lids off so they can have fresh air.
7. Watch the animals closely for signs of stress. If they start washing themselves extremely often, stop the trial and give the animals fresh air.
8. Handle the animals at the base of their tails. If you try anywhere else, you could break their tail, or it may even break off. Once you have them, quickly pick them up and let them sit on your other, gloved hand. Using their tail as a 'leash.'
9. If you do get bit, they shouldn't be able to bite through the glove. If they do happen to break the skin, tell the instructor so the wounds can be treated.

### Calculation Instructions

These instructions are to calculate the metabolic rate of your test animals. Metabolic rate will be recorded in: gm-cal/hour/cm<sup>2</sup>.

1. Record the total time in minutes (not minutes and seconds) for the gerbil to consume a given quantity (ml) of oxygen.
2. Calculate the number of ml of oxygen consumed per minute.
 
$$\frac{\text{ml Oxygen consumed}}{\text{total number of minutes}} = \text{ml/min}$$
3. Multiply ml/min by 4.8 gm-cal. We use 4.8 as we assume that a normal animal releases 4.8 gram calories of heat for each ml of oxygen consumed. You should now have gm-cal/min.
4. Multiply this number by 60 min to get gm-cal/hour.
5. You will now need to divide this number by the surface area of the gerbil. You may get the surface area off of the following table. You will now have the metabolic rate for your gerbil in gm-cal/hour/cm<sup>2</sup>.



**Surface Area Relationships for Small Rodents**

Wt of Animal (gm)	Surface Area (cm <sup>2</sup> )	Wt of Animal (gm)	Surface Area (cm <sup>2</sup> )
10	21.5	120	243.2
15	32.3	130	256.6
20	43.1	140	269.6
25	53.8	150	282.3
30	64.6	160	294.7
35	75.4	170	306.9
40	86.2	180	318.8
45	97.0	190	330.5
50	107.7	200	342.5
55	118.0	210	353.3
60	129.2	220	364.4
65	140.0	230	375.4
70	150.8	240	386.1
75	162.0	250	396.9
80	172.3	260	407.3
85	183.1	270	417.7
90	193.9	280	428.0
95	203.3	290	438.1
100	215.4	300	448.1
110	229.5		

**Planning Form**

Name \_\_\_\_\_ Date \_\_\_\_\_

Describe the **observation** in the background material that led to the **question** under investigation:

What **hypothesis** (casual explanation) are you proposing to explain the observations and answer the question?

Outline of your **Experiment**:

- A. How will you treat your **experimental group(s)**?
  
- B. What will serve as your control **groups(s)**?
  
- C. How will you **collect** your data (equipment, interval, method, and duration of sampling)?
  
- D. How will you **analyze** your results and compare them to those predicted from your hypothesis?

What are your **Prediction(s)**?

A. IF my hypothesis is SUPPORTED, then I predict that the results of my experiment will be that.....

B. IF my hypothesis is UNSUPPORTED, then I predict that the results of my experiment will be that....

References (textbook, library articles, WWW, other)

**Lab Notes**

Hypothesis to be tested:

Alternative hypothesis(es):

Justification for hypothesis:

**Experimental Design**

Independent (manipulated) variable:

Dependent (measured) variable:

Any modifications of laboratory manual procedures:

Observations during experiments:

How do your observations support or not support your hypothesis?

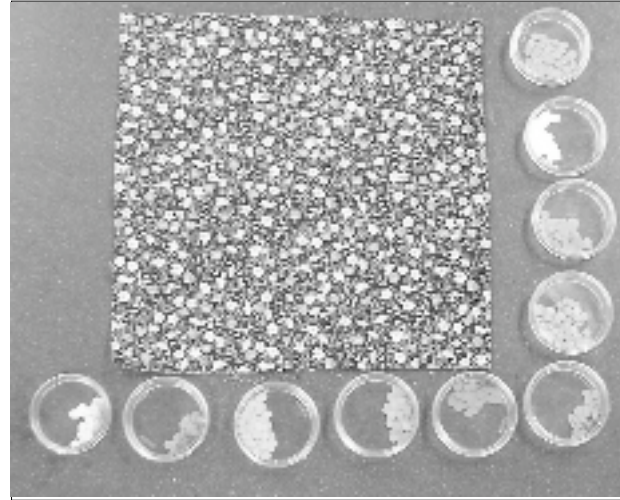
How do your observations relate to your references?

## Natural Selection: Are Albino Individuals More Easily Captured by Predators?

---

### Introduction

Scientists are investigating a species (*Circulus discus*), which is disappearing at an alarming rate. This species is circular in shape and highly dorso-ventrally compressed. It lives in large groups in environments, which are highly patterned. Samples of the environments and *C. discus* are seen on the left. (*C. discus* are in containment chambers.) It avoids predation by utilizing colors, which blend well with its surroundings.



Scientists have observed predation techniques and examined the stomach contents of the predator and find that the albino (white) *C. discus* are eaten more frequently than those of other colors. Population samples reveal an unequal number of each color. Scientists hypothesize that albino individuals are eaten more frequently than colored ones because they are easier to see. Are they correct?

---

### Lab Activities

After completing this lab you should be able to:

- describe how natural selection shapes the phenotypic, thus the genotypic make-up of a population of organisms
- discuss how natural selection can be a process that leads to evolution in a population of organisms

There is a plethora of information regarding this topic in the library and on the World Wide Web. This would be a good lab to easily add more than one reference. Be sure you carefully think out your experiment and also relate your results to the references you have selected.

**Planning Form**

Name \_\_\_\_\_ Date \_\_\_\_\_

Describe the **observation** in the background material that led to the **question** under investigation:

What **hypothesis** (casual explanation) are you proposing to explain the observations and answer the question?

Outline of your **Experiment**:

- A. How will you treat your **experimental group(s)**?
  
- B. What will serve as your control **groups(s)**?
  
- C. How will you **collect** your data (equipment, interval, method, and duration of sampling)?
  
- D. How will you **analyze** your results and compare them to those predicted from your hypothesis?

What are your **Prediction(s)**?

A. IF my hypothesis is SUPPORTED, then I predict that the results of my experiment will be that.....

B. IF my hypothesis is UNSUPPORTED, then I predict that the results of my experiment will be that....

References (textbook, library articles, WWW, other)

**Lab Notes**

Hypothesis to be tested:

Alternative hypothesis(es):

Justification for hypothesis:

**Experimental Design**

Independent (manipulated) variable:

Dependent (measured) variable:

Any modifications of laboratory manual procedures:

Observations during experiments:

How do your observations support or not support your hypothesis?

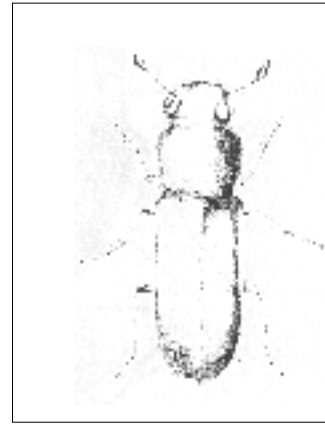
How do your observations relate to your references?

## Does competition affect population growth rates?

---

### Introduction

You have been culturing two species of flour beetle. You notice that when you grow them separately they each do very well. One day, however, in a laboratory mishap two of your cultures were mixed. Being the inquisitive person you are, you let the mixed cultures progress. In two-weeks time you noted that one species of flour beetle still did well, however the other species of flour beetle did very poorly and was on the road to extinction within the culture. Because you are a meticulous scientist you look back over your notes and realize that you have used the same culture media as food for both species of flour beetle.



To understand the relationship between two species, you decide to run another experiment on two closely related species of *Paramecium* (a protist). Generate a hypothesis about the relationship between competition and population growth rates. Be sure to include in your hypothesis(es) statements regarding how the *Paramecium* populations will grow separately and how they will grow when placed together.

---

### Lab Activities -- Week One

After completing these activities you should be able to:

- describe relationships between competition and population growth
- explain how availability of limited resources can limit population growth
- use computer programs to simulate population growth
- interpret collected data and graphs and explain what they mean

This week you will be “revisiting” your flour beetle experiment. You will access this experiment on the computers in the Math/Science Computer Lab (MSCL). You will actually be running a program that will model your experiment with the flour beetles.

You will need to turn in the graphs that these programs generate. To do this you will need to make a copy of the active window and paste it into a word processing program. Here are the steps to perform this task.

1. Click in the graph window to make it active.
2. Press Alt + **Print Scrn**.
3. Open Word or Wordperfect, and a new document.
4. In the new document, paste in your graph either by selecting Edit > Paste or press Control + v.
5. Once you have all your graphs pasted into the document, you may print them.

*Simulation Procedure*

1. In the tool bar, click on: Start > Programs> Biology > Growth
2. At this point make sure the Geometric Growth button is clicked.
3. Leave everything else the same.
4. To run this simulation with the variables the way they are, click; **Show Me**.
5. Save this graph. Note the X-axis is time in generations, and the Y-axis is the size of the population. Also note that the numbers on the Y-axis are very large.

*Experimental Procedure - Geometric Growth*

1. Be sure to save every graph you generate. Change the Starting Population Size (N) to 100. How did this change the growth of the population?
  
2. Change (N) back to 10. Now change the intrinsic rate of increase (r) to 0.6. How did this change the growth of the population?
  
3. Do natural populations tend to grow this way?

*Experimental Procedure - Logistic Growth*

1. Click on the Logistic Growth button. This will add environmental resistance, or Carrying Capacity (K).
  
2. Use the following data, run the program and save your graphs.
  - a. N = 10  
r = 0.2  
K = 400

What happened under these conditions?

- b. N = 10  
r = 0.6  
K = 400

What happened to the population under these conditions? Was it different than the first trial?

Do populations tend to grow this way? These graphs show that as populations near K, they start slowing their reproduction. Do you think this happens in natural populations?



*Logistic Growth - Time Lag*

In most natural populations there is a time lag. In other words organisms don't shut down production when they reach carrying capacity. How would they know they've reached K? So, what we will do now is introduce time lag into the equation.

c.  $N = 10$

$r = 0.2$

$K = 400$

Time lag (c) = 2

In your own words, describe what happened to the population.

d.  $N = 10$

$r = 0.1$

$K = 400$

$c = 2$

What happened to this population?

e. Perform at least two other experiments with this program. Alter any of the variables with which we have been working. Describe below what you altered, and how it affected the growth rates of the population.

When you are finished, close the program. If you get an error message, press **OK**.

*Populations in Competition*

Populations don't live in isolation. There are other populations around and some of them may even use the same resources. Let's look at what happened to our flour beetle populations. They eat the same food, so are in competition with one another.

Again be sure to save your graphs into a word processor so you can print them when you are finished.

*Procedure - Competition*

1. Click: Start > Programs > Biology > Competition
2. in this simulation Species 1 will be *Tribolium confusum* (the confused flour beetle) and Species 2 will be *Tribolium castaneum* (the red flour beetle).
3. Leave all the variable alone and just click **Show Me**.

What happened to each species?

In this program note that one of the variables is a bit confusing. It is Species 1 as 2 ( $\alpha$ ) and the other is Species 2 as 1 ( $\beta$ ). These numbers are a relative measure of how good a competitor the species is. The lower the number the better the competitor. In the first graph you should note that species 2 (the red flour beetle) is a better competitor and survived.

*Procedure - Experiment*

Change the following variables for each species.

- a. Species 1: no change  
Species 2:  $K = 100$   
 $\beta = 0.7$

What happened to each species? Why?

- b. Species 1: no change  
Species 2:  $\beta = 0.2$

What happened to each species? Note K for each species. Did they reach it? Explain.

c. *T. confusum* is a slightly larger beetle. This means it needs more food and more space than *T. castaneum*. *Tribolium castaneum* also reproduces faster. What do you predict will happen when these two beetles compete? Why?

To run this competition enter the following data:

Species 1	Species 2
N = 30	N = 20
r = 0.2	r = 0.3
K = 200	K = 400
$\alpha = 0.5$	$\beta = 0.2$

Explain what happened. Is this what you predicted? Why or why not?

A. What would happen if *T. confusum* (sp.1) were able to double its reproductive rate to 0.4? Run the experiment and explain what happened.

B. What would happen if *T. confusum* became a slightly better competitor ( $\alpha = 0.3$ )? Run the experiment and explain what happened.

C. What if there was less environmental resistance on *T. confusum*. In other words, they had a higher carrying capacity ( $K=300$ ). Run the experiment and explain what happened.

How could *T. confusum* “win” this competition?

There are terms or concepts that you may wish to use in your lab report. They include the following:

Carrying Capacity (K)

Niche

Competitive Exclusion

Intrinsic Rate of Increase (r)

Exponential Growth

Logistic Growth

Limited Resources

**Special Instructions**

You will be using two *Paramecium* species for this experiment. *P. caudatum* is a larger *Paramecium* with a massive macronucleus and a compact micronucleus. *P. aurelia* is a the smaller of the two with a macronucleus and two small micronuclei. It will be beneficial for you to observe each of these species under the microscope so you may identify them on your own, later.

You will need to observe these cultures at least every two days (preferably every day) during the week between lab sessions. Take a sample of each culture and on the gridded slides, estimate the number of individuals / mL.

When you are done with your simulations and have answered all your questions. You will need to set up your experiment and let it run until next week. The longer it runs, the better your results will be. If your lab group decides to run the experiment for longer than one week, you will have the opportunity to turn your paper in at a later date.

Again, be sure to carefully think out your experiment. This lab easily lends itself to doing more than one experiment at a time.

**Planning Form**

Name \_\_\_\_\_ Date \_\_\_\_\_

Describe the **observation** in the background material that led to the **question** under investigation:

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Outline of your **Experiment**:

- A. How will you treat your **experimental group(s)**?
  
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References (textbook, library articles, WWW, other)

### **Lab Notes**

Hypothesis to be tested:

Alternative hypothesis(es):

Justification for hypothesis:

### **Experimental Design**

Independent (manipulated) variable:

Dependent (measured) variable:

Any modifications of laboratory manual procedures:

Observations during experiments:

How do your observations support or not support your hypothesis?

How do your observations relate to your references?

## APPENDIX C

OUTLINE OF MODIFICATIONS TO INQUIRY-BASED LECTURES.

*Unit one* consists of the science of biology, atoms and biochemistry. This unit will not be changed.

*Unit two* consists of cell structure, membranes, energy and metabolism, respiration and photosynthesis. This unit will be converted to inquiry. During this unit, the teaching style will be less didactic, teacher-centered instruction. The instructor will solicit more input from students and ask more thought provoking questions. The inquiry instructor will ask the students to think about what a human body needs to do everyday to survive. The instructor will then give the class time to brainstorm individually and in groups to list systems or organs the body uses. The lecturer will then ask the students to equate that their list of human organ systems to a single cell. During this discussion, the instructor will equate the organelles of a cell and their functions, to organs and organ systems of humans.

Towards the end of this subunit, the lecturer will then ask students to equate a cell to anything else, besides a human body, list how their object is like a cell, and justify their choices. For instance a student might equate a cell to a car and explain that the engine is like a cell's mitochondria, both are powerhouses. The instructor will also present organelles in such a way that the students understand they interact. For instance, the instructor will discuss with students a particular cell, like a pancreatic cell and explain that it produces insulin, a protein hormone. The instructor will then ask the students what organelles that cell might have, in relative quantities. After a discussion about the cell, the instructor would tie in how the process of making, modifying, and shipping enzymes.

This will tie directly into the chapter on cell membranes. Here also, the instructor will have students tie in their previous knowledge of the processes of diffusion and

osmosis. Then, using everyday examples, the instructor will discuss different ways in which the cell moves particles across the membrane. An example would be moving something against its concentration gradient with active transport is similar to pumping water out of your basement. They are both “going uphill” and require energy to do so.

Again this ties into the next chapter about enzymes. Students begin to realize that cells rely on chemical reactions, and they produce proteins, some in the form of enzymes. These enzymes are used to regulate chemical reactions. So here we tie in, again, the process of building proteins and why they need to be packaged and modified at a later time. We will also talk about the function of enzymes and why they are necessary.

Understanding that cells perform chemical reactions constantly will then tie into the last two chapters in this unit, respiration and photosynthesis. We will slowly build up from cell components and their interactions, to how cells use energy, to finally how cells get that energy. Again we will tie in diffusion when we talk about the mitochondria and their use of oxygen, and chloroplasts and carbon dioxide. Drawing on student’s own knowledge, we will equate glucose as a “D” cell battery and ATP as a “AA” battery. Students will then realize if a device calls for “AA” batteries, they cannot put in a “D” battery since the voltage is wrong.

**Unit 3** consists of mitosis, meiosis, Mendelian genetics, DNA replication, transcription and translation. This unit will not be changed.

**Unit 4** consists of natural selection, population genetics, evolution, speciation, and population ecology. This unit will be converted to inquiry. In this unit students will be asked to think about populations and what they notice about them. With moderate help students should be able to come up with all five observations of Darwin and then draw



most of the same inferences that lead Darwin to the idea of natural selection. This introduction to the unit will be an instructor-generated question, but the students should arrive at the answers on their own through class discussion.

During the chapter on evolution students will be asked to observe data, like beak size in wet and dry years in the Galapagos and draw conclusions. Other examples that can be used include industrial melanism in moths, and perhaps closer to home in a rural community, pesticide resistance in insects. Using their knowledge of population genetics, students will be asked to brainstorm, during instructor-led discussions, on how species may originate. Finally tying in the final lab on competition, students will be asked to discuss different factors involved in population ecology. Using their general knowledge and knowledge gained from the lab experiment students will be asked to develop population growth models.

APPENDIX D

SURVEY INSTRUMENTS AND CODING RUBRIC

**Instructions:**

- 1) Please answer all of the questions carefully and to the best of your ability. Your answers will NOT affect your grade in any way.
- 2) DO NOT put your name or student ID on the SCANTRON sheet or any of the survey materials. In the upper right of your Research Consent Form is a randomly generated number. Please put this number in the NAME blank.
- 3) Please put your course number in the SUBJECT field. (e.g., 1010-01)
- 4) Please put all answers to the multiple choice on the SCANTRON sheet provided.
- 5) Please fill in some data starting with answer blank #1.

**Information about the student.**

1. Are you
  - a. male
  - b. female
  
2. Your standing is
  - a. freshman
  - b. sophomore
  - c. other
  
3. I plan to major in (for answers with multiple letters, please mark both letters on ScanTron)
  - a. undecided
  - b. education
  - c. preprofessional (premed, pre-dentistry, pre-vet, etc.)
  - d. science or math major (biology, chemistry, physics, wildlife, etc.)
  - e. vocational (welding, cosmetology, etc.)
  - ab. business (accounting, ag. business, computer science, etc.)
  - ac. social sciences (psychology, sociology, criminal justice)
  - ad. all other majors (humanities, English, music, art, etc.)
  
4. What grade do you anticipate earning in this course (be honest)?
  - a. A
  - b. B
  - c. C
  - d. D
  - e. F
  
5. What is the minimum grade you would be happy with in this course (be honest)?
  - a. A
  - b. B
  - c. C
  - d. D
  - e. F
  
6. What do you plan to do upon graduating from EWC?
  - a. transfer to another college or university
  - b. get a job
  - c. other

**GO ON TO THE NEXT PAGE**

This part of the survey contains 23 statements about your confidence in doing things related to biology. For each question, think about how confident you would be in carrying out a given task. There are no right or wrong answers. These are just your own thoughts and feelings about these topics. For each statement in the survey, fill in the bubble next to each question:

- A. If you are TOTALLY CONFIDENT that you can do the task.
- B. If you are VERY CONFIDENT that you can do the task.
- C. If you are FAIRLY CONFIDENT that you can do the task.
- D. If you are ONLY A LITTLE CONFIDENT that you can do the task.
- E. If you are NOT AT ALL CONFIDENT that you can do the task.

**Practice Item**

How confident are you that you could give a presentation about birds in northern Arizona? Suppose that you were “fairly confident” that you could give a presentation about birds in northern Arizona. You would mark the letter “C” on the ScanTron answer sheet.

- 7. How confident are you that after reading an article about a biology experiment, you could write a summary of its main points?
- 8. How confident are you that you could critique a laboratory report written by another student?
- 9. How confident are you that you could write an introduction to a lab report?
- 10. How confident are you that after reading an article about a biology experiment, you could explain its main ideas to another person?
- 11. How confident are you that you could read the procedures for an experiment and feel sure about conducting the experiment on your own?
- 12. How confident are you that you could write the methods section of a lab report (i.e., describe the experimental procedures)?
- 13. How confident are you that after watching a television documentary dealing with some aspect of biology, you could write a summary of its main points?
- 14. How confident are you that you will be successful in this biology course?
- 15. How confident are you that you could write up the results to a lab report?

**GO ON TO THE NEXT PAGE**

16. How confident are you that after watching a television documentary dealing with some aspect of biology, you could explain its main ideas to another person?
17. How confident are you that you will be successful in another biology course?
18. How confident are you that you could write the conclusion to a lab report?
19. How confident are you that after listening to a public lecture regarding some biology topic, you could write a summary of its main points?
20. How confident are you that you would be successful in an ecology (study of relationships between an organism and its environment) course?
21. How confident are you that you could analyze a set of data (i.e., look at the relationships between variables)?
22. How confident are you that after listening to a public lecture regarding some biology topic, you could explain its main ideas to another person?
23. How confident are you that you would be successful in a human physiology (study of how the body works) course?
24. How confident are you that you could tutor another student on how to write a lab report?
25. How confident are you that you could critique an experiment described in a biology textbook (i.e., list the strengths and weaknesses)?
26. How confident are you that you could tutor another student for this biology course?
27. How confident are you that you could ask a meaningful question that could be answered experimentally?
28. How confident are you that you could explain something that you learned in this biology course to another person?
29. How confident are you that you could use a scientific approach to solve a problem at home?

**GO ON TO THE NEXT PAGE**

Each of the statements below expresses a feeling toward biology. Please rate each statement on the extent to which you agree. For each, you may:

- A. strongly agree
  - B. agree
  - C. undecided
  - D. disagree
  - E. strongly disagree
30. Biology is very interesting to me.
31. I *don't* like biology, and it scares me to have to take it.
32. I am always under a terrible strain in a biology class.
33. Biology is fascinating and fun.
34. Biology makes me feel secure, and at the same time it is stimulating.
35. Biology makes me feel uncomfortable, restless, irritable, and impatient.
36. In general, I have a good feeling toward biology.
37. When I hear the word biology, I have a feeling of dislike.
38. I approach biology with a feeling of hesitation.
39. I really like biology.
40. I have always enjoyed studying biology in school.
41. It makes me nervous to even think about doing a biology experiment.
42. I feel at ease in biology and like it very much.
43. I feel a definite positive reaction to biology; it's enjoyable.
44. Please answer the following question thoughtfully and logically, using scientific reasoning to develop your response. **Please put your response on the answer sheet provided.**

A layer of ice has accumulated on the steps of the building's entrance. A conscientious student sprinkled table salt, left over from lunch, onto the steps. Minutes later that same student slipped and fell on the step. Her friend said table salt wasn't as effective as rock salt at melting ice.

How would you test her friend's assertion?

**END OF SURVEY**

**Post-test.**

Instructions:

- 1) Please answer all of the questions carefully and to the best of your ability. Your answers will NOT affect your grade in any way.
- 2) DO NOT put your name or student ID on the SCANTRON sheet or any of the survey materials. In the upper right of your Research Consent Form is a randomly generated number. Please put this number in the SSN blanks, starting with the first blank.
- 3) Please put your course number in the space provided in the SCANTRON sheet.
- 4) Please put all your answers on the SCANTRON sheet provided.
- 5) Please fill in some data starting with answer blank #1.

**Information about the student.**

1. Are you
  - a. male
  - b. female
  
2. Your standing is
  - a. freshman
  - b. sophomore
  - c. other
  
3. I plan to major in
  - a. undecided
  - b. education
  - c. preprofessional (premed, pre-dentistry, pre-vet, etc.)
  - d. science or math major (biology, chemistry, physics, wildlife, etc.)
  - e. vocational (welding, cosmetology, etc.)
  - ab. business (accounting, ag. business, etc.)
  - ac. social sciences (psychology, sociology, criminal justice)
  - ad. all other majors (English, music, art, computer science, etc.)
  
4. What grade do you anticipate earning in this course (be honest)?
  - a. A
  - b. B
  - c. C
  - d. D
  - e. F
  
5. What is the minimum grade you would be happy with in this course (be honest)?
  - a. A
  - b. B
  - c. C
  - d. D
  - e. F
  
6. What do you plan to do upon graduating from EWC?
  - a. transfer to another college or university
  - b. get a job
  - c. other

**GO ON TO THE NEXT PAGE**

This part of the survey contains 23 statements about your confidence in doing things related to biology. For each question, think about how confident you would be in carrying out a given task. There are no right or wrong answers. These are just your own thoughts and feelings about these topics. For each statement in the survey, fill in the bubble next to each question:

- A. If you are TOTALLY CONFIDENT that you can do the task.
- B. If you are VERY CONFIDENT that you can do the task.
- C. If you are FAIRLY CONFIDENT that you can do the task.
- D. If you are ONLY A LITTLE CONFIDENT that you can do the task.
- E. If you are NOT AT ALL CONFIDENT that you can do the task.

**Practice Item**

How confident are you that you could give a presentation about birds in northern Arizona? Suppose that you were “fairly confident” that you could give a presentation about birds in northern Arizona. You would mark the letter “C” on the ScanTron answer sheet.

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- E. strongly disagree

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  - 39. I really like biology.
  - 40. I have always enjoyed studying biology in school.
  - 41. It makes me nervous to even think about doing a biology experiment.
  - 42. I feel at ease in biology and like it very much.
  - 43. I feel a definite positive reaction to biology; it's enjoyable.
44. Please answer the following question thoughtfully and logically, using scientific reasoning to develop your response. Put your response on the answer sheet provided.

A student is witnessed guzzling a bottle of the sports drink Gatorade® in the hallway outside the classroom where she is about to take a final exam. Her friend asks if she would rather not go get something with caffeine, but she insists that no, this is going to do more for her mental performance.

How would you test the Gatorade® drinker's assertion?

**END OF SURVEY**

## Coding Rubric for Science Reasoning Test.

Rating	Category	Description
0	Unclear	Illegible, flippant, or did not address question
1	Sole reliance on expert or printed text	Student made no attempt at personal inquiry but instead suggested/referred to an expert for answer (does NOT include surveys where expert consulted as PART of an investigation)
2	Student's unspecified previous knowledge; or non-specific reference to "do research" or "set up an experiment"	Response consists of reference to prior knowledge, indicating he/she already knew the answer. OR vague reference to doing an experiment only.
3	Observes/studies the problem	Shows consideration for other possibilities/explanations, critiqued hypothesis
4	States hypothesis	Specifically and directly stated a hypothesis or predictive statement
5	Method	Any description of a way to carry out research on the question, regardless of appropriateness
6	Controlled	Specifies the use of experimental controls (but not just saying "I would control")
7	Refers to multiple tests	Employs at least two total trials or repetitions or multiple subjects
8	Identifies variables	If any variables (experimental factors) are identified as part of an experiment or in discussion of background and analysis
9	Sampling	Specifies a certain population ("group of males" or "the <i>same</i> person tries...")
10	Evaluates results	Any reference to analysis such as comparisons, statistical analysis, statement of degree of impact

APPENDIX E

INSTRUCTIONAL REVIEW BOARD APPROVAL

Oklahoma State University  
Institutional Review Board

Protocol Expires: 10/22/02

Date: Tuesday, October 23, 2001

IRB Application No AS0218

Proposal Title: STUDENT SUCCESS AND ATTITUDES TOWARDS THE SCIENCES WHEN USING  
INQUIRY-BASED LABS IN MULTIPLE SCIENCE CLASSES

Principal  
Investigator(s):

Nicholas Roster  
3200 West C Street  
Torrington, WY 82240

Christopher Wenzel  
3200 West C Street  
Torrington, WY 82240

Donald French  
430 LSW  
Stillwater, OK 74078

Reviewed and  
Processed as: Expedited

Approval Status Recommended by Reviewer(s): Approved

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Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 203 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

  
Carol Olson, Chair  
Institutional Review Board

## VITA

Nicholas Owen Roster

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE EFFECTS OF INQUIRY-BASED TEACHING ON ATTITUDES, SELF-EFFICACY AND SCIENCE REASONING ABILITIES IN STUDENTS OF INTRODUCTORY BIOLOGY COURSES AT A RURAL, OPEN-ENROLLMENT COMMUNITY COLLEGE.

Major Field: Zoology

Biographical:

Education: Graduated from Traverse City Senior High, Traverse City, MI in June 1987; received Bachelor of Arts degree in Biology and a Secondary Educational Teaching Certificate from Alma College, Alma Michigan in December 1990 and May 1991, respectively; received Master's of Science degree in Biology from Central Michigan University, Mt. Pleasant, Michigan in December 1995. Completed the requirements for the Doctor of Philosophy degree with a major in Zoology at Oklahoma State University in July 2006.

Experience: Employed as a lab instructor at Alma College 1991 – 1992. Employed as a Graduate Assistant at Central Michigan University 1992 – 1995. Employed as a Graduate Associate at Oklahoma State University 1996 – 1999. Employed as an adjunct instructor in Biology at Southeast Community College in Lincoln Nebraska 1999 – 2000. Employed as a Biology Instructor at Eastern Wyoming College in Torrington, Wyoming 2000 – 2005. Employed as an adjunct instructor in Biology at Northwestern Michigan College in Traverse City, Michigan 2005 – Present.

Professional Memberships: National Science Teachers Association, Society for College Science Teaching

Name: Nicholas O. Roster

Date of Degree: July 2006

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: THE EFFECTS OF INQUIRY-BASED TEACHING ON ATTITUDES, SELF-EFFICACY, AND SCIENCE REASONING ABILITIES OF STUDENTS IN INTRODUCTORY BIOLOGY COURSES AT A RURAL, OPEN-ENROLLMENT COMMUNITY COLLEGE.

Pages in Study: 166

Candidate for the Degree of Doctor of Philosophy

Major Field: Zoology

Publications such as *Beyond Bio 101*, *BIO 2010: Transforming Undergraduate Education for Future Research Biologists* and *College Pathways to the Science Education Standards* advocate science education reform in higher education institutions, including the use of student-centered pedagogies. While many studies about the effectiveness of such pedagogies have been conducted at universities and four-year colleges, few have been conducted at the community college level, where many students, including many would-be educators, choose to take their introductory science courses. This study investigated whether the same techniques used in universities to increase student attitudes, self-efficacy and science reasoning can also be effective at a small, rural community college. This study used pre and post-tests of student attitudes, self-efficacy and scientific reasoning to determine if inquiry-based learning positively affected each of these parameters. In wholly traditional classes, students' attitudes decreased, self-efficacy increased and scientific reasoning was unchanged. In classes with traditional lecture and inquiry labs, attitudes increased, self-efficacy increased and scientific reasoning was unchanged. Finally in a course designed with inquiry lecture and lab components, attitude did not change, self-efficacy increased, and scientific reasoning increased. This provides evidence that inquiry-based teaching can have a positive effect on community college students. It also provides evidence that using three different measures, allows for a more complete picture of the effects of inquiry-based teaching.

Advisor's Approval: Dr. Donald P. French

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