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Moving traditional teaching methods of advanced placement biology toward improving opportunity for students to develop understanding of scientific principles

Mabell Jeannette Martinez

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MOVING TRADITIONAL TEACHING METHODS OF ADVANCED PLACEMENT BIOLOGY TOWARD IMPROVING OPPORTUNITY FOR STUDENTS TO DEVELOP UNDERSTANDING OF SCIENTIFIC PRINCIPLES

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Science Education

by
Mabell Jeannette Martinez
September 2006
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ABSTRACT

This project investigated the role of the advanced placement program in the classroom. It identified the AP program’s most common method of teaching as lecture-based. The traditional method of teaching was explored in relation to students’ success and understanding of scientific principles in comparison with an inquiry-based approach. Through investigation of current and past research involving teaching methods used in advanced placement science classes and the research of an inquiry model of teaching, the benefits of inquiry-based instruction are noted. The comparison indicated that inquiry-based instruction is the best practice for improving student understanding. Thus, the research suggested that implementation of inquiry-based methods in science classrooms, including advanced placement biology courses, would improve student understanding. The challenge therefore was to change lecture-based lessons into inquiry-based lessons using the Biological Sciences Curriculum Study (BSCS) “5E” instructional model.

The five “E’s”: engage, explore, explain, elaborate, and evaluate are used to create an inquiry lesson. Within the “5E” model, three criteria are identified as missing from lessons from in a traditional method. The criteria
are: engaging students, students creating their own explanations to their investigations before the teacher lectures, and students practicing metacognition. The two other criteria of the “5E” model “elaborate” and “explore,” need to be addressed in different ways than in traditional lecture based lessons. Three samples of inquiry lessons from AP Biology topics that are covered in the AP Biology Laboratory Manual are used as evidence of how lessons can be transformed from traditional lesson plans and cookbook labs to inquiry instruction. These three inquiry lesson plans are compared to three traditional lessons plans showing the components that are missing in traditional labs and how to adjust “explore” and “elaborate” criteria in traditional lessons for inquiry learning. These lessons plans are used as examples of how to take a step towards practicing inquiry-based instruction and becoming an inquiry teacher.
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CHAPTER ONE

ROLE OF ADVANCED PLACEMENT COURSES IN
THE HIGH SCHOOL CURRICULUM

History of the Advanced Placement Program

The advanced placement (AP) program that emerged from the College Board in the 1950's intended to improve American education. Its purpose was to allow students the opportunity to obtain college level classes and therefore award credit toward college at the high school level in order to avoid repeating coursework in college. Thus, this allowed students that were highly motivated to work at the height of their potential and capabilities by advancing with their studies as quickly as possible through the advanced placement program (College Board AP Central, 2006).

The success of the AP examinations, which consists of two sections: a multiple choice and a constructed response, usually in essay form, received support from many colleges (Curry, MacDonald, & Morgan, 1999). In 1961, the University of California system was using AP exams for college placement and in 1982 it became a factor in admissions to the UC system (Geiser & Santelices, 2004).
Because minorities and underprivileged students were underrepresented in participation in the AP program, the "federal government, through the U.S. Department of Education, provided $3 million in grants in 1998 to pay the exam fees for economically disadvantaged students enrolled in AP courses" in order to "encourage more schools to offer AP courses and raise their academic standards" (Curry et al., 1999, Abstract, ¶ 4). Today, the AP program "has become one of the leading indicators used by educators to gauge the status of American education" (Curry et al., 1999, Abstract, ¶ 5).

The College Board has developed teacher training and workshops that help secondary teachers familiarize themselves with the AP course content that should be taught. Now the College Board's AP program has expanded and offers 35 courses in 20 subject areas where over 60% of high school students participate in the program (College Board AP Central, 2006). The increasing amount of high school students taking the AP exams is due to colleges and universities reviewing transcripts to determine how successful students will be in college. Colleges determine a student might be successful by comparing the course grades and the AP exam scores obtained in the AP classes. Their reasoning behind this is
due to past research indicating that students that do well in advanced placement classes are likely to do well in college.

How the Advanced Placement Program Works

In advanced placement courses, the students are able to earn an extra point toward their grade point average (GPA) granting a grade point value of an A = 5, B = 4, and C = 3. For example, a letter B in an AP course would count as if it was an A in a regular course (Geiser & Santelices, 2004). This acts as a motivator for students to challenge themselves to a college level course and not hurt their GPA. At the end of the school year beginning in April through May, the students take the AP exam which as stated previously, offers 35 courses in 20 subject areas and according to Curry et al. (1999) and the College Board AP Central website (2006):

Each examination (except Studio Art) consists of a multiple-choice section and a constructed-response section. Several variations of the constructed-response mode can be found across the disciplines, including writing essays in the social studies, solving problems in mathematics and science, writing programs in computer science, sight-singing
in music, speaking and listening in modern languages, and creating portfolios in art. (Curry et al., 1999, The Course and Examinations, ¶ 2)

After the students take the AP exams in their area, there are readers that are selected from colleges and secondary schools throughout the world that grade the tests using "reliability measures and rigorous procedures to ensure the questions are scored in a consistent manner" (College Board AP Central, All About the Exams, 2006). After the multiple choice and the constructed responses are scored, they are combined to form a collective score that is converted to a five point scale where three points and above is passing and therefore granted college credit for the course (Curry et al., 1999).

High Schools offer advanced placement courses that include a team of high school educators that are responsible for teaching the subject matter that would normally be taught at an introductory college level class. According to Curry et al. (1999):

The Course Description contains broad recommendations about the content and skills to be included in a given class. Teacher’s Guides, as well as the examinations, are based on these descriptions. The program does not dictate textbooks to be used, the
schedule of lessons, or teaching techniques. (The Course and Examinations, ¶ 1)

Thus, it gives the teachers the liberty to teach the content using whichever pedagogical strategy they wish. Although, according to Schofield as cited in the National Research Council (2002), the teacher’s guide for teaching AP biology gives quotes referring to instructional strategies that work for teachers teaching AP. These two examples include: "The primary goal of the class is to ensure that students leave having experienced an intense course of college-level biology. I do this mainly through lectures and discussions, during which time students are able to ask plenty of questions" (p. 45) and "I try to provide my students with a variety of teaching techniques that encourage both independent and group activities." (p. 73). These quoted examples indicate the preference of teaching techniques that should be used in the AP program.

Advanced Placement Research Leads to Controversy

This project focuses on how AP science, specifically biology, is affected by the advanced placement program. When approached to teach advanced placement biology at the high school, it was a concern of how the AP program worked and how these classes were taught. The author of this
project observed, substituted in the AP class, and inquired about the content and how scientific principles were taught to the students. As the author of this project shared some of the knowledge of inquiry that was learned in the master’s of science education program and how effective it was turning out to be with the regular biology classes with an AP teacher in California, it was devastating to find out that the AP teacher dismissed some of the information that was shared and said that lecture was the way to go in teaching AP biology. The teacher mentioned how the students had to be ready for college and the only way that the material could be covered was through lecturing everyday and conducting the labs in the AP Biology Manual. In consequence, the role of the advanced placement program and what is known about how effective lecture-based instruction can be for students’ success in gaining scientific knowledge was investigated for this project.

The College Board through the Educational Testing Service (ETS) has conducted research showing how their advanced placement program, including science, indicates students’ success in college (Morgan & Ramist, 1998; Morgan & Maneckshana, 2000). Some of their research is

However, there is growing evidence that AP courses do not prepare students for the academic challenges of college (Klopfenstein, 2005). According to Adelman (as cited in Geiser & Santelices, 2004), whom researched the effect of advanced placement courses in biology, taking AP courses in high school does not indicate future college performance. Adelman found that the most “powerful indication of college success was ‘academic intensity’ of the high school curriculum” (p. 5). Research shows that advanced placement classes “suffer from inadequate quality control as well as excessive pressure to fulfill their advanced placement function, which encourages teachers to attempt coverage of all areas of biology and emphasize memorization of facts rather than in-depth understanding” (Wood, 2002, p. 123). Due to the great amount of information to be taught, teachers resort to lecture-based classrooms where students are not experiencing or doing science, just listening about it. The purpose of science should be “not just to acquire biological knowledge, but rather to experience the process of biological science” (Wood, 2002, p. 126). In addition to lectures, the laboratories for the AP curriculum are not geared for
student investigation (Wood, 2002). They are just step-by-step cookbook labs where students are following a procedure without thinking of the purpose.

In contrast to traditional teaching methods, inquiry methods have shown to have positive effects in student understanding of biology. As a result, Llewellyn (2005) has given suggestions to change traditional lessons and cookbook laboratories into inquiry lessons where the classroom is student-centered instead of teacher-centered. In this setting, students are able to apply and analyze information in an inquiry-based learning environment, as opposed to a lecture-based class where students sit passively and absorb the information while a teacher talks to them.

Purpose and Significance of the Project

Currently, there is an abundance of research that involves inquiry methods in the science classroom. Studies have found that inquiry methods help students learn the material more effectively than traditional instructional strategies. New research conducted has been comparing inquiry methods in introductory college courses to traditional lecture courses. However, not many studies involve studying inquiry methods in an Advanced Placement
Biology class and how they affect understanding of science concepts. The purpose of this project is to propose why and how advanced placement science courses, specifically biology, should be taught using inquiry methods of teaching that promote and develop a superior understanding of scientific principles by demonstrating that traditional lesson plans can be modified following an inquiry style format. In this way, teachers of advanced placement courses can have an idea of how to illicit critical thinking among advanced placement biology students while still covering their subject matter.
CHAPTER TWO
REVIEW OF THE LITERATURE

Introduction

In order to justify changing traditional lesson plans into an inquiry style format, it is important to examine the research that addresses that the advanced placement program can be problematic in its teaching methods and that inquiry based methods are superior to those of traditional methods in various ways.

Advanced Placement Can Be Problematic

Morgan and Ramist (1998) found that students, who passed the advanced placement (AP) exam with a score of four or above, performed well in college introductory courses. However, they did not investigate those students that took the advanced placement courses but did not take the AP exams. They did not account for the large portion of students that go through the advanced placement program taking the courses, but decide not to take the exam, yet still have the benefit of receiving higher point value on their grade point average. On the other hand, a more recent study by Geiser and Santelices (2004) studied how AP courses, not tests affected college success. They found that the "number of AP and honors courses taken in high
school bears little or no relationship to students’ later performance in college” (p. 1). Sadler and Tai (2001) stated that their data revealed that “high school math courses and physics—even advanced placement (AP) physics—were not significant factors in predicting student performance” (p. 113). In addition, it is said that there is no evidence that the “AP experience provides preparation for college superior to that provided by a non-AP curriculum rich in math and science” (Klopfenstein, 2006, p. 17). Other factors, such as the teacher’s pedagogical approaches to teaching such as greater emphasis on understanding than on memorization might be the ones determining college success (Tai, Sadler, & Loehr, 2005).

College success in the previous research articles is determined by a high grade point average which is determined by test scores or the resilience to stay in college through the first couple of years as opposed to dropping out. However, none of these investigations clearly address the amount of knowledge that students gained as an indication of success, which in part determines students’ grades and is directly linked to grade point average. Students’ grades in college are usually calculated by how they perform on assessments that
show how much of the content was learned and understood. Besides grades, none of the research addresses the quality of content knowledge that the students gained and yet, the advanced placement science program sometimes lacks the ability to produce students with a clear understanding of scientific principles that will help them succeed in college level classes because of teaching methods that are employed in advanced placement classes.

According to Wood (2002), "the principal problem, especially for AP courses, is not that they teach too little but that they attempt to teach too much" (p. 125). This is due to the amount of content that needs to be covered in a short amount of time in order for students to be ready for the AP exams which will give them college credit. The attempt to cover too much information reduces the quality of the program and hinders student learning for understanding. Consequently, some high schools have even decided to stop their AP programs due to the pressure in covering so much material before testing (Chaker, 2004). There is evidence, that "[s]tudents who had high school courses that spent more time on fewer topics, concepts, problems, and labs performed much better in college than those who raced through more content in a textbook-centered course" (Sadler & Tai, 2001, p. 111).
Through the experience of talking to other science teachers, observing AP classes, and inquiring about how advanced placement courses are taught, most of them agree upon traditional lectures as the main method to teach AP classes. The AP program models college courses that practice the same traditional method of teaching. However, lecture based classrooms are not necessarily the best means for students to obtain a clear understanding of content and eventually learn and apply the content knowledge. A lecture based-teaching method does not actively involve students; they are not doing science, but writing and listening passively to the teacher talking (National Research Council, 2006). To the contrary, the constructivist theory of how students learn that is widely accepted today states that (Collins, 2002):

- learning is active;
- learning is the interaction of ideas and processes;
- new knowledge is built on prior knowledge;
- learning is enhanced when situated in contexts that students find familiar and meaningful;
- complex problems that have multiple solutions enhance learning;
- and learning is augmented when students engage in discussions of the ideas and processes involved. (p. 9)
This constructivist view does not deem lecture-based classrooms the best learning environment even though there are various forms of lecture, such as interactive lectures where the students will interact with the teacher and ask questions. Lecturing can be an effective tool for teaching but "wholesale lecturing is not an effective means of getting the majority of students engaged in constructing knowledge during class time" (Mestre & Cocking, 2002, p. 15). A science classroom with "instructional approaches where students are discussing science, doing science, teaching each other science, and offering problem-solution strategies for evaluation by peers will facilitate the construction of science knowledge" (Mestre & Cocking, 2002, p. 15). Thus far, research has shown that inquiry as an instructional method of teaching helps construct science knowledge and understanding necessary for students to succeed in science.

Inquiry

Inquiry as described in the National Science Education Standards (National Research Council, 1996) is the "ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p. 23). In teaching, it "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" (p. 23). According the National Science Education Standards (NRC, 1996), inquiry requires students to use "critical and logical thinking, and consideration of alternative explanations," and it requires students to "engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world" (p. 23). In a classroom where a full inquiry method of teaching is practiced, one would see students involved in:

- 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. (NRC, 1996, p. 23)

These characteristics of inquiry are the fundamentals to teach students the content knowledge for successful learning. When inquiry teaching strategies are compared to those that are lecture-based, results show that students gain higher critical thinking skills and better
understanding of scientific concepts using inquiry teaching strategies, than through lecture-based methods.

Table 1 shows the sequence of steps used for lesson planning based on the "5E" model of inquiry developed through Biological Sciences Curriculum Study (BSCS) by Rodger Bybee (Bybee, 2002). The first stage of the "5E" model of inquiry is engaging the student. This is the stage where students are asked to carry out an activity or are faced with a problem situation. For example, it could be as simple as asking probing questions; having the students write on what they already know on the topic that will be covered would be another example. This stage is where the teacher can recognize any misconceptions about science that the students have. The second stage is exploration where the students are able to test their ideas with their own experiences and compare them with others. The third stage is the explain stage. This is where the explorations are explained by the students first then clarified by the teacher. This is the stage where an interactive lecture might be appropriate. In this stage, the teacher can help facilitate information and introduce formal language, scientific terms, and content information that help students explain their experiences. The fourth stage is elaboration of the new material. This is where
students will extend their learning and apply it to a new, but similar situation. The last stage is evaluation. This stage provides an opportunity for students to use metacognition. A learning log of what students learned or have not learned would be appropriate. This can be used as a summative assessment for teachers to assess using a rubric what students learned and what they had difficulty understanding (Bybee, 2002). The "5E's" are the basic criteria used for lesson planning that are essential for an inquiry lesson.

Table 1. The 5E Instructional Model of Inquiry

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Engage</td>
<td>Engage lessons should involve the students in something that captures their interest in the concept being taught and the students are learning.</td>
</tr>
<tr>
<td>Explore</td>
<td>Explore lessons should require students to test their ideas and reasoning about the concept being taught and they are learning.</td>
</tr>
<tr>
<td>Explain</td>
<td>Explain lessons require student explanations. The teacher may decide to provide information and/or guidance on a &quot;need to know&quot; basis in order to carry out their task successfully.</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Elaborate lessons apply the knowledge to see if it is understood well enough to be useful, and to be remembered long term.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Evaluate lessons serve as a summative assessment. The students evaluate what they have learned, what puzzles them, and reflect on it.</td>
</tr>
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(Adapted from Bybee, 2002, p. 32)
Inquiry versus Traditional Lecture-Based Methods

In a comparison between inquiry-based instruction and traditional lecture-based instruction, Suits (2004) conducted an experiment that involved science and engineering majors (SEM) and non-SEM majors. Some SEM and non-SEM students were taught using inquiry approaches which were the treatment groups and the others (the control group) were taught by traditional lecture approaches and cookbook labs. As they tested the students using essay format questions, it was found that the SEM and non-SEM treatment students were superior in being able "to plan and describe a procedure to use, make and record observations during the experiment, collect data, and then calculate and properly record their results. In addition, they wrote better (in judgment of the two raters) and longer discussions" than the control group of SEM and non-SEM students (p. 252). The treatment group of students consistently scored higher than the control group. This research showed that an inquiry-based teaching approach increases the students' understanding of science to a higher level of thinking than do lecture-based classes.

Chang and Mao (2001) conducted a four week study of Earth Science Taiwanese students, which compared a traditional lecture method of teaching (control group)
versus cooperative learning and inquiry teaching (experimental group). Chang and Mao found that the students that were taught using an inquiry method of teaching scored higher on achievement tests than the control group. This study also showed that inquiry promoted more positive attitudes about science than the lecture science students.

Willden, Crowther, Gubanich, and Cannon (2002) performed an experiment involving undergraduate non-major biology students from the University of Nevada, Reno. They compared their introductory biology course that is a lecture-based course containing a lab versus a course that was initially funded by a grant from the Howard Hughes Medical Institute (HHMI). This class was taught collaboratively by the college of education and the college of arts and science. The lab was designed using a hands-on inquiry approach. At the end of the course, the final exam scores of both groups were compared. Willden et al. (2002) found that the “instructional style of inquiry and hands-on labs proved to be significantly superior to traditional means of instruction” (p. 20).

Another study conducted by Luckie, Maleszewski, Loznak, and Krha (2004) on undergraduate physiology majors, tested an inquiry sequence of laboratories called
"Teams and Streams" versus the usual traditional disconnected laboratories in a college science course. Luckie et al. (2004) discovered that 78% of the students had positive attitudes toward the inquiry labs as opposed to only 20% positive feelings among the students that did not have the "Teams and Streams" sequence of inquiry labs. The researchers also came up with qualitative data gathered from a content knowledge exam where questions resembled a medical college admission test that was given to the two groups. Those students that had gone through the "Team and Streams" inquiry labs outscored the ones that took the traditional, cookbook style labs. This research showed how the use of inquiry affected students' views of science in a positive way and how the test scores that assessed knowledge also increased.

Burrowes (2003) decided to put Thomas Lord's Constructivist Model of Inquiry adapted from the "5E" model developed through the BSCS by Rodger Bybee which is discussed in earlier, (see Table 1) to a test with her college biology class after a student’s evaluation indicated that he/she slept for most of the lectures because there was too much information. This statement also indicates that the lectures were not engaging to students, which allowed for students to sleep and miss
crucial information about the content. In general, Burrowes found that lectures only resulted in "lack of student motivation for the sciences, and limited learning reflected on poor content retention, few scientific skills, and inability to apply concepts" (p. 491). In addition, this traditional lecture-style instruction, "does not provide enough time for discussion, or engagement of students on inquiry-based exercises" (p. 491). As a result, Burrowes conducted an experiment with her two biology lecture sections each containing about one hundred students. Her control group was taught in a traditional lecture-style method with little room for interaction among students and her experimental group was taught using Lord's constructivist model of inquiry that allowed for cooperative groups. Burrowes covered the same content even using the same syllabus in both classes to keep it fair. When grading answers to tests that required higher-order thinking skills, Burrowes noticed that the experimental group obtained more correct answers, indicating that inquiry style teaching develops students' problem-solving skills needed for scientific thinking. In addition to scoring higher on exams, Burrowes noticed livelier students that were more prone to think critically by challenging exam questions and coming up with alternate
responses during the exams. Moreover, at the end of the semester, 70% of students from the experimental group expressed that they had high interest in biology as opposed to only 50% of the control group. Also, the experimental group expressed that they enjoyed the class more than their traditional style classes. This perception had to do with students having more time to interact with the content and their peers, which motivated them and in turn created a better learning environment where students did not fall asleep.

Llewellyn (2005) compares the traditional classroom where “The lesson is structured around ‘teacher talk’ and student responses” and where “[a] single textbook usually guides the teacher’s presentations and provides additional readings and questions for further discussion and homework” to an inquiry classroom (p. 55). The inquiry classroom is “student- or learner-centered” where the culture is “friendly and facilitating” and “[t]he atmosphere promotes an effective learning situation by making the students feel that their teacher and peers value their ideas, thoughts, and opinions. The classroom provides a positive socialization promoting active involvement along with inter- and intrapersonalization” (Llewellyn, 2005, p. 55-56). The comparison of the
different classrooms makes it evident that the inquiry classroom is where student learning is valued, and where students are responsible for their own learning as opposed to a traditional classroom. Since inquiry has been known to give positive results in student learning, Llewellyn (2005) offers recommendations to assist teachers to modify cookbook labs that are teacher-initiated into inquiry investigations that are student-initiated. Some suggestions that Llewellyn gives are to do labs before direct instruction. Data tables and charts should be removed to “reinforce their understanding of the difference between the dependent and the independent variables” (Llewellyn, 2005, p. 95). Other suggestions include revising the procedure section of a lab and the materials section and having students provide a list of materials or write their own procedure in order to make the labs more student-centered.

Summary

All the research demonstrates how inquiry is more effective than instruction using a traditional lecture-based approach. Inquiry is shown to provide a more effective learning environment and positive attitudes toward science, develop higher thinking skills, and thus
increase conceptual understanding. Since the literature shows that taking AP classes does not indicate college success, and the primary mode of instruction in advanced placement biology classes is lecture-based, the AP program needs to be changed and reform is needed to present teachers with ideas of different instructional strategies so they can provide students with a solid background and understanding of scientific ideas.

The BSCS's "5E" Instructional model has established itself to be a way of improving lessons to guide students into a more in-depth understanding about the content. Therefore, it is the basis for the criteria to develop inquiry lesson plans. In lessons that follow the "5E" model, the first stage includes engaging the students. During the "engage" stage, students are introduced to the major ideas by an activity or by the teacher posing a problem or eliciting students' prior knowledge. The second stage is "explore." This stage provides experiences for students and gives them a chance for them to test their ideas and/or carry out an investigation. The third stage is the "explain" stage that gives students the opportunity to make sense of their activities or investigations by explaining their ideas and understanding. It also allows for the teacher to introduce formal language, terms and
content information that helps students gain a deeper and better understanding of the topic. The fourth stage of the "5E's" is "elaborate." This is where students apply or extend the concepts in new activities and relate their previous experiences to the current activities. The final stage is "evaluate." Students and teachers evaluate in this stage. Students practice metacognition which serves as a summative assessment of what students know, do not know, and can do. According to the research, using the "5E" instructional model of inquiry that includes these five criteria is a step towards becoming an inquiry teacher and providing students with a deeper understanding of scientific principles.

Llewellyn (2005) builds upon the knowledge of the "5E" inquiry model and suggests ways to change a traditional lesson into an inquiry lesson. Some suggestions include modifying cookbook labs that are teacher-initiated into inquiry investigations that are student-initiated. Llewellyn also suggests doing labs before direct instruction and revising procedures and rules to make them more student-centered. These suggestions to change traditional lessons into inquiry are meant to provide a way for teachers to obtain positive results in student learning.
CHAPTER THREE

METHODOLOGY

Introduction

The review of the literature shows that the AP program does not determine college success. Even though it is a high stakes program that colleges and universities depend on, it is flawed in its execution. After observing some advanced placement science courses, substitute teaching in AP classes, and by informally talking to other advanced science teachers, it is noted that AP science classes are typically taught using traditional lecture-based methods. Yet, as an experienced biology teacher that has used different instructional methods to teach science, and after having taken science education classes, there was a realization that a lecture-based method of teaching can be very ineffective, especially when it is the only mode of instruction used. As a first year teacher, traditional lecture-based instruction was generally used in the classroom because high school and college used the same method of teaching. The students taught by traditional methods were not involved, were not learning, and did not do well on assessments. Whenever activities where used, the students were more engaged and
it appeared that they were more interested and motivated in learning.

While observing AP biology and other science classes, the common routine was that students walked in the classroom and took out their notebooks to take notes. Most of the talking that took place in the classrooms was by the teachers. There were moments that the teachers would ask questions, but frequently they were knowledge level questions that commonly involved memorization or repetition of what was just said. Experiences and observations have given a motive to conduct research to find a better method, such as inquiry to teach Advanced Placement Biology that perhaps will help students understand concepts for success in their future studies in science.

The literature review also reveals that when comparing an inquiry method of teaching and a traditional lecture-based approach, inquiry is more efficient in improving higher thinking skills, developing a better learning environment in which students are engaged in science, and increasing the understanding of content knowledge. The inquiry model's criteria for developing lesson plans include the use of the "5E's" which contain five criteria: engage, explore, explain, elaborate, and
evaluate. These five stages are critical to developing an inquiry lesson as a step towards providing students with a profound comprehension of scientific content.

Since the most common method of instruction in advanced placement biology classes is lecture-based, it is necessary to change these traditional lessons into inquiry form to offer teachers with different ideas of instructional strategies in order to provide students with a concrete understanding of scientific ideas.

Methods

For this project, different types of information were gathered. The first type was research on advanced placement programs, what they are, and how they work. The first step taken in conducting the research was collecting information about how the advanced placement program, especially in the sciences, works and how much impact they have in the classroom. A library search using the universities online database and a website search using keywords such as: “advanced placement courses,” “AP and education,” “advanced placement and college success” was conducted. Research that dealt with AP courses being an indicator of college success was found but was usually funded by the College Board itself which might have been
biased. Also fairly few, yet new research that demonstrated that the AP program did not have an impact on success was found. A focus of research dealing with science was intended, but was not dismissed if the articles were a different AP subject.

The next step was looking carefully and analyzing why advanced placement science, and any science class for that matter, was ineffective as some research indicated. As a consequence, the research led to looking at teaching methods in advanced placement and in general science classes. Yet, it was determined that research should address high school or college level due to the age range the project entailed. While conducting the literature review, it was found that classes that were practicing inquiry methods were successful in presenting subject matter. Also, it was where the students were learning material at higher levels than in traditional classrooms.

Much of the core ideas and information about inquiry came from textbooks that were used during science education classes. While concentrating in comparing a traditional method of instruction versus an inquiry method, all of the research found showed that lectured-based instruction is ineffective and that
teaching methods that involve inquiry methods can be effective in teaching scientific concepts.

Finally, how best to teach inquiry methods and move away from a traditional lecture-based teaching style was studied. Due to the literature which showed that inquiry methods were more effective at understanding concept knowledge, creating a higher level thinking of ideas, and gaining more interest among students, it was decided to develop some sample lesson plans to show how a traditional advanced placement lesson plan can be changed and incorporate Rodger Bybee’s BSCS “5E” instructional model of inquiry to be more effective in helping biology students in advanced placement.

The AP biology course description provides information about the AP program, the materials that should be used, and an overview of the program. Yet, it fails to provide “guidance to teachers about establishing a laboratory program that would enable student inquiry and no support for the goal stated in the AP Biology course description that students gain personal experience in scientific inquiry” (NRC, 2002, p. 74).

Due to the lack of the AP program establishing support of an inquiry based curriculum, some AP biology topics and a few laboratories from the AP handbook of
suggested labs were used as a reference. It was decided to change these traditional style labs that follow traditional lessons into inquiry lessons using the “5E” instructional model of inquiry. The lessons were placed into categories based on the major topics covered in the AP Biology Course Description (2006) downloaded from the apcentral.collegeboard.com website and by looking at AP Biology website. Using the AP Biology website from the College Board, the free response questions from the AP exams from the year 2002 to the year 2006 were examined to see if there were any patterns of topics always covered in the exams. Yet, most of the topics were evenly distributed throughout the years. If one version did not cover a specific topic, the other version did. In consequence, the content in the lesson plans was randomly chosen using the AP Biology Course Description of the three main topics and three lessons were created to change from traditional to inquiry using the “5E” instructional model (see Table 2).

Table 2. Categories of Advanced Placement Biology Lessons

<table>
<thead>
<tr>
<th>Major Topic</th>
<th>Lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecules and Cells</td>
<td>Diffusion and Osmosis</td>
</tr>
<tr>
<td>Heredity and Evolution</td>
<td>Mitosis and Meiosis</td>
</tr>
<tr>
<td>Organisms and Populations</td>
<td>Physiology of the Circulatory System</td>
</tr>
</tbody>
</table>
The biology content was divided into three major topics: Molecules and Cells, Heredity and Evolution, and Organisms and Populations. In the next chapter, the lesson created from traditional to inquiry using the “5E” criteria is based on: Diffusion and Osmosis. For additional lessons based on Mitosis and Meiosis, and Physiology of the Circulatory System see Appendix A. A sample of a traditional lesson plan and a sample of a “5E” inquiry lesson plan for each major topic are given. The traditional lesson plan format contains the following structure: Topic, Grade level, California Science Education Standard, Objectives, Materials, Activities or Procedures, and Assessment. The inquiry lesson plan format follows the “5E” instructional model: Grade level and subject, California Science Education Standard, National Science Education Standard, Objectives, Engage, Explore, Explain, Elaborate, Evaluate, and any relevant information such as a description of an activity or lab.

Both lesson plans used the AP Biology Lab Manual as a source for the content covered. For the inquiry lesson plans, there are times that some of the basic traditional lab procedures have been incorporated into the lessons, which is not the case for the AP laboratory manual which
just lists lab procedures with the instructor responsible for a lesson, unfortunately usually in a lecture format.

A typical traditional lesson plan usually starts with the teacher giving students a lecture of the content. Some teachers show demonstrations along with their lectures to try to attempt on grabbing the students' attention. Some teachers use overhead lectures and yet others now use PowerPoint presentations in order to make lecture more interesting by adding color graphics, animations, and manipulating information easier. Even though some teachers involve the students in their lectures by asking questions and getting some student feedback, the students for the most part, are still sitting down writing and taking notes while the teacher talks.

After a lecture, a traditional lesson is usually followed by an activity or laboratory exercise. These labs or activities usually come from a textbook or workbook, and in the case of AP Biology, they come from the AP Biology Lab Manual. These labs are considered “cookbook” labs in which students follow a given step by step procedure that has a predetermined outcome which students can either get right or wrong. Usually in these cases, students follow the procedure without knowing why they are carrying the steps out in the specific sequence. Sometimes
students are too busy trying to get the "correct" answer that they overlook critical steps into learning why a procedure works or they miss the idea behind the lab.

After or during the lab, students usually answer questions that check progressive understanding of the content. These right or wrong answers indicate what the students know or do not know and that is how the teacher determines what needs to be clarified in an additional lecture or needs to spend more time on.

At the end of the section, the teacher using traditional lessons gives a quiz or test that assesses the students' recall of information presented. These tests usually include multiple choice questions, short answer questions and essay questions that test the students' understanding. Depending on the teacher, some questions might apply the students' knowledge but for the most part, the bulk of the tests usually deal with recalling facts about what the students learned.

Unlike in a traditional lesson, a "5E" inquiry lesson includes five stages: engage, explore, explain, elaborate, and evaluate. In the "engage" stage students are given a task that introduces them to the topic and recalls prior knowledge and experiences. In this stage a teacher can ask a question, give students a problem or situation, show a
short video, or involve students in an activity that engages them. The next stage is the “explore” stage, where the students have the opportunity to carry out their own investigations or one assigned by the teacher. This stage is the lab part of the lesson. However, instead of students following a “cookbook recipe,” students should be given more challenges to think about the process. Students should work together in teams to find meaning to the content using their prior knowledge. The teacher facilitates by guiding students, asking questions, and providing materials for the investigation. The following stage is the “explain” stage where students pull together the information from their investigations and all of their experiences and communicate their explanations to themselves, their group, the class, and the teacher. This is where the teacher, using the knowledge that the students have explained, builds upon this knowledge by introducing formal language, terms, and content information which can be in a form of a lecture, a form of direct instruction. The fourth stage is the “elaborate” stage. This is the stage where the students use the knowledge that they have gained and apply it to new, but related situations. This can lead to new inquiry investigations and new understanding. The final stage of
the "5E" Instructional Model of Inquiry is the "evaluate" stage. This is where students think about what they learned and what they do not understand. This is an on-going process that can occur throughout the lesson. A reflective journal or learning log is ideal for students to process their thoughts and show what they have learned by expressing it on paper. Teachers should give a prompt to focus students on the objectives of the lesson and can be evaluated by the teacher as well as themselves.

In order to make the changes from traditional lessons that include AP labs to inquiry lessons, the identified criteria were used: engage, explore, explain—student then teacher, elaborate, and evaluate. These were determined by looking at the AP labs and other traditional cookbook labs usually found in laboratory manuals and by identifying the information that they were lacking when compared to the BSCS's "5E" criteria. The traditional lesson usually has the same three sections: lecture, lab, and assessment. The inquiry lesson, however, has to have the entire continuum of the "5E's": engage, explore, explain, elaborate, and evaluate. However, it was found that a traditional lesson has some forms of the "5E's" embedded in it such as an "explore" section where a lab is conducted. It can also have an "elaborate" section in which students are posed
with a question that allows them to apply what they learned. Therefore, in order to change these lessons from a traditional lesson to an inquiry lesson, the lesson had to fit the "5E" Instructional Model of Inquiry (see Table 1), but emphasize the three criteria that the traditional lessons were lacking, and rearrange and change the focus of the remaining criteria found in a traditional lesson.

The first criterion changed was that students must interact with the material before they are introduced to the topic. In an inquiry lesson, this is found in the "engage" section of the lesson plan. In this stage, students are able to engage and interact with the material to have experiences and build some prior knowledge. In addition, the teacher asking probing questions in this stage is important into getting the students to think critically. On the other hand, in a traditional lesson where lecture is the primary mode of instruction, teachers usually fail to have the students interact with the material. It was noticed that the AP labs in the laboratory manual just gave the students background into the topic and then gave the students directions on what to carry out. On the other hand, in inquiry lessons the purpose was to engage the students and ask them questions
based on prior knowledge, something that the AP Biology Lab Manual fails to do.

A traditional lesson usually includes a lab or activity. In an inquiry lesson, this portion would be included in the "explore" stage. Even though the traditional lesson can have students explore the material, this type of lesson usually is conducted after a lecture where the students follow a set procedures and have expected outcomes. In an inquiry investigation, students can explore by designing an experiment themselves or conducting an investigation given by the teacher. However, the exploring comes before a lecture because students are gaining knowledge by doing and experiencing, which allows students to form their own initial explanations connecting with their prior knowledge. Their explanations are more meaningful than the teacher explaining the content.

To make explorations more meaningful to students, changing traditional labs into inquiry investigations is important. Even though explorations are present in the traditional lessons, revising the materials, safety rules, procedures and results, and questions can help change the lab into inquiry so students can have a greater understanding of the content. Instead of having a list of materials, the teacher can have the students come up with
possible materials that they might need to conduct the investigations. Another option is to have students come up with an explanation of why they would need the materials. Having students come up with safety rules instead of giving them the list, can help students be more responsible about their actions in a laboratory setting. Instead of having the students follow a set procedure, the teacher can have the students design the procedure. If a set procedure is crucial to the investigation and is provided, the teacher can have the students come up with reasons of why they should carry out a specific procedure or ask questions along the way of why the specific procedure is important. A different option could be to give a wrong procedure and have students identify and explain why it is erroneous. Rearranging the order of a procedure can also be helpful for students to identify why the order of a procedure is important.

Removing given tables from the results sections of the lab can also help students think critically about the content. For example, the AP Biology Lab Manual gives data tables to students so they can write their data gathered from the investigation. Removing these tables and having students create their own, gives the students the opportunity to think about how their data is to be
arranged and the important aspects of the lab. The form of questioning is also important during the laboratories. The goal should be to change the questions into questions that apply the knowledge obtained from the exploration instead of recall questions that can be found in the text.

The second criterion lacking in traditional lessons is having students come up with their own explanation to the idea or activity they explored. This can be found in the "explain" portion of a "5E" lesson plan. As opposed to the teacher talking about the material in a lecture before the lab and telling the students the information, it is important to have students come up with their own explanations after their explorations. The teacher’s role should be to facilitate learning by elaborating and introducing scientific vocabulary and knowledge and where lecture can be introduced. The purpose of having the students explain before lecturing is so the teachers can build upon the students’ knowledge and address misconceptions that might still be present. Also, explanations and lectures at this point are more meaningful to students because they already have prior knowledge of the topic.

Application activities or questions can be found in traditional lessons after lecture and lab, and in inquiry
lessons during the "elaborate" section. This section can contain questions, pose a different but similar problem they investigated, activity, or new exploration that applies what they learned from their previous experiences. In traditional lessons, however, this section is sometimes left out due to time constraints. Yet, in inquiry lessons, it is crucial because it is a ways of assessing student learning.

The third criterion that is not present in traditional lessons or laboratories is having students practice metacognition. For example, the laboratories in the AP manual do not contain this section. Yet, in an inquiry lesson plan this can be a form of assessment included in the "evaluate" portion of the lesson plan. As opposed to a traditional quiz or test containing multiple choice questions and essay questions where the teacher is the only one evaluating, students are able to think about what they learned and did not understand. It is important that students take charge of their own learning and stop to evaluate their own thinking to gain and seek greater scientific knowledge. See Table 3 for a general model of how to change traditional lessons into inquiry lessons.
### Table 3. General Model of How to Change Traditional Lessons to Inquiry Lessons

<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E Instructional Model</th>
<th>Steps of How to Make Changes from Traditional to Inquiry Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lessons usually start with lecture</td>
<td>Engage—provides the opportunity for teachers to identify students' current concepts and misconceptions. These activities introduce major ideas in problem situations.</td>
<td>• Have students engage in an activity that can build or elicit prior knowledge.</td>
</tr>
<tr>
<td>• Students are not engaged.</td>
<td></td>
<td>• Pose a problem or question appropriate to the content.</td>
</tr>
<tr>
<td>• A lecture is sometimes followed by conducting a lab from a textbook or activity that has a determined outcome.</td>
<td>Explore—provides a common set of experiences for students and opportunities for them to test their ideas with their own experiences and those of peers and the teacher. It allows comparison of how students’ exploration and explanation of experiences compares with others.</td>
<td>• Show a video clip or other event that creates curiosity.</td>
</tr>
</tbody>
</table>

- Have students design their own investigation to a question or topic.
- Take some information out from traditional labs/activities such as tables that are usually provided. Instead, have students come up with their own tables and graphs.
- Have students come up with their own procedure.
- Jumble an existing procedure and have the students come up with the best possible procedure.
- Another option is to go over the procedure but have the students come up with a reason why the steps are important.
<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E Instructional Model</th>
<th>Steps of How to Make Changes from Traditional to Inquiry Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• After a lab or activity, students usually answer questions after the lab or activity to indicate some understanding of the topic.</td>
<td>Explain- provides opportunities for students to use their previous experiences to recognize misconceptions and to begin making conceptual sense of the activities through construction of new ideas and understandings. Allows introduction of formal language, terms and content information that makes students' previous experiences easier to describe and explain.</td>
<td>• After an investigation, it is important to have the students report their results to their group and class.</td>
</tr>
<tr>
<td>• Student explanations are not present</td>
<td></td>
<td>• They can create presentations on their findings on the main topic.</td>
</tr>
<tr>
<td>• There is only explanation by the teacher during the lessons or during re-teaching.</td>
<td></td>
<td>• As opposed to in a traditional lesson, this is where a teacher lecture will come in. The teacher will elaborate and address any misconceptions still present and guides them to a move in-depth understanding of the topic.</td>
</tr>
<tr>
<td>• Students can often apply what they learned by answering application questions at the end of the section or by questions posed by the teacher.</td>
<td>Elaborate- apply or extend the student’s developing concepts in new activities and relate their previous experiences to the current activities. In other words, how the new explanation works in a different situation.</td>
<td>• Students can still answer the application questions from the section but can elaborate by further conducting other activities that are new but related to the topic.</td>
</tr>
</tbody>
</table>
### Traditional vs. 5E Instructional Model

<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E Instructional Model</th>
<th>Steps of How to Make Changes from Traditional to Inquiry Lessons</th>
</tr>
</thead>
</table>
| • For evaluation purposes, teachers usually give a multiple choice and/or short response quiz or test.  
• Students are not involved in the process of assessing their own learning. | Evaluate—serves as a summative assessment of what students know and can do through metacognition. It shows how students understand and apply concepts and abilities that they learned. | • Students and teachers should be involved in the evaluation process. In traditional lessons, teachers are the only ones that assess.  
• Students should reflect how well they understand the concept and have met the objectives.  
• A learning log is ideal for assessing student understanding and teachers can assess this using a rubric.  
• Another way to evaluate can be to have students come up with a product using the knowledge they learned to a different and new situation. |

### Summary

As the literature points out, the advanced placement program does not indicate that students will be successful in college. Success is due to the teacher’s pedagogical practices in the classroom. Research shows that inquiry is more effective than traditional methods of teaching due to many factors. It has been found that inquiry creates an effective learning environment with better attitudes about science than in traditional classrooms. It has also been
shown to increase student understanding of science and develop higher thinking skills when compared to the traditional method of teaching. The Biological Sciences Curriculum Study (BSCS) developed the "5E" instructional model, as a basis to form inquiry lessons that include the five criteria: engage, explore, explain, elaborate, and evaluate. The "5E's" were used to create a general model of how to change traditional lessons into inquiry lessons by identifying that three out of five criteria were not present in traditional lessons: engaging students, student led explanations, and metacognition as student evaluation.

Chapter Four gives an example of how a traditional lesson is transformed into an inquiry lesson based on the three criteria that are incorporated into a "5E" inquiry lesson and missing in a traditional lesson. Following the lesson plans, both types of lessons are compared in regards to the "5E's" emphasizing the three missing criteria which are critical for student understanding, and rearranging cookbook labs into more open-ended ones and lectures/direct instruction placed after students have reported on their explanations of the lab experiences.
CHAPTER FOUR
THE CHANGE OF ADVANCED PLACEMENT
BIOLOGY LESSONS TO INQUIRY

Introduction

This chapter contains a traditional lesson plan and an inquiry lesson plan for AP Biology from one of the major categories in the AP Biology Course Description: Diffusion and Osmosis (see Table 2, CHAPTER THREE) that is based on the general model of how to change traditional lesson plans into inquiry lesson plans in Chapter Three (see Table 3, CHAPTER THREE). For the additional lessons on Mitosis and Meiosis, and Physiology of the Circulatory System see Appendix.

The AP Biology Lab Manual (College Board, 2001) was used as a reference to address some of the topics covered in AP Biology. Since the labs in the AP Lab Manual are just procedures and follow-up questions, it is inferred that the topics covered would be covered in a traditional lecture as in most AP classrooms and therefore the basis for a traditional lesson plan. Therefore, most of the information in these labs has been changed to fit the BSCS “5E” inquiry model, making complete lessons that incorporate laboratories similar to the AP program’s labs.
The inquiry lesson, however, differs in how the lab gives meaning to the content. Using inquiry the labs are integrated within the lesson to initiate and drive the learning process. Traditional methods do not offer the seamless incorporation of lab and lesson, but rather separates the lab from the lecture.

This chapter is structured so that the first lesson is the traditional lesson. Following the traditional lesson is the inquiry lesson covering the same topic. At the end of the lesson plans, there is a comparison of both traditional and inquiry lesson plans using the "5E's" as criteria emphasizing the three criteria that are lacking in traditional lesson plans: engaging the student, student explanation, and metacognition. The lessons are discussed in relation to the three criteria. These inquiry lessons should help biology teachers see how to facilitate students' understanding of scientific concepts using an inquiry method.

Diffusion and Osmosis Traditional Lesson Plan

Topic: Diffusion and Osmosis

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standard:
Cell Biology, 1a: Students know cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.

Objectives:

a. Students will differentiate between diffusion and osmosis.

b. Students will describe the movement of water and particles through a selectively permeable (semipermeable) membrane.

c. Students will discuss the importance of diffusion and osmosis as it applies to their own body and other organisms.

Materials:

PowerPoint Lecture on Diffusion and Osmosis, See materials list in the Teacher’s guide for AP Biology Lab Manual for the Lab on Diffusion and Osmosis.

Activities or Procedures:

Teacher will lecture using a PowerPoint lecture of Diffusion and Osmosis. Teacher will make sure that students understand that diffusion involves traveling of solutes through the semipermeable membrane and osmosis is water diffusion. At the end of the lecture, have students make a T-chart comparing both diffusion and osmosis. After the students have
understood these concepts, do Lab One: Diffusion and Osmosis from the AP Biology Lab Manual (College Board, 2001, p. 1-18). Model the lab and its different parts if needed and make sure students know how to use all the equipment. Make sure students understand the questions following the lab. Clarify any questions that students might have.

Assessment:

Students will take a multiple choice and short answer quiz addressing the objectives and some knowledge of the lab.

Diffusion and Osmosis Inquiry Lesson Plan

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standard:

Cell Biology, 1a: Students know cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.

National Science Education Standard:

Life Science Content Standard C: As a result of their activities in grades 9-12, all students should develop understanding of The Cell. Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane
that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.

Objectives:

a. Students will differentiate between diffusion and osmosis.

b. Students will describe the movement of water and particles through a selectively permeable (semipermeable) membrane.

c. Students will discuss the importance of diffusion and osmosis as it applies to their own body and other organisms.

d. Students will design their own experiment that illustrates diffusion through a semipermeable membrane.

The Diffusion Lesson Itself

1. Engage- Start out by using a clear plastic cup and food coloring. Ask students to hypothesize what will happen if a drop of food coloring is dropped in the cup of water. Have them draw it (this will help the
visual learners) and describe what they will see. Have the students drop a few drops of food coloring in the water. While students are observing, spray some perfume of air freshener in the classroom in one specified place. Teacher should ask probing questions to the students to describe what is happening. For example, what is moving in the cup and air and in what direction? Why is this happening? What will happen after a few minutes? What are the similarities between both examples? What if the temperature of the cup of water is increased? This is intended for students to understand that particles move in a specified manner. Students will start questioning and start hypothesizing. The students should record their observations and thoughts into their notebooks.

2. Explore- Do Exercise 1A: Diffusion (included at the end of this lesson). Make sure to discuss any unknown reagents and materials that students might not be familiar with.

3. Explain- Go over the post lab questions in groups and then as a class. Students should explain what their results were from the lab. Students should have come up with a basic understanding of how
molecules move in and out of the tubing (there should be an understanding of molecules moving from a high to low concentration) and how the membrane of the tubing was selective. Introduce how the cell membrane is similar to the dialysis tubing and how the vocabulary such as diffusion, dialysis, selectively permeable, and concentration gradient are related to each other. This is the part where the teacher can introduce a short lecture if needed for clarification and further detail.

4. Elaborate- Have students design a different experiment that involves diffusion and have them test it out if possible. Ask the students why their experiment a good representation of diffusion.

5. Evaluate- Have students write in a learning log. What did the students learn about a cell’s membrane? What do they not understand? How could they change the experiment? Make sure that their answers meet all of the objectives. Teachers can use a general rubric that scores the students understanding of the content (See Table 4).
Table 4. General Scoring Rubric for Student Reflections

<table>
<thead>
<tr>
<th>Elements to be Evaluated</th>
<th>Scoring Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following objectives should be addressed:</td>
<td>Points 1-4:</td>
</tr>
<tr>
<td>(This is where the objectives should be listed)</td>
<td>4- Reflection provides an in depth analysis of what was learned in the context of the topic. There are many examples and supportive details that are clearly explained providing a clear understanding of the topic.</td>
</tr>
<tr>
<td></td>
<td>3- Reflection gives a general analysis of what was learned in the context of the topic. There are few or general examples and supportive details that show a general understanding of the topic.</td>
</tr>
<tr>
<td></td>
<td>2- Reflection is very general in explaining what was learned in the context of the topic. There are no clear examples or details which are unsupported that show lack of understanding of the topic.</td>
</tr>
<tr>
<td></td>
<td>1- Reflection does not adequately address what was learned. There are no examples or details that show understanding of the topic.</td>
</tr>
</tbody>
</table>

Exercise 1A: Diffusion

Overview: A solution of glucose and starch will be placed inside a bag of dialysis tubing. Distilled water will be placed in a beaker, outside the dialysis bag. After 30 minutes, the solution inside the dialysis tubing and the solution in the beaker will be tested for glucose and starch. The presence of glucose and starch will be tested using Benedict’s solution (blue in color) and Lugol’s solution (Iodine-Potassium- Iodide, IKI; brown in color).
Pre-Lab Questions:

1. Describe what you know about dialysis tubing. Why do you think we are using this type of tubing? Explain.

2. Why did we use Benedict’s solution and Lugol’s solution? What do they test for? (Make sure you know before the experiment).

3. Read the Procedure. Draw the setup of this lab. Set up a data table(s) that address your results and is consistent to this experiment. Predict the initial and final colors of your indicated solutions. Record your results on your data table(s).

Procedure:

1. Get a piece of 2.5 cm dialysis tubing that is 30 cm long and has been pre-soaked in water. Tie off an end of the tubing to form a bag. Then, open the other end of the bag by rubbing the end between your fingers to separate the edges.

2. Test your 15% glucose/1% starch solution for glucose by performing a Benedict’s solution.

3. Place 15 mL of 15% glucose/1% starch solution in the bag created in the first step. Tie off the other end leaving enough space so the contents in the bag can have room to expand. Record Results in your data table.
4. Fill a cup or 250 mL beaker 2/3 full with distilled water. Add approximately 4 mL of Lugol’s solution to the distilled water. Test the solution for glucose. Record the color in your data table.

5. Submerge the bag into the cup or 250 ml beaker of solution. This setup should be left to stand for about 30 minutes.

6. When time is up, record the final color of the solution in the bag and the solution in the cup/beaker in your data table.

7. Finally, test the liquid in the cup/beaker and in the bag for the presence of glucose using the appropriate solution. Record your results in your data table.

Post-Lab Questions:

1. Which substances(s) are entering the bag and which are leaving the bag? Draw your setup and using arrows indicate which substances are entering and leaving. What evidence from your experiment supports your answer?

2. Explain the results obtained. How are they different or similar to your predicted results? Include the concentration differences and how the size of the
pores (holes) in the tubing might affect the results.

3. What was the purpose of leaving the setup for 30 minutes? Would your results differ at different times? Explain.

4. Using the observations during this exercise, rank the following by size, beginning with the smallest: glucose, molecules, water molecules, IKI molecules (from the Lugol’s solution), dialysis tubing pores, starch molecules. Explain how you determined this ranking.

5. What results would you expect if the experiment started with glucose and Lugol’s solution inside the bag and only starch and water outside? Explain your expected results?

The Osmosis Lesson Itself

1. Engage- Have students carry out Exercise 1B: Osmosis Using Grapes, which involves grapes in three solutions, which is included at the end of this lesson. Have students answer: What is the purpose of this experiment? Can we use another fruit? What would we need to change if we changed the fruit? Explain.
2. Explore- Students will carry out Exercise 1C: Osmosis Using Dialysis Tubing (included at the end of the lesson). The teacher should facilitate students and go around asking questions to help students begin understanding the concept.

3. Explain- Students will explain and/or draw what happened with their grapes (Exercise 1B) and their dialysis tubing (Exercise 1C). Students should have some idea of how particles are moving. Students should be able to differentiate where the solute and solvent are moving. This is a good place to introduce the terms hypertonic, hypotonic, isotonic, and vocabulary pertaining to osmosis. It is very important that the students come up with an explanation of their own and make sense out of the material rather than the teacher telling the students. Ask the students what were the similarities and differences between the exercise with the grapes and the one with the dialysis tubing.

4. Elaborate- Students will answer the post-lab questions, focusing on question #4 and discuss their answers with their groups and the class. Have students report on an everyday example of how
diffusion and osmosis is important in life of different organisms.

5. Evaluate- Students will reflect on their understanding of diffusion and osmosis. Also ask: What would happen to your cells if you had to live off of salt water? How much salt do you think your cells could take? (You can add or use other substances or chemicals). Teachers can use a similar rubric to grade the reflection using Table 3’s scoring rubric.

Exercise 1B: Osmosis Using Grapes

Overview: There are three grapes under three different solutions. The three solutions are: grape juice, sugar solution and water. Predict what will happen to grapes under these environments.

Procedure:

1. Make a data table that addresses the following: the three types of solutions, predictions of what will happen to the grapes in the three solutions, observations before and after 24 hours, and initial and final mass of the grapes.

2. Label three jars: grape juice, sugar solution, and water. Fill them according to their labels.
3. Take the mass of 3 grapes and place them in each jar and record on your table. Close the lid on each jar and let them sit for 24 hours.

4. Fill in the “Observations before 24 hrs.” and “Predictions/Predicted mass of grape after 24 hrs.” with any descriptions and predictions from what you already know about substances moving.

5. After 24 hours, remove the grapes removed from their jar and dry with a paper towel to remove excess water.

6. Weight the 3 grapes and record their mass.

7. Describe your observations of what the grape looked like after 24 hours.

Exercise 1C: Osmosis Using Dialysis Tubing

1. Take six 30 cm strips of presoaked dialysis tubing and tie knots at one end of each piece of dialysis tubing to form 6 bags.

2. Pour approximately 15-25 mL of each of the following solutions into separate bags (the solution should fill about 1/3 to 1/2 of the piece of tubing):
   Distilled water, 0.2 M sucrose, 0.4 M sucrose, 0.6 M sucrose, 0.8 M sucrose, and 1.0 M sucrose.

3. Make a data table that includes these six solutions in the bag, the initial and final mass of the bags.
(in grams), the mass difference, and the percent change in mass.

4. Remove most of the air from each bag by drawing the dialysis bag between two fingers. Tie off the other end of the bag leaving sufficient space for the expansion of the contents in the bag.

5. Make sure to rinse each bag with distilled water to remove sucrose spilled during the filling.

6. Blot the outside of each bag and record the initial mass of each bag in your data table.

7. Set each bag inside an empty cup or 250 mL beaker and label the cup/beaker according to your solutions in step 2.

8. Fill each cup/beaker two-thirds full with distilled water. Make sure to completely submerge each bag in the water.

9. Let the bags stand for 30 minutes.

10. When 30 minutes are up, remove the bags from the water and blot to remove excess water. Determine the mass of each bag and record your results in your data table.

Post-Lab Questions:

1. What happened to the dialysis bag in each of the six cases? Describe the direction that water moved and
the direction the solutes moved. Use the terms isotonic, hypertonic, and hypotonic in your answer.

2. Why did you calculate the percent change in mass rather than using the difference in mass?

3. Predict what would happen to the mass of each bag in this experiment if all the bags were placed in 0.4 M sucrose solution instead of distilled water. Explain.

Comparison of Traditional Lesson versus Inquiry Lesson

When comparing the differences between the traditional lesson plan and the inquiry lesson plan it is demonstrated how the three criteria: engaging students, explanations from students, and metacognition are lacking in traditional lessons. It is noticeable that the lecture on diffusion and osmosis is not engaging to the students. On the other hand, in both inquiry lessons about diffusion and osmosis students are doing science. They are carrying out an investigation as simple as placing food coloring in water and placing grapes in different solutions. These activities engage students in thinking about the topic as opposed of taking notes to a lecture. When comparing the traditional lessons and the inquiry lessons, it is noticeable that in the inquiry approach, there are
experiences first. For example, the lab or activity precedes a lecture which is a trait that promotes inquiry in the classroom. In contrast, in the traditional approach, lecture comes first.

Both traditional and inquiry lessons include the “explore” stage of the “5E’s.” However, as opposed to just conducting the lab from the AP Biology Lab Manual as the traditional lesson does, the inquiry lesson modifies the lab. The lab follows similar procedures. However, there are pre-lab questions included that the AP Biology Lab Manual does not include. These pre-lab questions are a way for students to analyze the procedure that they will carry out and make sense out of it. There are questions that might be just recall questions in both lessons, but in the inquiry lesson it is the teacher’s role to ask probing questions during the process of investigation.

During the “explain” stage of the lessons, the traditional lesson has the teacher doing the explanation before the lab. The teacher is the only one providing explanations while students are just listening and receiving information. In the inquiry lesson, the students are explaining the results of their diffusion and osmosis experiments to their group and the class. This will help them know what they learned from conducting their
investigations. The teacher builds upon the students' explanations by introducing the vocabulary needed and covers material necessary for deeper understanding. This is unlike in the traditional lesson where students have already had a lecture and students answer questions from the lab to report their findings.

Depending on the teacher, students can carry out further experiments or answer questions that apply their knowledge. In traditional lessons, such as the one given, the application questions are usually used at the end of the investigation or during the final quiz or test that the student takes. In the inquiry lesson example, students are given further chance to elaborate on their understanding and ideas by creating their own experiment of how diffusion can be shown. In the osmosis lesson, students are to apply the knowledge that they learned from both diffusion and osmosis and report how these processes are important to different organisms.

In traditional lessons only the teacher is assessing the students, so the students do not have the opportunity to think about what they understand and what they do not. In this case, the lesson involves the student taking a multiple choice quiz which assesses the students' memorization skills to the facts learned. In the inquiry
lesson, the students reflected on what they understood and what they did not. They also thought of ways that they could change the diffusion experiment. In the osmosis lesson students were given a chance to reflect new questions were asked: What would happen to your cells if you had to live off of salt? How much salt do you think your cells could take? These questions can lead to other questions, discussions, and explorations. Inquiry lessons allow the students to think and get to their own explanations that help clear misconceptions and therefore teacher intervention in the form of probing and leading questions is critical to understanding. See Table 5 for a table that compares the traditional lesson versus the inquiry lesson on diffusion and osmosis.
Table 5. Comparison of Traditional Lesson versus Inquiry Lesson on Diffusion and Osmosis

<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E’s with Criteria used to change from Traditional to Inquiry</th>
<th>Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are given a lecture on the diffusion and osmosis; Students are not engaged</td>
<td>Engage- students interact with material (criterion one)</td>
<td>Diffusion lesson: Students do a simple test of food coloring and water; Osmosis lesson: Students place grapes in different solutions and predict what will happen to the grapes; Teacher helps out by asking probing questions in both situations</td>
</tr>
<tr>
<td>Students carry out the Lab on Diffusion and Osmosis from the AP Biology Lab Manual</td>
<td>Explore</td>
<td>Students carry out the Exercises 1A-1C on Diffusion and Osmosis; Teacher questioning of student is important</td>
</tr>
<tr>
<td>Teacher does the explaining; Students answer written questions from the lab</td>
<td>Explain- students will provide their own explanations (criterion two)</td>
<td>Students explain and discuss their results within their groups and to the class; The teacher elaborates on the topic</td>
</tr>
<tr>
<td>Some questions from the lab/quiz are application questions</td>
<td>Elaborate</td>
<td>Students create their own experiment to test diffusion</td>
</tr>
<tr>
<td>Students take quiz; no metacognition, students do not stop to think what they understood and what they did not</td>
<td>Evaluate- Students will practice metacognition (criterion three)</td>
<td>Students reflect on what they understood and what they still had questions on; Students need to think how they could change the lab to make it better; Teacher uses these questions and asks questions to evaluate their learning.</td>
</tr>
</tbody>
</table>

**Conclusion**

These sample lesson plans are just one way to go about transforming lesson plans from a traditional method.
to an inquiry form. Llewellyn (2005) also gives suggestions and recommendations of how to modify lessons and labs into inquiry investigations. For example, Llewellyn suggests doing labs first as opposed to where most textbooks place them. Also, the questions in the lab should be revised and it is suggested that information such as data tables, charts, and safety rules should be removed so students can come up with this information on their own. In addition, revising a procedure to include some errors, and add extension questions to labs that usually do not contain these questions is a good start into transforming a traditional lab into an inquiry lesson. These are all techniques into having more student involvement in their own learning. According to Llewellyn (2005), everybody takes a different path to inquiry due to the personal experiences one encounters in teaching. Yet, "[r]Regardless of the path one takes, the transition to becoming an inquiry-based teacher usually follows four distinct stages: starting at the traditional approach, next exploring inquiry, followed by transitioning to inquiry and finally practicing inquiry" (Llewellyn, 2005, p. 63). In addition, being a reflective teacher and trying to acquire the best practices to help students gain scientific knowledge are vital components of becoming an
inquiry-based teacher. Thus as a teacher that seeks better methods for students to gain content knowledge, an inquiry-based approach has been pursued to change traditional methods of teaching in the AP classroom that have not proved successful, and share them with others.
CHAPTER FIVE
CONCLUSION AND DISCUSSION

Summary

The AP program's purpose to improve American education and provide superior educational content knowledge has stimulated controversy among researchers who seek to find if the program determines that students will succeed post-high school. Through the investigation of research available and because of personal experiences, it has been concluded that the AP program is not successful in improving student learning in the sciences. This is partly due to the quality of the traditional lectured-based instructional methods that AP teachers practice, and because of its tremendous content coverage which has given it limitations for student success. Success in the subject matter is affected due to the lack of understanding of scientific content.

All of the research that compares traditional instruction versus inquiry-based teaching points to inquiry instruction as a superior way to get the students to critically think and understand science. It is important to understand that lecture can be a part of the inquiry model, yet should not be solely used for
instruction because as research points out, this form of instruction looses students' interest and disengages them. Because inquiry suggests that students' understanding increases, it is suggested that traditional lesson plans that are lecture based are changed to inquiry lessons using the Biological Sciences Curriculum Study (BSCS) "5E" instructional model.

Three traditional lesson plans and three inquiry lesson plans have been provided as models of how one can take a traditional lesson and cookbook lab and turn it into an inquiry lesson, using the BSCS "5E" instructional model, that benefits student understanding of scientific knowledge (see CHAPTER FOUR and APPENDIX). These lessons were created using a general model of how to change lessons from traditional to inquiry and the criteria that was lacking in traditional lessons. The criteria missing from traditional lessons were: engaging students, students creating their own explanations to their investigations, and students practicing metacognition. The criteria that the traditional lessons had, which were explore and elaborate, had to be adjusted to include more open-ended questions and activities that preceded explanations from the teacher to make content more meaningful to the student. Both traditional and inquiry lessons were
compared to each other using the all of the "5E’s"
emphasizing the three criteria stated. This comparison
showed how inquiry lessons force student involvement and
the responsibility for learning. These lessons are
examples of how to take a step towards practicing inquiry,
and how becoming an inquiry teacher can be approached.

Conclusions and Recommendations
The present method of teaching advanced placement
courses, which is mostly through traditional means, has
defied the purpose of the advanced placement program into
improving students’ education through a high quality
program. Even though the College Board has not indicated
instructional methods to teaching their subject matter,
the amount of information covered and their suggestions to
teach the content have been mostly through traditional
lecture-based instruction. In order to keep high quality
instruction and help students understand scientific
knowledge to consequently be successful, the need to
improve pedagogical practices in the advanced placement
classroom is needed. A problem that arose during the
process of this project was that there was research
indicating how the AP program might not indicate college
success, but researchers failed to clearly elaborate and
point out why the AP program was not successful. Research pointed to the instructional strategies practiced by the AP teachers affected the AP program, but there was no clear research that addressed that the AP program was not successful due to the instructional strategies practiced in the AP classes. Therefore, more research needs to be conducted in this area.

So far, inquiry has deemed to be a method that has succeeded in developing student understanding. Yet researchers' main focus is at the elementary level. There are few studies about inquiry in high school and even less research on the undergraduate level. The studies done at the undergraduate level indicate that inquiry can be practiced in large classrooms as opposed to some people thinking that inquiry is geared for a small group of students. Research of inquiry on the undergraduate level is crucial to the educational system because these college students are the future teachers that will teach our students. If teachers would have been taught using inquiry-based instruction, today teachers would have been familiar with the process and would not have struggled to realize that traditional lecture-based instruction is not the best instructional method for scientific discovery and learning.
Consequently, the teacher's credential program that teaches pedagogical methods to improve teaching needs to be reformed to show some of the instructional strategies that are successful in all subjects including science. During the California State University, San Bernardino credential program, all the teachers were required to do lesson plans using a variation of the traditional lesson plan template. If an inquiry-based method was the pedagogical method of practice for teaching, then programs such as the university credential program would advocate this method as well.

This project is intended to show that inquiry is one way to improve instruction in the science classroom by changing present traditional lessons into inquiry lessons. Yet, teachers should practice various instructional strategies that will indicate the best methods of teaching for their students. There are other ways to get students to understand scientific knowledge such as problem-based learning which deals with the teacher presenting a big theme and/or problem that students work on for various weeks. There are programs such as the “Teams and Streams” program discussed in Chapter Two, which have also helped students gain a deeper understanding of science concepts. There are different programs and strategies that arise
from inquiry methods having the same or similar components of the BSCS “5E” instructional model. More research on inquiry and its effect on learning should be conducted to solidify that inquiry-based teaching should be the direction that teachers should move towards to improve student understanding. Furthermore, the model created as a guide to change traditional lesson plans into inquiry lessons created in this project that has been provided here can be further used to help teachers create unit plans or help revise AP coursework in the future. This model can help design programs which help students develop inquiry skills, so they become superior and successful learners.
APPENDIX

ADDITIONAL LESSON PLANS
Mitosis and Meiosis Traditional
Lesson Plan

Topic: Mitosis and Meiosis

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standards:

Genetics, 2a: Students know meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.

Genetics, 2b: Students know only certain cells in a multicellular organism undergo meiosis.

Genetics, 2c: Students know how random chromosome segregation explains the probability that a particular allele will be in a gamete.

Objectives:

a. Summarize the events of mitosis and meiosis in animal and plant cells indicating differences and similarities in each.

b. Describe how independent assortment and crossing over can generate genetic variation among the products of meiosis.
c. Relate chromosome activity to Mendel’s laws of segregation and independent assortment.
d. Use models to illustrate mitosis and meiosis.

Materials:
PowerPoint Lecture on Mitosis and Meiosis, See materials list in the Teacher’s guide for AP Biology Lab Manual for the Lab on Mitosis and Meiosis

Activities or Procedures:
Students will take notes and draw the appropriate steps of mitosis and meiosis. Make sure to cover how Mendel’s Laws of Segregation and Independent Assortment apply and can be demonstrated by meiosis. Teacher will ask the students what the differences were between mitosis and meiosis and what the similarities between the two using a t-chart. Have students complete Lab 3: Mitosis and Meiosis from the AP Biology Lab Manual (College Board, 2001, p. 29-44). Students will answer the questions in the lab.

Assessment:
Students will identify slides in a microscope and label it with the appropriate stage. Also, students will have a short quiz from the material covered in lecture and lab.
Mitosis and Meiosis Inquiry Lesson Plan

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standard:

Genetics, 2a: Students know meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.

Genetics, 2b: Students know only certain cells in a multicellular organism undergo meiosis.

Genetics, 2c: Students know how random chromosome segregation explains the probability that a particular allele with be in a gamete.

National Science Education Standard:

Life Science Content Standard C: As a result of their activities in grades 9-12, all students should develop understanding of molecular basis of heredity. Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic
information to offspring, occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.

Objectives:

a. Summarize the events of mitosis and meiosis in animal and plant cells indicating differences and similarities in each.

b. Describe how independent assortment and crossing over can generate genetic variation among the products of meiosis.

c. Relate chromosome activity to Mendel’s laws of segregation and independent assortment.

d. Use models to illustrate mitosis and meiosis.
The Mitosis Lesson Itself

1. Engage- Students will draw and describe different stages of mitosis from a prepared slide of an onion root tip. At this point, students should have understanding/knowledge of chromosome structure, number in different organisms, and location within the cell. Students should be aware that they are looking at chromosomes within cells and their purpose is to look for different stages of chromosome location/movement. Students will then watch a short video clip regarding mitosis. During the video, the students’ job is to name their drawings according to the different descriptions in the video and add more descriptions to their drawings.

2. Explore- Students will summarize their pictures and model the stages of mitosis describing each stage. There are different kits for mitosis and meiosis where beads can be used to model chromosomes. Other options are using pipe cleaners, yarn, or clay to model chromosomes. Model Meiosis using Exercise 3B: Meiosis from the AP Biology Lab Manual (College Board, 2001, p. 35-40) or any other preferred meiosis modeling lab. Teacher should monitor.
students modeling each stage. While students are modeling meiosis, they should start relating how these events were similar to what they drew about mitosis and what the differences were. Students will watch a video on meiosis.

3. Explain- Students will summarize both mitosis and meiosis and their importance in life and indicate the big differences between each. Share the summaries with the class. Also students will determine how meiosis I and II differ and how are they similar. Students will complete a table of similarities and differences between mitosis and meiosis; have the students come up with as many differences and similarities as they can. Similarities and differences of mitosis and meiosis can include: purpose/function, number of divisions, number of DNA replications, chromosome number of parent and daughter cells, and number of daughter cells produced, (College Board, 2001). This is the stage where the teacher clarifies confusion and will fill in the gaps that students might have missed while modeling the stages and introduce vocabulary pertaining to the topic by lecturing when necessary. Making a table and talking about each stage will be
helpful in recording students' explanations and clarify any misconceptions. Ask questions like: How does crossing over in meiosis affect chromosome information? Why is mitosis and meiosis important? Differentiate between meiosis and mitosis.

4. Elaborate- Give students Mendel's law of segregation and have students demonstrate how these laws can be illustrated by the process of meiosis using their models.

5. Evaluate- Students will reflect on what they learned about mitosis and meiosis and how it is important to life. Ask: What do you think might happen if something went wrong during mitosis? Meiosis? Explain. This question can lead to talking about mutations and chromosomal disorders and lead to further explorations. Use a rubric like to assess student understanding of objectives (see Table 4, CHAPTER 4 for a sample scoring rubric).
### Table 6: Comparison of Traditional Lesson versus Inquiry Lesson on Mitosis and Meiosis.

<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E's with Criteria used to change from Traditional to Inquiry</th>
<th>Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are given a lecture on the mitosis and meiosis; Students are not engaged</td>
<td>Engage- students interact with material (criterion one)</td>
<td>Students will use the microscope to look and draw mitosis in an onion root tip; They will watch a short video clip covering mitosis; Teacher asks probing questions in both situations</td>
</tr>
<tr>
<td>Students carry out the Lab on Mitosis and Meiosis from the AP Biology Lab Manual</td>
<td>Explore</td>
<td>Students model the stages of meiosis paying attention to specific events in each; they can also carry out the Lab on Mitosis and Meiosis from the AP Biology Lab Manual. Teacher questioning of student is important</td>
</tr>
<tr>
<td>Students Answer written questions from the lab; Students make a T-chart stating the differences of meiosis and mitosis after teacher explains the information. Students do not provide their own explanations.</td>
<td>Explain- students will provide their own explanations (criterion two)</td>
<td>Students explain and discuss their results within their groups and make a T-chart stating the differences of meiosis and mitosis; Students will watch a meiosis video. The teacher elaborates on the topic and there is discussion between teacher and students</td>
</tr>
<tr>
<td>Some questions from the lab/quiz are application questions</td>
<td>Elaborate</td>
<td>Students figure out how and why Mendel’s laws of independent assortment and segregation can be illustrated by meiosis</td>
</tr>
<tr>
<td>Students take a quiz using the microscope slides and short answer format; Students do not stop to think what they understood and what they did not; no metacognition</td>
<td>Evaluate- Students will practice metacognition (criterion three)</td>
<td>Students reflect on what they understood and what they did not and determine how these processes are important to life. They were asked questions can lead to further explorations.</td>
</tr>
</tbody>
</table>
Physiology of the Circulatory System

Traditional Lesson Plan

Topic: Circulatory System

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standard:

Physiology, 9a: Students know how complementary activity of major body systems provides cells with oxygen and nutrients and removes toxic waste products such as carbon dioxide.

Objectives:

a. Students will trace the movement of blood to and away from the heart.

b. Students will compare and contrast the human circulatory system to another organism’s circulatory system.

c. Students will compare and contrast systolic and diastolic pressure.

d. Students will know how to use a sphygmomanometer.

f. Students will measure blood pressure and heart rate.

e. Students will know how temperature affects heart rate.

Materials:

PowerPoint Lecture on the circulatory system, See materials list in the Teacher’s guide for AP Biology
Lab Manual for the Lab on Physiology of the Circulatory System.

Activities or Procedures:

The teacher will give a short explanation of Lab 10: Physiology of the Circulatory system from the AP Biology Lab Manual (College Board, 2001, p. 109-124) so students can complete it. Students will answer the questions after each exercise. Then have students ask any questions that they have. This will lead into lecture that is more detailed discussing the anatomy and physiology of the human circulatory system and other organism's circulatory system.

Assessment:

Students will have a quiz regarding the circulatory system both from their lecture and lab. Students should also research diseases or disorders that can affect blood pressure and present it to the class.
Physiology of the Circulatory System:
Focus on Blood Pressure
Inquiry Lesson Plan

Grade level: 9-12, Subject: Biology, AP Biology

California Science Education Standard:
Physiology, 9a: Students know how complementary activity of major body systems provides cells with oxygen and nutrients and removes toxic waste products such as carbon dioxide.

National Science Education Standard:
Science as Inquiry Content Standard A: As a result of their activities in grades 9-12, all students should develop abilities necessary to do scientific inquiry. Design and conduct scientific investigations. Formulate and revise scientific explanations and models using logic and evidence. Recognize and analyze alternative explanations and models.

Objectives:

a. Students will compare and contrast systolic and diastolic pressure
b. Students will know how to use a sphygmomanometer.
c. Students will measure blood pressure.
d. Students will design an experiment to determine if blood pressure is different at different bodily positions.

The Blood Pressure Lesson Itself

1. Engage- In pairs of two, students will take their blood pressure using a sphygmomanometer and stethoscope. The teacher should demonstrate how to use this equipment and to focus on sounds to look for while listening through the stethoscope. Questions that the teacher might ask: What are the two sounds they hear? What do you think they indicate? Have Students record and describe what they listen to. Lead students to indicate that they are the systolic and diastolic blood pressure. Have students research and find out which one is which from what they heard. What is the normal human blood pressure? After they figure this out, have students take their blood pressure again. Have them identify systolic and diastolic pressure. How did they know, which one is which?

2. Explore- Students will design an experiment that answers the following questions: Is blood pressure the same at different positions or activities? Yes
or No? How and why? Give students the liberty to choose the variables to test making sure they record everything and answer the question. Examples of possible comparisons: blood pressure while reclining or standing, exercising or sitting, laying down and sitting up.

3. Explain- Using all the information that the students gained from their exploration, students will explain through discussion with their groups and then with the class, the difference between systolic and diastolic. Students will determine some factors that make blood pressure rise or lower. Teacher can explain further the anatomy and physiology of heart.

4. Elaborate- Students will apply what they know about blood pressure in answering this prompt: How do certain diseases affect blood pressure? Why is high blood pressure a health concern? Allow them 1-2 periods to investigate and report to the class.

5. Evaluate- Students will reflect on what they did or did not understand about blood pressure. What else would they want to know? Teacher will use a rubric to assess student learning (see Table 4, CHAPTER 4 for a sample scoring rubric).
Table 7: Comparison of Traditional Lesson versus Inquiry Lesson on Physiology of the Circulatory System.

<table>
<thead>
<tr>
<th>Traditional</th>
<th>5E's with Criteria used to change from Traditional to Inquiry</th>
<th>Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are given a short explanation/lecture on how to do the lab of the</td>
<td>Engage- students interact with material (criterion one)</td>
<td>Students will take each other's blood pressure; Teacher helps out by asking probing questions in both situations</td>
</tr>
<tr>
<td>circulatory system; Students are not engaged at this moment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students carry out the lab on the circulatory system from the AP Biology</td>
<td>Explore</td>
<td>Students design their own experiment that involves testing blood pressure at different positions.</td>
</tr>
<tr>
<td>Lab Manual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher does the explaining in lecture; Students Answer written questions</td>
<td>Explain- students will provide their own explanations (criterion two)</td>
<td>Students explain and discuss the results from their experiment and explain the difference between systolic and diastolic; The teacher elaborates on the topic</td>
</tr>
<tr>
<td>from the lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some questions from the lab/quiz are application questions; Students</td>
<td>Elaborate</td>
<td>Students answer prompt and are given time to research and report on how certain diseases affect blood pressure and why high blood pressure is a health concern; These questions extend the knowledge of the topic.</td>
</tr>
<tr>
<td>research diseases or disorders that can affect blood pressure and present</td>
<td></td>
<td></td>
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<tr>
<td>it to the class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students research diseases or disorders that can affect blood pressure and</td>
<td>Evaluate- Students will practice metacognition (criterion three)</td>
<td>Students reflect on what they understood and what they still had questions on; Teacher asks questions to evaluate their learning.</td>
</tr>
<tr>
<td>present it to the class; Students take quiz; No metacognition, students do</td>
<td></td>
<td></td>
</tr>
<tr>
<td>not stop to think what they understood and what they did not</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES


