THE CLEM MODEL: PATH ANALYSIS OF THE MEDIATING EFFECTS OF ATTITUDES
AND MOTIVATIONAL BELIEFS ON THE RELATIONSHIP BETWEEN PERCEIVED
LEARNING ENVIRONMENT AND COURSE PERFORMANCE IN AN
UNDERGRADUATE NONMAJOR BIOLOGY COURSE

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ABSTRACT

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The problem addressed in this study stems from three crises currently faced by post-secondary science educators in the United States: relatively low scientific literacy among students entering college, the need for more students to pursue science related careers, and poor attitudes among students toward studying science. In this dissertation the following questions are addressed: Is there a relationship between students' perceptions of their learning environment and course performance, and what roles do motivation and attitudes play in mediating that relationship? This study also examines the effects of gender and ethnicity on motivation, attitudes, and course performance. The purpose of this study is to test a path model describing the mediating effects of motivation and attitudes on constructivist learning environments and course performance. The following study considers contemporary understanding of teaching and learning as well as motivation and attitudes to suggest a direction for future reform efforts and to guide post-secondary science education instructors and leaders in the design of constructivist learning environments for undergraduate nonmajor biology courses.

This study concludes that, although the classroom learning environment has a small direct effect on course performance, there is a moderate total effect on self-efficacy and intrinsic goal orientation. The classroom learning environment also had a moderate indirect effect on attitudes toward biology. Furthermore, attitudes have a moderate direct effect on course performance and self-efficacy has a strong direct effect on both course performance and attitudes toward biology. Self-efficacy seems to be particularly important; however, each of these constructs is important in its own right and instructors in higher education should strive to

enhance each of them among their students. If students are to learn using constructivist methods they need the proper motivation and positive attitudes to encourage them to prepare for class and to participate in class activities.

Faculty may be viewed as students of pedagogy and leaders should model best practices and provide support for reform-based motivation-minded introductory biology courses. By enhancing attitudes and motivation of both faculty and students, the recommendations from this study may be a step forward in addressing some of the critical problems faced by leaders and educators in postsecondary science.

This dissertation is dedicated to my parents, Dr. Ronald L. Partin and Janet E. Partin, and to my
brother Brett M. Partin.

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CHAPTER I. INTRODUCTION

Overview

The problem to be addressed in this study stems from three crises currently faced by post-secondary science educators in the United States: relatively low scientific literacy among students entering college (AAAS, 1990; Beatty, 1997; Campbell et al., 1997, Governor's Commission on Higher Education and the Economy, 2006; Ohio Board of Regents, 2006), the need for more students to pursue science related careers (Daempfle, 2004; Montgomery, 2005; Ohio Board of Regents, 2006), and poor attitudes toward studying science among students (Osborne, Simon, & Collins, 2003). So, how do we improve science education at the post secondary level? If the problem is motivating students to study science and to increase their attitudes toward studying science, the question becomes: can instructors use the design of their learning environment to increase (a) motivation for better course performance and (b) attitudes toward studying science? In this dissertation the following question will be addressed: Is there a relationship between students' perceptions of their learning environment and course performance, and what roles do motivation and attitudes play in mediating that relationship? The purpose of this dissertation is to test a path model describing the mediating effects of motivation and attitudes on constructivist learning environments and course performance. The following dissertation considers contemporary understanding of teaching and learning as well as motivation and attitudes to suggest a direction for future reform efforts and to guide post-secondary science education leaders in the design of learning environments for undergraduate nonmajors.

Introduction to the Problem

The National Commission on Mathematics and Science Teaching for the 21st Century

(Department of Education, Washington, DC, 2000) was a national year-long commission, chaired by former senator and astronaut John Glenn, and charged with the task of developing a strategy to improve mathematics and science teaching in all United States K-12 classrooms. Based on recent reports such as the Third International Mathematics and Science Study (Beatty, 1997) and the National Assessment of Educational Progress (Campbell et al., 1997), the Commission expressed concern with declining performance in science classes in the United States in the face of a contemporary society that requires a high level of scientific literacy. The report stated that American students must raise math and science performance to succeed in the modern world and to ensure the United States stays competitive in an integrated global economy. The Commission also warned of a potential mathematics and science teacher shortage in the near future and recommended a significant increase in the number of teachers in these disciplines and an improvement in their preparation at the post-secondary level. The report emphasized that sweeping changes are necessary for crucial reform in mathematics and science education. America's poor science performance problem has been vigorously defined and studied by educational researchers at the K-12 level; however, there are concerns about the state of science education at the post secondary level as well (see, e.g., AAAS, 1990).

Of special interest to science educators at the post-secondary level is attracting students into college science courses, motivating students to pursue science majors, and retaining science majors (see Daempfle, 2004). Unfortunately, as students in the United States and Europe progress through school their attitudes toward science classes drop significantly by the end of high school and into college (Osborne, Simon, & Collins, 2003). This decline in attitudes has been attributed to the traditional "lecture style" or instructor-centered teaching commonly found in highest-level science classes (Osborne, Simon, & Collins, 2003). In fact, an unsettling exodus

of undergraduates from science to non-science majors in the United States has also been partially attributed to the instructor-centered teaching typically found in undergraduate science classes (Daempfle, 2004; Montgomery, 2005) as well as an unpleasant and competitive learning environment (Daempfle, 2004).

A report by the American Association for the Advancement of Science (AAAS, 1990) called *The Liberal Arts of Science: Agenda for Action*, recommended radical reform in science curricula and instruction from preschool through university level, especially in the undergraduate natural sciences curricula. Many other recent studies also suggest a need for reform at the undergraduate level (Apedoe & Reeves, 2006; Druger & Dick, 2004; French et al., 2007; Hanuscin, Akerson, & Phillipson-Mower, 2006; McLean & Van Wyk, 2006; Wainwright, Morrell, Flick, Schepige, 2004; Walczyk, Ramsey, & Zha, 2007; Yager, Kaya, & Dogan, 2007). These studies recommend that faculty move away from lecture courses in favor of active learning, or inquiry-based constructivist courses.

The scientific research society, Sigma Xi (Sigma Xi, The Scientific Research Society, 1989), asserts that entry-level higher education courses are key factors that will decide the fate for science in the future of the United States. Sigma Xi feels that these courses have the greatest impact on students' understandings of science and the greatest influence on attracting undergraduates to science related careers. A literature review by Gottfried et al. (1993) also recommended the review and reconceptualization of the undergraduate science curriculum, with particular focus on introductory courses. They proposed a large research agenda, which included examining instructional strategies as well as the characteristics of student/faculty interactions that promote positive attitudes toward science and students' understanding of the nature of science.

The National Association of Biology Teachers (NABT) formed the Standards in College Biology Teaching Committee in 1989. The committee of association members was composed of two and four-year college level teachers and one high school teacher. The purpose of the committee was to study college biology teaching issues and develop recommendations for teaching and learning (Gottfried et al., 1993). Their preliminary literature search centered on the “seven fundamental topics” described in a national advisory report by the scientific research society Sigma Xi (Sigma Xi, 1989). Gottfried et al. (1993) explain that the committee was quite surprised to find very little research specifically regarding college biology teaching, so they proceeded to organize the existing college biology teaching literature into four categories: perceptions and attitudes, curriculum and instruction, women and minorities, and the physical environment. They concluded that further studies are needed (a) to build a larger body of knowledge to assist researchers, educators, administrators, and policy makers as they make crucial decisions regarding college biology reform and (b) to ultimately increase the number of graduating biologists (Gottfried et al., 1993). It is clear to see that educators and policy makers have been calling for reform in the sciences at the post-secondary level for the past two decades, but very little has changed in practice. Today, despite recent efforts by the National Research Council (Brandsford, Brown, & Cocking, 2000) and others to promote science education reform at the post-secondary level, the traditional lecture style of teaching is still the most common format found in large introductory science courses (Daempfle, 2004), and the results are the same: low scientific literacy and insufficient numbers of students pursuing the sciences.

Rationale

The United States is interested in not only increasing the number of science majors and graduating scientists but also increasing the scientific literacy of all students. Scientific literacy

may be defined as the knowledge and understanding of the scientific processes and concepts required for individual decision making, partaking in civic and cultural matters, and economic productivity (National Academy of Sciences, 1996). A key component of scientific literacy is an adequate understanding of the nature of science (NOS) (AAAS, 1990). The nature of science refers to the way in which scientific knowledge is acquired and reviewed. The goal of helping students achieve sufficient understanding of the NOS has been commonly agreed upon and stated by scientists and science educators for the past 85 years (Abd-El-Khalick & Lederman, 2000).

Today's students must obtain the scientific knowledge, skills and mindsets needed to become productive members of the contemporary global society (AAAS, 1990; National Research Council [NRC], 1996). According to a recent 2006 Mathematics and Science Education Policy Advisory Council document (Ohio Board of Regents, 2006) "United States' and Ohio's high school students are among the lowest performing in science and mathematics achievement among the world's developed nations" (p. 1). The report also explains that the United States is falling short in the production of graduate level mathematicians, engineers, and scientists. In fact, it is estimated that by the year 2010, more than 90 percent of all scientists and engineers on Earth will be living in Asia. To address these concerns, The Ohio Board of Regents (Ohio Board of Regents, 2007) policy guide explains that since the start of 2006, both the President of the United States and the Ohio Governor have championed the importance of Science, Technology, Engineering, and Mathematics (STEM) fields to improve the competitiveness of the United States and Ohio. The report goes on to explain that in order to be competitive in the 21st century workforce, more students "need an understanding of the kinds of information needed for particular projects, knowledge about where good information might be

found, and an ability to assess the quality of information” (p. 44) and “students need to develop flexible and cross-functional skills in problem solving, communication, and analytical thinking” (p. 44). In an April, 2006 update by the Ohio Governor’s Commission on Higher Education and the Economy (CHEE) (Governor’s Commission on Higher Education and the Economy, 2006), Recommendation three is to “Increase the number and proportion of Ohioans with mathematics and science knowledge skills, and degrees” (p. 3). This is the type of knowledge or scientific literacy expected to be gained in an undergraduate introductory science class.

Introductory Science Courses

In higher education, introductory science courses have a vital function addressing several important goals (Lawrenz, Huffman, & Appeldoorn, 2005). One goal is to provide science majors with the initial college experiences in the area of study in which they hope to focus their future careers. Both majors and nonmajors introductory courses need to provide a strong foundation for additional science coursework. Secondly, introductory science courses are often required to meet liberal education requirements for students majoring in non-science fields. Science majors could be potentially recruited from these courses. These introductory courses should be motivating, offer insight into the science culture, and cultivate scientific literacy (Lawrenz, Huffman, & Appeldoorn, 2005). A third function of introductory science courses is to give pre-service science teachers the content and the skills in science thinking they will need to provide appropriate education for their future students. Because teachers often teach as they have been taught (Thomas & Pedersen, 2003), it is important that instructors of introductory science courses model best practices techniques (Saunders et al., 2003). However, if introductory science courses are to meet the needs described above, they need to operate within ideal institutional and classroom environments (Lawrenz, Huffman, & Appeldoorn, 2005).

Institutional environment includes the supportive climate and incentives established by higher education administrators. If the institutional environment is not supportive of innovative teaching practices, it may constrain what occurs in classrooms. Institutions should appreciate good pedagogy, provide support for improvements, encourage shared professional communities, and present very few barriers to best practices instruction (Lawrenz, Huffman, & Appledoorn, 2005). Currently, among colleges and universities in the United States, teaching is valued and supported to some degree, but barriers do exist to teaching (Lawrenz, Huffman, & Appledoorn, 2005). Barriers include the enormous amount of work required of faculty unrelated to teaching; and budget reduction, which results in large class sizes and lack of materials or equipment and resort to lecture style teaching (Lawrenz, Huffman, & Appledoorn, 2005).

The 1996 National Research Council report, *Bio2010: Transforming Undergraduate Education for Future Research Biologists*, recommends undergraduate biology education reform involving interdisciplinary problem solving with a focus on research. However, the report warns that university administrators must provide support for change to occur. For example, cross-departmental barriers to collaboration must be reduced and faculty must be provided with time, encouragement, and resources to develop new approaches and corresponding assessment techniques to help students achieve appropriate learning goals (Brenner, 2003).

The classroom learning environment may be described as the format of the course and how it affects the development of the student. The learning environment contributes significantly to student perceptions and outcomes such as course performance (Fraser & Wallberg, 2005; Fraser & Kahle, 2007). Classes that are viewed as motivating, challenging, cohesive, and goal directed typically have more positive student outcomes such as course performance and attitudes (Fraser & Wallberg, 2005; Seymour & Hewitt, 2000).

Constructivism

Constructivism is a concept often mentioned when discussing science classroom-learning environments. In fact, much of the current science education research and literature has focused on constructivism. Constructivism is a philosophy about how people learn, and specifically addresses how knowledge is acquired and constructed. More specifically, “according to the constructivist view, meaningful learning is a cognitive process in which individuals make sense of the world in relation to the knowledge which they already have constructed, and this sense-making process involves active negotiation and consensus building” (Fraser, 1998, p. 13). Science educators may agree that constructivism is ideally more desirable over more traditional methods of instruction, such as direct instruction; however, many debate exactly how knowledge is built. The two primary descriptions of constructivism derive from Jean Piaget’s (1954) theory of cognitive development and Lev Vygotsky’s (1978) social constructivism. Cognitive constructivism focuses on internal cognitive processes (Piaget, 1954) and an individual’s attempts to make sense of the world (Von Glasersfeld, 1995), whereas social constructivism stresses the significance of society, culture, and language (Lemke, 2001), where knowledge is socially constructed and acquired in specific social and cultural contexts. Despite their differences, both branches of constructivist thought stress the importance of experiential learning and acknowledge that motivation is crucial for the construction of knowledge and the progression of conceptual change. The literature contains many testimonials and experimental research studies that support the idea that meaningful learning is tied to experience (Angelo, 1990; Bodner 1986; Bybee, 1993; Caprio 1994; Lawson 1990, 1992, 1993; Leonard, 1989a, 1989b; Lord, 1994; Lorsch & Tobin 1995; Roth, 1994; Seymour, 1995). The National Research Council’s 1999 Report, *How People Learn* (Brandsford, Brown, & Cocking, 2000), is also in

concert with the constructivist view and suggests *inquiry-based learning* as a way to have students doing real scientific investigations similar to the way in which practicing scientists define problems, formulate and test hypotheses, and draw conclusions. Inquiry-based learning has many nonscience classroom applications as well.

One instrument used to assess classroom environment perceptions is the Constructivist Learning Environment Survey (CLES) (Nix et al., 2005; Taylor et al., 1994). Fraser (1998) explains that “the CLES was developed to assist researchers and teachers to assess the degree to which a particular classroom’s environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice” (p. 13). The CLES may be used to assess student’s perceptions of their learning environment on five scales. The five scales that make up the CLES are (a) *personal relevance*: relevance of learning to students lives; (b) *uncertainty of science*: provisional status of scientific knowledge; (c) *critical voice*: legitimacy of expressing a critical opinion; (d) *shared control*: participation in planning, conducting and assessing of learning; and (e) *student negotiation*: involvement with other students in assessing viability of new ideas. The CLES will be used in this study and provide the only exogenous variable in the hypothesized path model.

Currently there are many models of constructivist learning (e.g., Glasson & Lalik, 1993; Hewson & Tabachnick, 1999; Nussbaum & Novick, 1982). However, David Palmer (2005) examined the extent to which motivational strategies have been considered in the design of existing constructivist informed teaching models and found that existing models were inadequate in explicitly integrating motivation. Palmer also found that some models, in fact, conflict with the currently accepted views of motivation. Chapter II will discuss this further.

Motivation, Attitudes, and Autonomy

For the past 40 years, the science education research community has spent a great deal of effort examining students' attitudes toward studying science at the K-12 level. However, there is little research examining college students' motivation to achieve in their science courses. This body of knowledge has become increasingly important as both the demand for college students pursuing scientific careers and the need for a scientifically literate society has increased (Gore, 2007, 2008). British researchers Jonathan Osborne, Shirley Simon, and Sue Collins (2003) conducted a recent literature review of research on students' attitudes toward science and recommended that educators increase students' personal autonomy. Personal autonomy refers to students' desires to be self-governing and involved in their lessons. The value of a student's personal autonomy is tied to the value that student places on participating in the lesson.

A study conducted by Black and Deci (2000) with college level organic chemistry students revealed that students' perceptions of a more autonomy-supportive instructor predicted increases in autonomous self-regulation, higher perceived competence, and higher interest in the course. According to Schunk and Zimmerman (1997) self-regulation refers to "planning and managing time; attending to and concentrating on instruction; organizing, rehearsing, and coding information strategically; establishing a productive environment; and using social resources effectively" (p. 195). Students in the Black and Deci study also reported decreases in anxiety over the semester. The resulting change in students' autonomous self-regulation was successfully used to predict students' performance in the course. Furthermore, instructor autonomy support directly predicted student performance for students who reported initially low levels of autonomous self-regulation. Instructor autonomy support also predicted student performance when controlling for student ability. The course performance variable was measured as the final

grade received in the course.

Black and Deci (2000) describe autonomy support as the level of self-determination a teacher allows a student so the student may attach his or her behavior to personal goals, interests, and values. The opposite of an autonomy-supportive environment is a controlling environment, where leaders or teachers use coercion and other external rewards, pressures, and controls. While it seems that autonomy-supportive classrooms are beneficial for student motivation, the body of literature on the subject is not entirely clear on what an autonomy-supportive science classroom should look like, particularly at the post-secondary level. Furthermore, there seems to be a natural connection between self-determination theory and constructivist thought, but the connections have not been clearly delineated. However, inquiry-based courses are not always an autonomous experience for the learners.

Osborne et al. (2003) maintain that attitudes and motivation are closely linked and conclude that science educators interested in increasing students' attitudes toward studying science should draw from the large body of literature on the study of motivation. Osborne et al. were also surprised by the deficient body of knowledge dealing with science teaching and learning that engages students and stressed that there is "hardly a more urgent agenda for research" (p. 1074). While addressing specific misconceptions held by nonmajor biology students may be an urgent topic of discussion, student motivation and attitudes must be addressed as well. A well-designed biology curriculum will be ineffective if students do not exert the effort to prepare for class and learn the material. Therefore, motivation must come before learning.

Albert Bandura (2006) viewed motivation in terms of an individual's perceived level of competence. Proponents of self-efficacy believe that an individual high in self-efficacy for a task

will tend to persist at the task until the task has been successfully completed, whereas an individual low in self-efficacy for a task will tend to give up quickly after experiencing difficulty with the task or make no effort at all. Self-efficacy has been shown to be a better predictor of academic achievement than standardized test scores (Zusho et al., 2003).

Summary

There is clearly a need for reform in the natural sciences at the post-secondary level (Seymour & Hewitt, 2000), as indicated by researchers, educators, and policymakers across the United States. Introductory level courses are a logical focal point because they are positioned to make a relatively large impact on the general populace. The type of reform frequently discussed is a shift toward a constructivist learning environment including inquiry-based experiences. However, if students are to learn in a constructivist classroom, they must be motivated to participate in class and to spend time out of class preparing. Another related factor is the level of student autonomy afforded by a particular learning environment. Students who feel their learning is self-determined may have more positive attitudes toward studying in a particular class.

In order for reform to become a reality, change must begin at the institutional level to reduce current barriers and to provide encouraging incentives for faculty to implement the needed changes within their classrooms. To gain institutional support, administrators and faculty must have information about the current state of their introductory classes and a deep understanding of the expected outcomes when specific changes are made. The relationships between the learning environment, motivation, attitudes, and course performance may give insight into an understanding of students' perceptions of their current learning environment and how it impacts students' desires to persist, participate, and perform in their classes. This type of understanding may shed some light on the types of curricular and instructional changes that will

be effective when implemented in an undergraduate nonmajor biology course.

Purpose of the Study

The purpose of this study is to test the Constructivist Learning Environment and Motivation (CLEM) model (see Figure 1). The CLEM model is a mediated model that explains the causal relationships among aspects of the learning environment as defined from a constructivist perspective (shared control, student negotiation, personal relevance, critical voice, and uncertainty of science; depicted as *CLES_TOTAL* in Figure 1), motivation constructs (intrinsic goal orientation and self-efficacy for learning and performance), attitudes toward biology, and course performance in a large undergraduate biology course for nonmajors. No other educational researcher has previously included these particular variables into a single model. The CLEM model has incorporated the ideas of Bandura's (Bandura et al., 1977) Self-Efficacy Theory, Fraser and Wallberg's (2005) view of the constructivist-learning environment, Dorman and Adams' (2004) views on the relationships between classroom environment, academic efficacy, and grades, Palmer's (2005) ideas of incorporating motivation and constructivism, Osborne, Simon, and Collins' (2003) views on attitudes toward science and motivation, and Deci and Ryan's (1985) views on Self-Determination Theory and intrinsic motivation. The CLEM model was created by the author of this dissertation and will be assessed by path analysis.

This dissertation will address the following central question: Is there a relationship between students' perceptions of their learning environment and course performance among nonmajor biology students, and what roles do motivation and attitudes play in mediating that relationship?

The secondary purpose of this study is to examine the influence of demographics

(ethnicity and gender) on perception of learning environment, attitudes towards biology, self-efficacy for learning and students' performance, intrinsic goal orientation, and course performance in a large undergraduate biology course for nonmajors. These will be compared with analysis of variance.

Variables were measured by administering three Likert-style surveys with demographic questions to approximately 450 introductory biology students at a mid-western state university during the final week of the 2007 fall semester. Final lecture grades will be acquired from their professors after the semester is completed. The data for this study were acquired as an existing dataset collected by an educational research group.

Figure 1. The Constructivist Learning Environment and Motivation (CLEM) Model.

Research Questions

In this study, the following research questions were addressed in an undergraduate nonmajor biology course:

- 1) Does the Constructivist Learning Environment Survey (CLES), a multi-dimensional assessment of classroom learning environment, directly predict course performance, self-efficacy, intrinsic goal orientation, or attitudes towards biology?
- 2) Does the Constructivist Learning Environment Survey (CLES), self-efficacy, intrinsic goal orientation, attitudes toward biology, or course performance significantly vary by ethnicity or gender?
- 3) Does self-efficacy, intrinsic goal orientation, or attitudes toward biology directly predict course performance?
- 4) Is the proposed CLEM model — which describes the causal effects among the variables perception of learning environment (CLES), attitudes toward biology, intrinsic goal orientation, self-efficacy for learning and performance, and course performance — consistent with observed correlations among these variables?

Significance of the Study

Colleges and universities must make fundamental decisions on how to address radical reform recommendations in their introductory natural science courses to produce more scientists and science teachers, to help students be successful in the classroom, and to improve general scientific literacy in the United States. This study will help leaders in science education produce more graduating scientists and science teachers by attracting and retaining more students who find their introductory level biology classes both exciting and relevant to their lives and therefore choose to pursue biology related careers. Inspired teachers may go on to instill their own

excitement for biology into the minds of their future students. By presenting biology courses in a favorable or optimal atmosphere, universities may also produce more scientifically literate non-science majors who will surely vote on issues related to the life sciences (e.g., stem cell research, genetic engineering, xenotransplantation, DNA related issues) sometime throughout their lives. This may be the result of students who have greater motivation to achieve in their biology courses. Finally, this study may address methods of producing more life long autonomous learners of the biological sciences who will seek out and understand science related articles in the popular press and media. Ultimately, this study may help identify factors that impact college science student motivation, attitudes, and grades, which may contribute to a more scientifically literate society.

Definitions of Terms

Academic Achievement

Academic achievement is the measure or evaluation of a student's performance at the conclusion of a course (Lazarowitz et al., 1988).

Attitude

Attitude is a psychology concept in which views on an "attitude object" are expressed as positive, negative or neutral (Eiser, Shook, & Fazio, 2007). An attitude object may be a person, behavior or event. In this study it is biology. It is possible to possess both positive and negative attitudes toward an attitude object. However, attitude will be measured on a single continuum in this study using the Biology Attitude Scale (Russell & Hollander, 1975).

Androgogy

Androgogy is the art or science of teaching adults (Kaufman, 2003). Many do not recognize the distinction between androgogy (teaching of adults) and pedagogy (teaching of

children) and simply use pedagogy to describe the art or science of teaching.

Autonomy-Support

Within self-determination theory in psychology, autonomy refers to autonomy support versus control. Autonomy-supportive social situations tend to encourage self-determined motivation, healthy development, and optimal functioning (Deci & Ryan, 2000).

Constructivism

Constructivism is a theory about the character of human learning and the way in which new knowledge is built on preexisting knowledge. Constructivism advocates developmentally appropriate teacher-supported learning that puts students at the center of the learning process through first hand experiences or discussion (Bransford, Brown, & Cocking, 2000).

Course Performance

How well a student performs in an academic course. In this study, course performance will be measured as students' final course grades.

Intrinsic Goal Orientation

Intrinsic motivation is mirrored in behavior engaged in for its own sake, and the pleasure and satisfaction resulting from involvement (Deci & Ryan, 1985). In this study, intrinsic goal orientation refers to students studying biology for its own sake.

Motivation

In psychology, motivation means the initiation, direction, intensity and persistence of behavior (Geen, 1994). Motivation is having the support and desire to do something.

Pedagogy

Pedagogy is the art or science of teaching children (Kaufman, 2003). Many do not recognize the distinction between androgogy (teaching of adults) and pedagogy (teaching of

children) and simply use pedagogy to describe the art or science of teaching.

Self-Efficacy

Self-efficacy is an individual's level of perceived competence in a task (Bandura *et al.*, 1977). Self-efficacy is made up of two components, *efficacy expectation* and *response-outcome expectancy*. Efficacy expectation is an individual's belief about whether they are able to perform an action. Response-outcome is an individual's belief about whether the performed action will produce the desired outcome. An individual may have high self-efficacy for some tasks and low self-efficacy for others. Proponents of self-efficacy believe that an individual high in self-efficacy for a task will tend to persist at the task until the task has been successfully completed, whereas an individual low in self-efficacy for a task will tend to give up quickly after experiencing difficulty with the task or make no effort at all. In this study self efficacy refers to students' self-efficacy for learning and performance.

Student Centered Instruction

Hancock et al. (1997) explain that student centered teaching makes the students the focus of each lesson as opposed to the teacher. Advocates believe that learning is most meaningful when topics are relevant to the students' lives, needs, and interests and when the students themselves are actively engaged in creating, understanding, and connecting to knowledge. It is believed that students will have higher motivation to learn when they feel they have options and a real stake in their own learning (Black & Deci, 2000). In educational psychology, a student centered environment where the teacher shows empathy for the students and offers the students opportunities for decision-making is referred to an *autonomy-supportive environment* (Black & Deci, 2000).

Teacher Centered Instruction

Teacher centered instruction refers to a teaching style with a high degree of teacher direction and center of focus. This is often referred to as traditional or lecture style teaching. In educational psychology, if the teacher also uses coercion or seduction to pressure the students to behave in a particular fashion this is referred to as a *controlling environment* (Black & Deci, 2000).

Organization of the Remaining Chapters

This proposal contains three chapters. Chapter II is a review of related literature. Chapter III will specifically describe the method of data collection and analysis used in this study. Chapter IV summarizes the results found in this study and Chapter V discusses the implications of the findings of this study and suggests future directions for research.

CHAPTER II. LITERATURE REVIEW

Introduction

Currently, science education is a topic of national interest and concern, particularly among the natural sciences at the post-secondary level. Two topics of concern are student attitudes and scientific literacy. A larger body of literature discussing the current understanding of nonmajor biology students is needed for policy makers, administrators, educational researchers, and instructors to make crucial decisions involving curriculum and instruction to address these concerns. This chapter presents a summary of the history of science education in the United States and literature related to learning environment, attitudes toward biology, motivation, and course performance. This chapter also discusses women and minorities as well as literature related to students understanding of the nature of science.

History of Science Education

Science education has a long history in the United States. Throughout the early 1900s science education in the U.S. was considered a low priority, except for “practical” topics such as health and hygiene (Scruggs & Mastropieri, 1992). However, in the late 1950s, the Soviet Union launched the Sputnik satellites and challenged the United States to regain scientific superiority. In response, a nation-wide reform in science education was put into motion, funded in part, by the National Science Foundation and federal and state science programs like the Eisenhower funds. The goal was for scientists and educators to design better science curriculum materials (Blough & Schwartz, 1990). These programs endorsed concept learning and developmental perspectives that “stressed the limitations of direct instruction” (Eylon & Linn, 1988). They favored activity based, inquiry-oriented science education which was actually implemented throughout the 1960s (Esler & Esler, 1989). However, science classes at this time were designed

for only the “best and the brightest” to succeed. The ultimate goal was to increase the number of scientists and to bolster technological advances.

By the mid-1970s, the United States launched the “back to basics” movement which led to the return of direct instruction. Since the late 1980s there has been a renewed interest in reform in science education due to the low international competitiveness of U.S. students in science, and the belief in Japan’s growing scientific and technological superiority (Blough & Schwartz, 1990). In 1983, the need for reform in classroom practices was brought to the attention of the U.S. public with the publication of “A Nation at Risk” (National Commission on Excellence in Education, 1983) and “Educating Americans for the 21st Century” (National Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983). Those documents claimed that competing in today’s global economic environment depended on a work force knowledgeable about the mathematical, scientific, and technological aspects of the emerging information age. The documents explained that schools in the United States were failing to prepare children to join a competitive world market.

Some researchers believed that the problem stemmed from a scientifically illiterate populace (National Commission on Excellence in Education, 1983). This belief was based on scores showing that precollege students were not doing well on standardized science tests (Education Commission of the States, 1983) and their teachers were not current on the latest ideas in science teaching and learning, and science topics. In response to the problem of a scientifically illiterate population, many believed that the science curriculum needed to be both minds-on and hands-on (Hurd, 1983), schools needed to be safe for students to learn (Martinolich, 1979), and public schools should be held accountable for student learning (Culyer, 1988).

The perceived failure to educate our students to the desired outcomes was viewed as a result of the traditional lecture style teaching commonly practiced in U.S. schools (Romberg, 1998). In a traditional classroom, students usually do not do rigorous or even simulated scientific investigations. As the recent Third International Mathematics and Science Study [TIMSS] (Beatty, 1997) documented, the traditional middle and secondary school curriculum, in contrast to those of other industrialized nations, is a “mile wide and an inch deep” and lacks coherence. Superficial coverage of a large number of ideas is the norm, and little is examined in depth. The results from TIMSS made it clear that traditional practices prevail in most middle and secondary school mathematics and science classrooms, and reinforce the claim that reforms in school math and science are needed (Romberg, 1998).

In an attempt to initiate reforms in science education, The American Association for the Advancement of Science (AAAS) developed Project 2061 (American Association for the Advancement of Science, 2005). This project was born from their initial effort, Science for All Americans (American Association for the Advancement of Science, 1989). This project specified the knowledge and skills that every high school graduate should possess. The National Research Council (NRC) has also recently distributed its “National Science Education Standards”. Its goal is to “create a vision for the scientifically literate person and standards for science education, that when established, would allow the vision to become a reality” (National Research Council, 1996). The NRC also set standards for science teaching, professional development for teachers, science assessment and evaluation, science content, school science programs, and science education systems. These reform efforts are meant to include every K-12 student in the United States, because it is believed that all students can learn quality science (Atwater & Brown, 1999).

Over the last twenty years the economy in the U.S. has changed from manufacturing and

industry based to focusing more on technology and information systems (Drummond, 1999).

This has led scientific advocacy groups such as the American Association for the Advancement of Science (AAAS), the National Science Foundation (NSF), and the National Academy of Sciences (NAS) to recognize the need for all students to become scientifically literate. They believe that the thinking processes historically used by scientists are highly critical to the responsibilities of all citizens trying to survive in a technologically advanced society (Leonard, 1997).

The Benchmarks for Science Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) have made a major contribution in identifying what understandings about science are essential for every person who graduates from high school. Being strong advocates of science, the AAAS and NRC have set some high goals for K-12 science education. Since goals are considered unrealistic and they are not being reached, many science educators and scientists believe that a more realistic goal would be to have high school graduates meet most of the standards and have college graduates meet all of the standards. This would be a major step forward in national scientific literacy (Leonard, 2000).

In 2002, George W. Bush reauthorized the Elementary and Secondary Education Act (ESEA) of 1965 under the popular name “No Child Left Behind” (NCLB). The new policy is in favor of standards-based reform and has mandated that states produce standards of competency for K-12 students and standards based assessments. States are also mandated to ensure that schools have “highly qualified teachers” teaching each of the core classes. NCLB also implemented a systems change, switching authority and resource allocation from the Eisenhower Professional Development Program to the Math and Science Partnership (MSP).

At the State level, the Ohio Governors Commission on Higher Education and the

Economy (CHEE) produced a report in 2004 (KnowledgeWorks Foundation, 2004) and an update in 2006 (Governors Commission on Higher Education and the Economy, 2006). The 2004 report recommended a system change creating the Joint Council between the Ohio board of Regents and Department of Education. The purpose is to ensure a pipeline of education from Kindergarten through college and beyond. The 2006 update explained that Senate Bill 6, signed in 2005, codified the *Partnership for Continued Learning*, Ohio's official P-16 Education Council. Also at the state level, the board of regents in Ohio has created Centers of Excellence in Math and Science in five Ohio regions. One such center is NWO in Northwest Ohio, made up of institutions of higher education including: Bowling Green State University (COSMOS), University of Toledo, Owens Community College, Lourdes College, and the University of Findlay. Other partners of the NWO Center include regional school districts, businesses, and community agencies. The center's mission is to address current issues in science and mathematics education.

College Science Learning-Retention

According to a 1990 University of California Berkeley learning-retention study, most college students only remember about 20% of what is presented in a traditional lecture several days after class (Angelo, 1990). Traditional lectures are a teacher-centered format where a professor does the majority of the talking, the students take notes, and the students are periodically tested over their notes. The traditionally taught college biology course typically covers a large number of topics at a relatively shallow depth. This is the format in which most undergraduate biology courses in the United States are taught (Angelo, 1990). The Berkeley learning-retention study concludes that the reason for such a low retention is that students spend most of their efforts taking notes instead of thinking about what is being discussed. They also

added that knowledge retention would increase if students studied their notes soon after the lesson, but few of them do. The study also mentions that in a typical classroom of undergraduates, fewer than 15% are paying attention to what is being presented at any one time during the class. However, this does not include the first eight minutes. During that time most students are attentive. The study suggests that students need to be actively thinking about what is being presented if they are to retain the information (Angelo, 1990). A truly interactive lecture, interactive group learning, or an experiential learning setting such as laboratory or fieldwork, provide opportunities for students to process, interpret, and internalize the concepts they experience. The literature contains many testimonials and experimental research studies, which support the idea that meaningful learning is tied to experience (Angelo 1990; Bodner 1986; Bybee 1993; Caprio 1994; Lawson et al., 1993; Leonard, 1989; Lord 1994; Lorsch & Tobin, 1995; Roth 1994; Seymour 1995).

The current educational system in the United States is based on the belief that students will learn on demand (Brooks & Brooks, 1999). This belief has led to the current educational standards and assessments that assume all students will learn the same material at the same time with the same level of understanding. Current teaching methods may lead to the construction of knowledge in some students, but not all. As explained by Brooks and Brooks (1999), current educational systems focus on high stakes accountability schemes, which cause teachers to push aside the true learning experiences in favor of rote memorization and specific details covered on exams. The emphasis on the memorization of specific details is at the expense of concept development and the nurturing of higher order thinking and questioning. Furthermore, students will not remember much of the material soon after they are tested on it. The current educational standards and assessments methods ignore what years of important research have told us about

student learning (Brooks & Brooks, 1999).

How People Learn

In December of 1998 the National Research Council released a report that combines the foremost research on human learning called *How People Learn: Brain, Mind, Experience and School* (Brandsford, Brown, & Cocking, 2000). Shortly afterwards the National Research Council released *How People Learn: Bridging Research and Practice* (Donovan, Brandsford, & Pellegrino, 1999). The 1999 follow-up report explored the types of research and development that could help incorporate the insights gained from the 1998 report into classroom practice and they proposed a future research agenda.

The committee members for the 1999 follow-up report (Donovan, Brandsford, & Pellegrino, 1999) focused on three findings from the 1998 report because they had a solid research base to support them and strong “implications for how the enterprise of education is conducted” (Donovan, Brandsford, & Pellegrino, 1999, p. 1). The first finding of focus was “Students come to the classroom with preconceptions about how the world works” (Donovan, Brandsford, & Pellegrino, 1999, p. 2). It is important for teachers to assess students’ prior knowledge and help shape an understanding that reflects the discipline’s current concepts and knowledge. The second finding of focus was “To develop competence in an area of learning, students must have both a deep foundation of factual knowledge and a strong conceptual framework” (Donovan, Brandsford, & Pellegrino, 1999, p. 2). The conceptual framework allows experts to organize knowledge into clusters that are much easier to retrieve for problem solving, and mastery of concepts facilitates learning to new problems. The third finding of focus was “Strategies can be taught that allow students to monitor their understanding and progress in problem solving” (Donovan, Brandsford, & Pellegrino, 1999, p. 2). This in fact is what experts

on any topic do. The strategies involved are part of a “culture of inquiry” that can be taught in the context of subject matter. Teachers may shape and discuss monitoring questions and observations in the classroom with the ultimate goal of training students to practice independent monitoring and learning.

The 1999 follow-up committee (Donovan, Brandsford, & Pellegrino, 1999) focused on research and development that could help bridge research and practice and produced five overarching goals to guide the design of a research agenda. The five goals are as follows (Donovan, Brandsford, & Pellegrino, 1999):

- Elaborate the messages in *How People Learn* at a level of detail that makes them usable to educators (including teacher educators) and policy makers.
- Communicate the messages in *How People Learn* in a manner that is effective for each of the audiences that influences educational practice.
- Use the principles of learning for understanding articulated in *How People Learn* as a lens through which to evaluate existing education practices (K-12 and teacher training programs) and policies.
- Conduct research in teams that combine the expertise of researchers and the wisdom of practitioners.
- Extend the frontier of learning research through more intensive study of classroom practice. (p. 3)

The original 1998 report (Brandsford, Brown, & Cocking, 2000) not only discussed the manner in which people learn, but it also discussed the design of classroom learning environments. The report concluded that the current body of research and understanding does not provide a recipe for designing effective learning environments, but it does help guide the design

and evaluation of learning environments that can optimize learning. The literature shows that learning environments must be student centered, knowledge centered, assessment centered, and community centered. *Student centered environments* encourage students to make connections between previous knowledge and their current academic engagements. This may be accomplished by providing students with shared control in the planning, conducting, and assessment of learning. *Knowledge centered environments* provide developmentally appropriate lessons that present well-organized knowledge that is accessible in appropriate contexts, which will in-turn encourage learning and problem solving. Knowledge centered environments teach meta-cognitive strategies that further facilitate future learning and focus on depth of knowledge rather than factual memory, as well as hands-on “doing with understanding”. *Assessment centered environments* use formative assessments that allow students opportunities to revise and improve their thinking, and help teachers identify misconceptions that need to be addressed. *Community centered environments* establish norms where students are not afraid to take academic risks and make mistakes. The classroom should promote intellectual camaraderie and positive attitudes toward learning that build a sense of community within the classroom and provide a sense of student negotiation where students are involved with assessing the viability of new ideas. Students should also build a critical voice where they may express critical opinions. These classrooms should also link classroom learning to other aspects of students’ lives to promote personal relevance. It is important to note that the design framework described above applies equally well to adult learners as children (Brandsford, Brown, & Cocking, 2000).

Another topic discussed in *How People Learn: Brain, Mind, Experience and School* (Brandsford, Brown, & Cocking, 2000) was motivation to learn. The amount of time that people are willing to devote to learning is affected by motivation. People will work hard for both

extrinsic rewards and punishments, but they will also work hard for intrinsic reasons. However, tasks must be assigned at the appropriate level. If they are too easy, student will lose interest and if they are too difficult, students will become frustrated. Successes achieved at the appropriate level, or zone of proximal development, provide the intrinsic motivation for further learning.

The report also explains that more highly motivated students are more persistent and persistence is strongly affected by whether students are “performance oriented” or “learning oriented”. If students are performance oriented in a particular discipline, they are more concerned about making errors than about learning. Students who are learning oriented enjoy new challenges. Currently, it is not known whether performance or learning orientations are stable traits, but it is suspected that they are not (Brandsford, Brown, & Cocking, 2000).

Another factor affecting motivation is social opportunities. Students are motivated when they feel they are contributing something to others. Furthermore, learners of all ages are more highly motivated when they understand the value of what they are learning and when they can use what they have learned to do something that has an impact on others, particularly in their local community (Brandsford, Brown, & Cocking, 2000).

Constructivism

Three major philosophies that have been studied recently to address improved teaching and learning in the sciences stem from the work of Jean Piaget (1954), David Ausubel (1963), and Lev Vygotsky (1978). The first, Ausubel’s theory of verbal learning, has focused attention on ways students acquire specific biology concepts. Ausubel is a psychologist who promoted a theory, which differentiated meaningful learning from rote learning. Ausubel argued that in order for meaningful learning to take place, students must link new knowledge to what they already know. He proposed an advance organizer as a way to facilitate the linking of ideas with new

material or concepts. Ausubel believed that during learning, new concepts are incorporated into more general concepts or ideas. These more general concepts or ideas are advance organizers and may be depicted as verbal phrases or graphic organizers, such as a concept map. The advance organizer provides the mental scaffolding to learn the new information.

The second major philosophy that has been studied recently to address improved teaching and learning in the sciences is Piaget's (1954) cognitive developmental theory, which focused attention on ways students acquire and use general scientific reasoning patterns. Piaget explained that new knowledge was *assimilated* into the current internal cognitive structures. Piaget defined assimilation as "the integration of any sort of reality into a structure" (Piaget, 2003, p. S17). In assimilation, the general understanding of something, or *schema*, does not necessarily need to change. However, the learner must fit new information into their preexisting schemas.

Accommodation occurs when prior knowledge conflicts with the new information. During accommodation, the schema must change. The process of balancing the new and old information with their view of the external world into a schema that makes logical sense to the learner is called equilibration. Equilibration is the "elimination of incompatibilities" (Piaget, 2003, p. S17). For example, a student knows how to measure a flat piece of paper with a ruler in inches. She has full mastery of that schema. When she is asked to measure a new flat object, such as a book, she transfers this old schema to the new object. This is called assimilation. When the student is asked to measure a third object, such as the circumference of a ball, she may try her old schema with poor results. The old schema will adapt and the student may wrap a string around the ball and then measure the string to produce a new schema. This is called accommodation, specifically accommodating an old schema to a new object. Finally, this new schema may be assimilated to measure the circumference of a fourth object, such as a cylinder.

During childhood, children think at a concrete operational level. This means that to optimize learning, developmentally appropriate lessons should include concrete examples and objects to explore (Piaget, 1954). One example is “discovery learning”, where children are allowed to explore a topic or problem on their own before receiving instruction. Students should also be encouraged to classify and sort information into groups. During adolescence, student may reach formal operational thinking. It is believed that about 30-35% of high school students are thinking at this level (Piaget, 1954). Students at this level are better equipped to think about complex information in the abstract. To optimize learning, students should be encouraged to talk out their reasoning and explanations. This is the level that carries on through adulthood. Piaget believed that people gain more complex schemas as they gain more knowledge throughout life. He also explained that students cannot be taught to think at higher levels. Piaget believed that biological processes determined when someone will advance to the next level. Lessons must be geared to the correct level of the student or frustration may occur. Many adults operate at a concrete operational level (Piaget, 1954).

The constructivist paradigm was derived from Piaget’s (1954) cognitive developmental theory. Constructivism, or the way in which students’ acquire and construct knowledge, has been the predominate paradigm of learning in science at all levels. However, there has been considerable debate over how to implement constructivism most effectively in the classroom. Constructivist teaching methods may be widely accepted among educators, yet they are not widely practiced or implemented (Palmer, 2005). Nevertheless, constructivist learning has been supported by the literature from philosophical discussions, testimonials by instructors who have seen constructivism work successfully with their students, and experimental studies showing higher student performance and attitudes in constructivist learning environments (Bodner, 1986;

Braathen & Hewson, 1988; Bybee, 1993; Caprio, 1994; Glynn, Yeany, & Britton, 1991; Lawson, 1988; Leonard et al., 1991; Lord, 1994; Lorsch & Tobin, 1995; Seymour, 1995; Tobin, 1990).

As described by Lord (1994), knowledge is gained by students when the information they encounter interacts with their existing perceptions. This is the basis for constructivism.

Constructivist educators believe that students make sense of what they experience by associating new information with prior knowledge. After the new material is properly accommodated, true understanding may be reached, and the student should have the ability to explain the new information to others. By explaining what one knows about a topic, the explainer may test understanding. Similarly, while trying to understand what a colleague is saying, listeners may question and challenge their own understandings and try to fit the material into their already established cognitive framework (Duffy & Jonassen, 1992).

According to constructivist theory, when students learn about science any new information is compared with existing knowledge, beliefs, interests, and goals, which may lead to the modification or revision of their ideas (Palmer, 2005). Knowledge is constructed and reconstructed as students are exposed to new experiences and ideas (Driver & Bell, 1986). Although constructivism has become the predominate philosophy in science education, many still debate the manner in which knowledge is constructed (see, e.g., Piaget, 1954; Vygotsky, 1978).

The third major philosophy that has been studied recently to address improved teaching and learning in the sciences is a branch of constructivist thought called *social constructivism* influenced by the ideas of Lev Vygotsky (1978). Similar to Piaget, Vygotsky believed that knowledge was constructed, but he emphasized the role of social interactions during the construction process. In social constructivism, students' prior knowledge and background is

important. This includes their culture, language, customs, and traditions. This is the “lens” through which new information is acquired and this lens needs to be considered. Vygotsky emphasized that learning takes place in a zone of proximal development. Students can understand concepts slightly higher than their current level of understanding, but not higher than that. This is where lessons should be focused. The teacher or peers with higher levels of understanding may help the student learn through scaffolding. It is important for teachers at all levels to identify the proper zone of proximity and to scaffold learning through group activities and a great deal of discussion (Vygotsky, 1978).

Scaffolding is a variation of teaching by modeling where a student is given support by a teacher at sequentially higher levels until the student reaches a higher level of understanding and mastery. The scaffolds help the student build on prior knowledge and integrate new information. The lessons offered in a scaffolding instruction style are just beyond the level of what the learner can do alone, thus helping the learner through the zone of proximal development. For example, if an instructor wishes to teach a student how to acclimate a fish from one system to another, the instructor may first show the student the necessary steps involved and then allow the student to perform them in sequence. Next, the instructor may improve the student’s understanding of the process by demonstrating other methods of acclimation that are appropriate for differing circumstances and how to handle larger fish. The student’s understanding may be further enhanced through lessons and discussions concerning pH, the effects of pH on a fish, the nitrogen cycle, ammonia’s effect on pH, carbon dioxide’s effect on pH, buffers, etc. As the student moves more and more fish, the instructor slowly removes the scaffolding by giving less and less assistance. Eventually, the student will come to an understanding of how to move any type of fish into or out of any pH situation without harming the fish.

The two major branches of constructivism have some distinctions. Cognitive constructivism focuses on internal cognitive processes (Piaget, 1978) and an individual's attempts to make sense of the world (Von Glaserfeld, 1995). Individuals interpret experiences to build meaning and their own personal understanding. The teacher's role is to provide appropriate experiences for that individual to facilitate learning. Conversely, social constructivism stresses the significance of society, culture, and language (Lemke, 2001), where knowledge is socially constructed and acquired in specific social and cultural contexts. Proponents of social constructivism believe that learning occurs when a student interacts with a more competent individual, such as a teacher, who leads the student to gradually develop skills and knowledge in a process called scaffolding. Students use language to express ideas and to ask questions until sufficient understanding is reached. With an emphasis on communication, teachers are regarded as central to student learning (Palmer, 2005). Therefore, the major distinction lies in the function of the teacher. According to cognitive constructivists, the teacher is a facilitator and peripheral the center of focus, whereas social constructivists place the teacher in a more central role.

Constructivism has been the predominate paradigm of learning in science at all levels. However, there has been considerable debate over how to implement constructivism most effectively in the classroom. Over the past twenty years, educational researchers have proposed many models of constructivist informed teaching methods, but currently none has gained wide acceptance (Palmer, 2005). Yet, constructivist learning has been supported by the literature from philosophical discussions, testimonials by instructors who have seen constructivism work successfully with their students, and experimental studies showing higher student performance and attitudes in constructivist learning environments (Bodner, 1986; Braathen & Hewson, 1988; Bybee, 1993; Caprio, 1994; Glynn, Yeany, & Britton, 1991; Lawson, 1988; Leonard et al., 1991;

Lord, 1994; Lorsch & Tobin, 1992; Seymour, 1995; Tobin, 1990).

Marin, Bennaroch, and Gomez (2002) explain that both cognitive constructivist and social constructivist views portray learning as an active process where students integrate new information with prior knowledge to construct their own meaning. Constructivism advocates developmentally appropriate teacher-supported learning and implies that learning must be initiated and directed by the student. Since effort is required for learning, one would logically deduce that motivation is an integral prerequisite or co-requisite to initiate and continue student participation (Palmer, 2005).

Constructivism and Motivation

According to Palmer (2005), the current body of research on science learning and constructivism has neglected motivation and has primarily focused on the description and analysis of student conceptions. It is generally agreed that among science students' misconceptions are common, can interfere with learning, and some misconceptions are resistant to change by conventional teaching methods (Hewson & Tabachnick, 1999). Because of this focus on misconceptions, science learning is often viewed as conceptual change. The most frequently used conceptual change model (i.e., Posner, Strike, Hewson, & Gertzog, 1982) explains what conditions are necessary for conceptual change to occur, but fails to address the student motivation driving conceptual change. Pintrich and Marx (1993) as well as Tyson, Venville, Harrison, and Treagust (1997) believe that behavioral indicators of motivation including the decision to engage in a task, the level of involvement in the task, and the decision to continue at the task influence conceptual change. More recently, Sinatra and Pintrich (2003) proposed *intentional conceptual change* to describe goal-directed construction of knowledge controlled by the learner. Intentional conceptual change supports the idea that motivation is an

integral factor in the conceptual change process.

Inquiry-Based Learning

Apedoe and Reeves (2006) presented a case for inquiry-based learning where students do real science, and digital libraries where students can gain access to peer reviewed resources in undergraduate science education. In their article, they reiterate the “widely acknowledged weaknesses in undergraduate science teaching” (Apedoe & Reeves, 2006, p. 322) and explained that inquiry-based learning stems from constructivist thought as well as situated cognition. Situated cognition theory (Brown et al., 1989) asserts that what people learn is fundamentally situated within the context in which they learned it. From this perspective, knowledge is a tool that cannot be used properly by a student without an understanding of the accepted cultural views and uses of that tool. Applied to science education, it is important for students at all levels to receive authentic science experiences to gain an appreciation and understanding of scientific inquiry. *Inquiry-based learning* is a pedagogical technique used in science education where students learn science by using similar or comparable methods, attitudes, and skills as practicing scientists do when they are conducting scientific research. Inquiry-based learning should give students a stronger understanding of the nature of science.

Apedoe and Reeves (2006) explain that the National Science Education Standards (NSES) are targeted for K-12 science educators, but the National Science Teachers Association (NSTA) believes that higher education science instructors should realize that they are part of and affected by the current reform efforts. In fact, according to the NSTA K-16 Coordination position statement: “Teachers of college/university science courses must integrate the principles of the National Science Education Standards into their own teaching to reinforce the comprehensive science experiences of students” (as cited in Apedoe & Reeves, 2006, p. 325).

Apedoe and Reeves (2006) point out that due to successful reform efforts at the K-12 level, students may soon be entering into higher education with strong inquiry skills and high expectations for inquiry engagement.

Understanding of the Nature of Science

Abd-El-Khalick and Lederman (2000) describe the phrase “Nature of Science” (NOS) as the “epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (p. 666). However, beyond this they explain that among researchers, no consensus exists on a specific definition for NOS. They explain that this lack of agreement is due to the complex nature of the subject. The understanding of the Nature of Science has changed as the scientific disciplines themselves have changed and today usually refers to scientific thinking skills.

Research on NOS

NOS has been extensively studied over the past half-century. A comprehensive review was presented by Lederman (1992). He grouped NOS studies into four distinct groups or lines. These lines were:

(a) Assessment of student conceptions of the nature of science; (b) development, use, and assessment of curricula designed to ‘improve’ student conceptions of the nature of science; (c) assessment of, and attempts to improve, teachers’ conceptions of the nature of science; and (d) identifications of the relationship among teachers’ conceptions, classroom practice, and students’ conceptions.

(Lederman, 1992, p. 332)

Among studies concerned with the first line of research, results were consistent. Students typically have not demonstrated an adequate understanding of NOS (e.g., Aikenhead, 1973;

Rubba & Andersen, 1978; Zohar & Tamir, 1991). These studies claim that even the most interested and capable students lacked knowledge of NOS and, therefore, demonstrated naïve conceptions of NOS. Scholars reasoned that curricula were responsible for students' lack of understanding and thus launched the second line of study.

Research efforts focusing on curricula began (Lederman, 1992). Significant increases in students' posttest scores were found in several studies designed to assess curricula, courses, and units (Lederman, 1992). These curricula used history and philosophy of science as well as NOS instruction to build proper understanding. However, these studies ignored the teacher as a variable. According to Lederman (1992) these researchers claimed that the teachers' understanding of NOS was independent of their students' gains. The belief was that once teachers were shown how to use the materials properly, student gains would result as a consequence of the curriculum not the teacher. Many researchers became skeptical (Lederman, 1992).

Lederman (1992) explains that when variables such as pre-testing, teacher experience, and student prior knowledge were controlled for researchers began to understand the function of teachers as the main conveyers of science curriculum. Studies began to support the idea that learning was influenced by teachers' understandings, interests, attitudes and classroom activities. This triggered the third line of research.

Third line studies consistently demonstrated that some teachers possessed inadequate conceptions of NOS (e.g., Abd-El-Khalick & Boujaoude, 1997; Carey & Stauss, 1970; Pomeroy, 1993). For example, many teachers believed that scientific knowledge is not tentative and a positivistic, idealistic view of science was common (Lederman, 1992). This unsettling discovery brought about the third line of research focusing on the improvement of teachers' conceptions of

NOS.

The Relationship Between Teachers' Conceptions of NOS and Classroom Practice

Julie Libarkin (2001) developed an assessment of student conception of the nature of science based on Rubba and Andersen (1978) and attitudes toward science. In an effort to determine the effectiveness of science courses for nonmajors, a series of general education and introductory science courses at the University of Arizona were assessed with pre and posttests. The three constructs tested were Attitude Toward Learning Science, Attitude Toward Science, and the Conception of Science. Almost all of the students entered the course with negative attitudes toward learning science. Those attitudes changed very little over the course of the semester. There seemed to be no significant change among any of the constructs among any of the groups except for attitudes toward science, but the authors did not feel that this construct was as reliable as the others. The authors suggested that a better understanding of students' attitudes and conceptions could greatly facilitate the teaching process. Overall, the instrument was found to be valid and reliable.

Motivation

Palmer (2005) explains that in education, motivation refers to anything that initiates and sustains learning behavior. Educational motivation has typically been studied from either a behaviorist perspective, emphasizing the impact of environmental factors such as rewards, or a social cognitive perspective, emphasizing the significance of student beliefs about themselves and the learning environment. The majority of recent studies in educational motivation support the idea that social cognitive perspective is of primary importance. Pintrich and Schunk (1996) explain that the social cognitive perspective views motivational beliefs as a construct significantly influenced by classroom context and not the fixed personality trait portrayed in

older models. The social cognitive perspective implies that student motivation may be optimized through the manipulation of the classroom environment.

According to Ryan and Deci (2000), motivation refers to being “moved to do something”. Ryan and Deci explain that if an individual feels no inspiration to act, he or she is unmotivated, whereas an individual who is energized toward an end is motivated. Most motivation theories view motivation as a unitary phenomenon ranging from very little motivation to great amounts of motivation. However, Ryan and Deci (2000) feel that motivation is not unitary because for a given task, people not only vary in amount of motivation, but they also vary in orientation or type of motivation. The underlying attitudes and goals that give rise to action are the focus of orientation of motivation. For example, two people may have the same amount of motivation to run for exercise, but one may engage in the activity for inherent or *intrinsic* reason, such as personal enjoyment, while the other may engage in the activity for *extrinsic* reasons, such as better health or improved performance in a peripherally related sport as a result of running for exercise.

Intrinsic and Extrinsic Motivators in Education

In education, extrinsic motivators may include rewards, praise, privileges, or attention. Although commonly used, external motivators have been shown to have a strong negative influence on other types of motivation. For example, external rewards have been shown to undermine intrinsic motivators (Deci, 1971) because the reward shifts the individual from a more internal to external perceived locus of causality. Although this issue has been debated, a recent meta-analysis by Deci, Koestner, and Ryan (2001) demonstrated that any type of contingent, expected, tangible reward (excluding unexpected rewards and verbal praise) undermines intrinsic motivation. Tangible rewards diminish intrinsic motivation. Furthermore, threats (Deci &

Cascio, 1972), deadlines (Amabile, DSeJong, & Lepper, 1976), directives (Koestner, Ryan, Bernieri, & Holt, 1984), and competition pressure (Reeve & Deci, 1996) also diminish intrinsic motivation. According to Cognitive Evaluation Theory (CET) (Deci & Ryan, 1985), students will view these external motivators as controllers of their behavior. However, choice and opportunities for self-direction enhance intrinsic motivation because they give a greater sense of autonomy (Ryan & Deci, 2000). According to intrinsic motivation theory (White, 1959) when an individual succeeds in a challenge or learns something new, that individual feels innate enjoyment and the internal drive to engage in further learning activities for the satisfaction of succeeding. Thirty years of research has shown that intrinsic and extrinsic motivators produce different quality of experience and performance (Deci & Ryan, 2000). Generally, intrinsic motivation has been shown to be more successful in promoting learning and achievement (Deci et al., 2001). However, extrinsic motivation may not need to be eliminated entirely. For example, Lin, McKeachie, and Kim (2001) as well as Lin and McKeachie (1999) administered the Intrinsic Goal Orientation and Extrinsic Goal Orientation scales of the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993) to 578 college biology students at the University of Michigan and 72 psychology students in Korea. Results indicated that high levels of intrinsic motivation and intermediate levels of extrinsic motivation together produce higher levels of course performance. The curvilinear relationship between extrinsic motivation and grades demonstrates that some extrinsic motivation may be necessary to produce optimal grades. They also found that students who reported mid or high intrinsic goal orientation were also high in self-efficacy and low in test anxiety.

Various factors affecting intrinsic motivation are challenge, curiosity, fantasy, and control (Lepper et al., 2005). Challenge refers to a teacher setting the level of the challenge to a

point where students will not find it too easy or too difficult. Set at the correct level, intrinsic motivation will be enhanced. Curiosity refers to students experiencing novel, unusual, or discrepant events. If the event evokes curiosity, internal motivation may be temporarily enhanced. Discrepant events demonstrations are commonly used by teachers to engage students and capture their attention at the beginning of a lesson (Nussbaum & Novick, 1982). Fantasy refers to students' using the creative power of the imagination to solve hypothetical problems mirroring the real world. Control refers to students' feelings of self-control and autonomy. Students will be more highly motivated when they feel they are in control of their behaviors or self determined.

Self-Determination Theory

According to Ryan and Deci (2000), research based on *Self-determination Theory* (SDT) deals with the social-contextual conditions that nurture or hinder the natural processes of self motivation and healthy psychological development. Particularly, SDT theorists have studied various factors that improve or undermine intrinsic motivation, self regulation, and well being. Studies based on SDT have led to the proposal of three innate psychological needs: competence, autonomy, and relatedness. When the three innate psychological needs described by SDT are satisfied the result will be improved self-motivation and mental health, and when dissatisfied the result will be diminished motivation and well-being.

Black and Deci (2000) explain that SDT proposes that interpersonal context affects the extent to which individuals are *autonomous* as opposed to the extent to which individuals are *controlled*. *Autonomy-support* means that the leader or instructor takes the subordinates or student's perspective, shows empathy towards that person, provides relevant information, and offers opportunities for making decisions. It also involves the reduction of pressures and

demands on the subordinate or student. In educational research, this type of teaching is often referred to as *student centered*. On the other hand, a *controlling* authority uses coercion or seduction to pressure subordinates to behave in a particular fashion. They typically offer implicit or explicit rewards or punishments. This teaching style is often referred to as *teacher-centered*. Both teaching styles may facilitate learning gains.

According to self-determination theory, autonomy-supportive classes will maintain or enhance intrinsic motivators and promote identification with external regulations, while control oriented classes tend to undermine intrinsic motivation and hinder internalization (Black & Deci, 2000). Autonomy-supportive classrooms are associated with higher levels of intrinsic motivation (Deci, Schwartz, Sheinman, & Ryan, 1981) and internalization (Grolnick & Ryan, 1989) than controlling classrooms. Parents who are autonomy-supportive tend to have children who are more autonomous in completing their school-work (Grolnick, Ryan, & Deci, 1991). Autonomy-supportive environments are also associated with better conceptual learning (Grolnick & Ryan, 1987), more creativity (Koestner, Ryan, Bernieri, & Holt, 1984), and more positive influence on attitudes (Ryan & Grolnick, 1986) than controlling environments. The significance of an autonomy-supportive social context to enhance feelings of autonomy has been maintained at all levels of education from elementary (Grolnick & Ryan, 1997) to college (Black & Deci, 2000) to postgraduate studies (Williams & Deci, 1996).

Cognitive Evaluation Theory (CET) and Organismic Integration Theory (OIT)

Deci and Ryan (1985) presented two sub-theories, Cognitive Evaluation Theory (CET) and Organismic Integration Theory (OIT), within Self-determination Theory. The first sub-theory, Cognitive Evaluation Theory, was created to explain variability in intrinsic motivation and deals with social and environmental factors that facilitate or undermine intrinsic motivation

(Ryan & Deci, 2000). According to Ryan and Deci (2000), “developmentalists acknowledge that from the time of birth, children in their healthiest states are active, inquisitive, curious, and playful, even in the absence of specific rewards” (p. 70). Intrinsic motivation is believed to be inherent and will be enhanced when individuals are placed in environments or conditions favorable toward its expression. So, social environments can promote intrinsic motivation by supporting or preventing an individual’s innate psychological needs (Ryan and Deci, 2000). Ryan & Deci (2000), claim that studies have clearly shown that psychological satisfaction for both autonomy and efficacy have been strongly linked to intrinsic motivation. However, CET only deals with activities that are either intrinsically interesting, have the appeal of novelty, appropriate challenge level, or aesthetic value. In other words, the principles of CET only apply to activities that are intrinsically motivating to begin with.

Self-Determination Theory proposes that extrinsic motivation can differ significantly in level of autonomy. According to Ryan and Deci (2000), the second SDT sub-theory, called Organismic Integration Theory (OIT), deals with the different forms of extrinsic motivation and the contextual factors that promote or obstruct internalization and integration of these behaviors. The distinction between intrinsic motivation, extrinsic motivation, and amotivation is stressed in a model of the Self-Determination Continuum (Deci & Ryan, 1985). The model depicts a continuum of increasing levels of self-determination and shows the types of motivation with their regulatory styles, loci of causality, and corresponding processes. On the far left side of the model lies amotivation, which may be defined as a lack of motivation or no intent to act. People who are amotivated lack either a sense of efficacy or sense of control with respect to a desired outcome (Pelletier, Dion, Tuson, & Green-Demers, 1999). Amotivation is not regulated and has an impersonal locus of causality. The center of the model is a continuum of extrinsic motivators

ranging from *external regulation* (external locus of causality), *introjected regulation* (somewhat external locus of causality), *identified regulation* (somewhat internal locus of causality), and *integrated regulation* (internal locus of causality). On the far right side of the model lies intrinsic motivation. As previously defined, intrinsic motivation has an internal locus of causality and motivation comes from within the student.

Ryan and Connell (1989) tested the continuum of extrinsic motivators and explain that the more students are externally motivated, the less they demonstrated interest, value and effort toward achievement. Externally motivated students also tended to shift blame for poor results to their teachers and others. Introjected regulation positively related to expending more effort, but was associated with more anxiety and poor coping with failure. Identified regulation was associated with positive interest, enjoyment, and effort in school as well as relatively better coping mechanisms. Other educational studies showing that more autonomous extrinsic motivation was associated with higher levels of engagement (Connell & Wellborn, 1991), better performance (Miserandino, 1996), lower dropout rates (Vallerand & Bissonnette, 1992), and higher quality learning (Grolnick & Ryan, 1987). Ultimately, Ryan and Deci (2000) explain that environments supportive of autonomy, competence, and relatedness were found to foster greater internalization and integration than environments that prevent satisfaction of these needs.

Achievement Goal Theory

Achievement Goal Theory (AGT) has played a large role in recent research on student motivation. According to AGT, students have a range of personal goals, mastery goals, and performance goals. Personal goals include social goals and gaining the approval of teachers or peers, mastery goals are a student's desire to learn or master concepts and facts, where as performance goals are the desire to demonstrate success to others by outperforming peers or to

receive a high grade. Harackiewicz, Barron, Tauer, and Elliot (2002) explain that performance goals may be further broken down into *performance approach goals*, where students compare personal success with that of others, and *performance avoidance goals*, where students put forth the minimum amount of effort to not appear incompetent to others. Both types of performance goals have negative effects, because they focus partially on other students' performance and not entirely on the self. On the other hand, Pintrich (2000) has found mastery goals, which focuses on the self, to be related to better performance (Pintrich, 2000). Therefore, competition should be avoided, because competition tends to promote performance goals. Instead, to maximize goal achievement, some classroom autonomy should be offered and materials should be meaningful and relevant to the students so they will perceive the comprehension of course concepts as beneficial, thus promoting the development of mastery goals (Ames, 1992).

Interest

Interest is the psychological state of focused attention or a kind of consciousness accompanying and stimulating attention. Hidi (1990) described two types of interest as personal interest and situational interest. Personal interests are relatively long lasting and deeply rooted preferences for a topic, but personal interests may vary widely within a classroom (Chen, Darst, & Pangrazi, 2001). Situational interests are short term interests brought about by specific events. Flowerday, Schraw, and Stevens (2004) demonstrated that situational interests increase the level of engagement among students and that situational interests can take precedence over personal interests. Since situational interests are easily incorporated into any classroom or lesson, they are commonly studied and various causes have been identified. For example, Hidi and Harackiewicz (2000) believe that situational interest may be aroused by novel or discrepant events. Mitchell (1997) believes that lessons that actively involve students and are relevant to students' lives will

bring about situational interest. Furthermore, Palmer (2004) found that novelty, meaningfulness, and involvement all produced situational interest in a science class for elementary pre-service teachers.

Expectancy Value

Expectancy value deals with *expectancy beliefs* or students' expectations of success for a task, and *task value* or students' perceived usefulness of that task (Wigfield & Eccles, 2000). The three types of identified task values are *attainment value* or the extent to which the student identifies with the task, *utility value* or the perceived usefulness of the task, and *intrinsic value* or the inherent pleasure of doing the task. Research has shown that expectancy beliefs are related to task values and are predictive of students' participation, effort, and achievement in learning (Xiang, McBride, & Guan, 2004). Task values seem to be related to students' enrollment choices, whereas expectancy beliefs (such as self-efficacy) are related to performance (Greene, DeBacker, Ravindran, & Krows, 1999). Also, gender differences have been shown to effect values among female mathematics and science students who view these subjects as masculine (Stipek & Gralinski, 1991). Zucho, Pintrich, and Coppola (2003) believe that task values in chemistry courses could be increased by assuring that the material presented in class is relevant to the students' everyday lives.

Self-Efficacy

Self-efficacy was first proposed by Bandura (1986) as an individual's level of perceived competence in a task. Self-efficacy is made up of two components, *efficacy expectation* and *response-outcome expectancy*. Efficacy expectation is an individual's belief about whether they are able to perform an action. Response-outcome is an individual's belief about whether the performed action will produce the desired outcome. An individual may have high self-efficacy

for some tasks and low self-efficacy for others. Proponents of self-efficacy believe that an individual high in self-efficacy for a task will tend to persist at the task until the task has been successfully completed, whereas an individual low in self-efficacy for a task will tend to give up quickly after experiencing difficulty with the task or make no effort at all. Self-efficacy has been shown to be a better predictor of academic achievement than standardized test scores. For example, Zusho et al. (2003) examined achievement among college students in a chemistry course and found that self-efficacy and task value beliefs were better predictors of final grades in the course than SAT mathematics scores.

Four factors identified by Bandura (1997) may increase self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and physiological/affective state. *Mastery experiences* are previous experiences of success with a task and will result in higher self-efficacy of that task. Therefore, students should be given a series of short-term proximal goals to steadily increase or maintain self-efficacy (Pajares, 2002). *Vicarious experiences* occur when students watch a teacher or other students successfully perform a task and the student feels as if he/she could do just as easily perform that task. This results in higher self-efficacy. Also, if the teacher openly and honestly admits making mistakes, students will understand that mistakes are acceptable and can be overcome (Pajares, 2002). *Verbal persuasion* occurs when students receive positive feedback for success and effort. This too will result in higher self-efficacy. *Physiological/affective state* refers to a student's awareness and interpretation of their physiological responses to stressful situations. If students treat this response as a normal process rather than as a sign of inability, self-efficacy will increase.

Based on replicable findings from several studies, Bandura (1997) felt that gender and attitude influence academic achievement through their mediating effects on an individual's self-

efficacy beliefs. Several studies (Andrews, 1998; Chemers, Hu, & Garcia, 2001; Liu et al., 2006; Pintrich, Roeser, & DeGroot, 1994) have found that self-efficacy is one of the significant influences on both general academic achievement and science achievement. In a longitudinal study of 1st-year university student adjustment, Chemers, Hu, and Garcia (2001) examined the effects of academic self-efficacy and optimism on students' academic performance, stress, health, and commitment to remain in school. At the end of the first academic quarter, predictor variables (high school grade-point average, academic self-efficacy, and optimism) and moderator variables (academic expectations and self-perceived coping ability) were measured and related to end of the school year measures of classroom performance, personal adjustment, stress, and health. Academic self-efficacy and optimism were strongly and directly related to academic achievement. They were also indirectly related through expectations and coping perceptions (challenge–threat evaluations) on classroom performance, stress, health, and overall satisfaction and commitment to remain in school.

Self-efficacy and intrinsic motivation

Garcia and Pintrich (1991) used structural equation modeling to demonstrate the relationships among intrinsic motivation, self-efficacy, and self-regulated learning over time. In their model they placed the motivational constructs of intrinsic motivation and self-efficacy as preceding self-regulated learning. Intrinsic motivation at the beginning of a college semester was hypothesized to direct behaviors, and sense of efficacy and strategic behaviors were considered to influence both motivational constructs at the end of a college semester. This study placed self-efficacy as an influence on intrinsic motivation.

The results of a study with 367 college students who completed the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993) indicate that intrinsic motivation and self-

efficacy had substantial affects on self-regulated learning. Furthermore, they found that intrinsic motivation had a strong affect on self-efficacy. This study placed intrinsic motivation as an influence on self-efficacy. It is noteworthy to mention that the results of the aforementioned study also showed that a subject's belief in his or her capabilities was more likely to lead to higher levels of self-regulated learning. Higher levels of self-regulated learning are known to lead to higher academic achievement, but Pintrich and De Groot (1990) explain that self-regulated learning components may be more directly related to performance than motivational factors. In other words, students need to have both the “will” and the “skill” to be successful in classrooms.

Attribution Theory

Attribution Theory, described by Weiner (1985), deals with a student's perceptions about the causes of failure or success for a past task. These perceptions will affect the way the student will approach the same task in the future. This theory has three components, locus, stability, and control. *Locus* refers to students' perceived causes of their successes or failures. Students may have an *internal locus of causality* where they attribute success or failure to themselves, or an *external locus of causality* where they attribute failure or success to outside factors acting on them. *Stability* refers to *stable* long term causes such as ability level or *unstable* short term causes such as effort. *Control* refers to the amount of influence students have over the cause. *Learned helplessness* occurs when students believe their past failures at a task are the results of factors outside of their control. Future attempts will be met with passive helplessness and poor attitudes.

Motivation and Classroom Learning Environment

Lyke and Kelaher-Young (2006) conducted a study of 322 undergraduate students

enrolled in four sections of a Human Development course at a large, comprehensive regional university in the Midwest. They examined students' goal orientations (intrinsic or extrinsic) and perceptions of the classroom environment (i.e., task or performance structured) as predictors of student use of deep or surface level cognitive strategies. Results confirmed that intrinsic goal orientation was related to use of deep cognitive strategies and extrinsic goal orientation was related to use of rehearsal. They also noted no interaction between intrinsic and extrinsic goal orientations on use of either cognitive strategy. In addition, students' perceptions of classroom environment were significantly correlated with students' goal orientations. Specifically, intrinsic goal orientation moderated the effect of perceived classroom structure on the use of deep cognitive strategies. Constructivist classrooms focus on the learning process and deep cognitive strategies, such as paraphrasing, and summarizing, are known to produce better understanding of course material than do surface strategies such as rehearsal (Garcia & Pintrich, 1991).

Learning Environment, Academic Efficacy, and Course Performance

Dorman and Adams (2004) conducted a study on the relationship between psychosocial environment and academic efficacy among 2651 mathematics students from Australian and British secondary schools. They concluded that enhanced classroom environments were associated with higher levels of academic efficacy among students. In their literature review they explained that their findings are in agreement with Fraser (1998) who has shown that the quality of the classroom environment has a significant relationship with student learning. In other words, students learn better when they perceive the classroom environment positively. Fraser (1998) helped develop the Constructivist Learning Environment Survey to aid in the assessment of the constructivist aspects of learning environments. Dorman and Adams (2004) also explain that many studies have shown that student perceptions account for large amounts of variance in

learning outcomes, even while accounting for student background characteristics. They also explained that studies have provided consistent and substantial evidence that academic efficacy is positively related to academic motivation (Schunk & Hanson, 1985), persistence (Lyman et al., 1984) memory performance (Berry, 1989), and academic performance (Schunk, 1991). Furthermore, Multon and Brown (1991) performed a meta-analysis and showed that academic efficacy is a consistent positive predictor of academic achievement. Dorman and Adams (2004) believe that studies should be conducted examining the relationship among classroom environment, academic efficacy, and student outcomes such as grades, in a structural model. They suspect that academic efficacy acts as a mediating variable. However, perceptions of the classroom environment may be dependent upon academic efficacy.

Encouraging Feedback, Self-efficacy, and Course Performance

Tuckman and Sexton (1991) conducted two studies of influences on self-regulated performance. They surveyed 126 education majors at a large state university for the first study and 63 students from the same course for the second study. Results showed that perceived self-competence level affected performance. They also found that encouraging feedback by the teacher increased students' self-efficacy on the task and subsequent performance on the task. Statistical analyses showed that when performance was held constant, encouragement was seen to affect self-efficacy, but when self-efficacy was held constant, encouragement had no effect on performance. Hence, self-efficacy functioned as a mediator of performance.

Attitudes, Motivation, and Science Achievement

Two studies examine the relationship between attitudes, motivation, and course performance. In one study, Tuan, Chin, and Shieh (2005) developed a questionnaire to measure student motivation toward science learning (SMTSL). Six scales were developed: self-efficacy,

active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. By stratified random sampling, 1407 junior high school students from central Taiwan, varying in grades, sex, and achievements, were selected to respond to the questionnaire. There were significant correlations of the SMTSL questionnaire with students science attitudes and with the science achievement test.

A study by Liu (2005) examined the effect of a hypermedia-enhanced problem-based learning environment in 437 sixth-graders science knowledge, attitude toward learning science, and motivation toward learning. Results showed a moderate positive relationship between the intrinsic goal orientation and attitudes, and a weaker positive relationship between intrinsic goal orientation and science knowledge. A weak, yet significant, positive relationship was also found between attitudes and science knowledge scores. Liu also noted a significant negative relationship between extrinsic goal orientation and science knowledge scores.

Attitudes Toward Science

There is some evidence that there is a causal relationship between attitude toward science and course performance (Mattern & Schau, 2002). However, much of the research on attitudes involving science has been ambiguous due to lack of clarity about what is meant by attitudes toward science. Various researchers have used the same term, but ascribed different meanings to attitudes toward science. Gardner (1975) began to bring some consistency and clarity by distinguishing between attitudes toward science and scientific attitudes. Scientific attitudes are cognitive in nature and characterize scientific thinking. In other words, scientific attitudes foster skepticism of the illogical as well as traits such as questioning, the collection of data, and the analysis of that data. However, attitudes toward science refer to beliefs about science, scientists, learning science in school, or science's impact on society. These attitudes toward science and

their development through adolescence into young adulthood are the focus of this literature review and study.

Osborne et al. (2003) describe two major difficulties encountered when studying attitudes toward science. The first is the fact that attitudes toward science are made up of many subconstructs that each contributes in varying degrees to an individual's attitudes toward science. Osborne et al. (2003) cite fourteen studies and over ten subconstructs, including perception of the science teacher, anxiety toward science, self esteem at science, motivation toward science, enjoyment of science, the nature of the classroom environment, and achievement in science.

The second major difficulty with studying attitudes mentioned by Osborne et al. (2003) is that measures of attitude are really measures of an individual's articulated inclinations and feelings toward a task. However, the measured attitude may not necessarily reflect the individual's expressed behaviors. This is because other attitudes not being measured by the researcher may be more strongly held by the participants, motivation to act in a different way may be stronger than the motivation to act on the measured attitude, or individuals may anticipate consequences for expressing a particular attitude toward a task, thus producing a behavior inconsistent with a held attitude (Potter & Weatherall, 1987).

Because students may exhibit a behavior inconsistent with attitudes, behavior rather than attitudes has become an area of interest among many. Social psychologists Ajzen and Fishbein (1980) address behavior prediction in their *theory of reasoned action*. This theory distinguishes between attitudes toward an object and attitudes toward an action to be performed on that object. Applied to science, their theory distinguishes between attitudes toward science and attitudes toward studying science in school. Ajzen and Fishbein would argue that attitudes toward school science are better predictors of behavior. Thus, their theory describes the relationship between

attitude, intention, and behavior. Attitudes and subjective norms (beliefs about how others will view a given action) jointly produce intention, and intention produces the behavior. The theory of reasoned action applied to science education has demonstrated that peer social support and attitude toward enrolling for a course are strong determining factors of whether students will autonomously choose to take science course (Crawley & Coe, 1990; Koballa Jr., 1988; Oliver & Simpson, 1988). This theory may be used to help researchers decide what causes students to enroll in college science courses.

Subject Preference Studies

One type of measurement of attitudes toward school science involves asking students to rank school subjects from least favorite to most favorite. Osborne and Collins (2000) used focus groups made up of 16-year-old British students to examine views and attitudes toward science to confirm the results of previous studies (e.g., Ormerod, 1973; Ormerod & Duckworth, 1975). They found that physics ranked higher than chemistry and that biology was viewed as considerably more favorable than both chemistry and physics. Their results indicate that the curriculum of the students they interviewed lacked intellectual challenge and emphasized undemanding activities such as copying and recall.

Another preference ranking study by Lightbody and Durndell (1996) at one school indicated that boys were much more likely to report enjoying science than girls were. Jovanic and King (1998) reported that girls ranked science lower than boys did because the girls perceived that they themselves were more competent in other subjects.

These types of ranking studies are useful because they are easy to present and understand; however, their major drawback is that they are based on relative scales. For example, a student who enjoys school learning may like science, but that student may prefer many other subjects

over it, whereas another student may intensely dislike science and give science the same ranking, and yet another student may dislike all subjects but ranks science highest. These types of studies are also not suitable for measuring changes in attitudes toward science over time, because attitudes toward other subjects may change as well. However, they are useful for comparing science to other subjects. Therefore, ranking studies should be used in conjunction with other types of data collection techniques (Osborne et al., 2003).

Attitude Scales

Attitudes toward science have often been measured through the implementation of Likert-scale surveys consisting of questions such as “I enjoy science” or “science is confusing”. Each item contributes to a rating scale that is made up of various opinion statements indicating either a favorable or unfavorable attitude to the construct being studied. The participant is usually offered a five or seven item Likert-scale ranging from “strongly agree” to “strongly disagree”. Participants’ responses indicate the strength of their agreement or disagreement for each particular statement. The scores for negative items are reversed and then the sum of all scores gives the participant a total score. The design of attitude scale instruments usually involves researchers giving groups of subjects open-ended, free response questions. The responses are used to create the instrument items and objects. Next, the newly created instrument is then administered to small groups and piloted for refinement by statistical analysis until an acceptable level of consistency and validity has been achieved, and extraneous, non-distinguishing questions have been eliminated.

One commonly used science attitude assessment instrument is the Scientific Attitude Inventory developed by Moore and Sutman (1970). Although the Scientific Attitude Inventory widely used, Munby (1983) criticized it for poor reliability and producing inconsistent results.

Furthermore, the instrument measures attitudes toward aspects of science in society and not attitudes toward learning science in school. This has led to the development of many newer instruments covering a broad range of foci. For example, Simpon and Troost (1982) developed the Attitudes Toward Science instrument used to assess 4500, K-12 students in North Carolina, and the Attitudes Toward Science Inventory (Gogolin & Swartz, 1992), developed as an adaptation of Sandman's (1973) instrument to assess attitudes toward mathematics. Another example is the Views on Science, Technology, and Society developed by Aikenhead, Ryan, and Fleming (1987) used to measure students' views of the nature of science. The Views on Science, Technology, and Society instrument was created by views expressed by students and offers greater validity than the others. It has been recently adapted by Bennett (2001) to assess undergraduate college students' views of chemistry and to create profiles of typical students who held positive or negative views of chemistry.

However, attitude scale instruments have been criticized severely. For example, Gardner (1975) states that all of the items within a scale must be aligned to a single attitude object. He explains that measuring more than one object on a single instrument and producing a summative rating is akin to measuring the various dimensions of a dining room table, adding the dimensions all together, and comparing the sum to other dining room tables on a dining room table a dining room table index. Gardner felt that the summative rating of a multiple object instrument is meaningless and therefore the individual constructs should be used individually to look for significance.

Another criticism of attitude scale instruments is that many are not internally consistent and unidimensional (Gardner, 1995). Gardner explains that internal consistency is the measure of the precision of the instrument or the degree to which the instrument assess the same

characteristic, skill or quality. Internal consistency is commonly used throughout attitude measurement literature and is commonly measured by Cronbach's alpha. Gardner further explains that unidimensional scales only measure one dimension and will be internally consistent because each object measures the same construct, but internally consistent scales may not necessarily be unidimensional. The explanation for this is that the scale may be composed of several groups of items each measuring a distinct factor. If every item correlates highly with other items, a high Cronbach's alpha will result. Therefore, the unidimensionality of a scale should be examined by a statistical technique such as factor analysis. If a scale does measure what its creators claim it measures, then the variance should be explained by a loading on a unitary factor.

Gardner (1995) also explains that semantic differential scales where a word or phrase representing the attitude object is presented and the subject is presented with a five or seven point scale ranging from one extreme to the other. For example, the attitude object may be "science is" and the scale ranges from "exciting" to "boring" or "very easy" to "very difficult". Semantic differential scales are susceptible to the same criticisms as attitude scale instruments.

The Biology Attitude Scale (BAS) is a unidimensional, 22-item survey designed to measure students' attitudes toward biology in terms of like or dislike (Russell & Hollander, 1975). The survey consists of 14 Likert-style questions and 8 semantic differential questions. To test validity and reliability, Russell and Hollander (1975) surveyed three introductory biology courses as well as an education class as a control. The first biology course was intended for biology majors and was taught by a traditional lecture-laboratory method. Students' attitudes toward biology significantly decreased from pretest to posttest. The second course was also intended for biology majors, but was taught by an alternative method called the audiotutorial

method. In this group, students' attitudes toward biology did not significantly change from pretest to posttest. The third course was intended for biology nonmajors and was taught with the audiotutorial method. In this class, students' attitudes toward biology significantly increased from pretest to posttest. The students in the education course showed no significant change in their attitudes toward biology from pretest to posttest. Russell and Hollander (1975) explained that the study demonstrated the relative sensitivity of the instrument and that it is both valid and reliable with a demonstrated reliability coefficient of $\alpha=.90$ for the Likert scale and .80 for the semantic scale.

In the past, it was believed that students would acquire positive attitudes toward science as they learned more science. This was overturned by a study conducted by William Rogers, and Robert Ford (1997). In their study, they confirmed the reliability of the Likert portion of the Biology Attitude Scale designed by Russell and Hollander (1975). The Likert portion of the instrument was administered as a pre and posttest to two separate introductory biology classes at two different universities. Results found all positive changes in attitudes at one university and mostly positive, but one negative change for the biology majors at the other. All changes were significant. Rogers and Ford (1997) concluded that whether a student is a biology major or nonmajor is not a determining factor when measuring the effect of an introductory course on changing attitudes toward biology. They also confirmed a Cronbach's alpha reliability coefficient of $\alpha=.95$ for the BAS Likert scale.

Interest Inventories and Subject Enrollment

Interest inventories may be used to measure interest in science. Participants are presented with a list of items and asked which ones they are interested in. However, these inventories only offer a limited view and may or may not indicate attitudes toward science (Osborne, 2003).

Another source of data comes from subject enrollment or charting the numbers of students enrolled in science courses over a period of time. Charts showing trends of incline, decline, or steadiness in science course enrollment may produce a dramatic presentation. However, many factors other than attitudes toward science or interest in science may be responsible for the trends.

Qualitative Studies

Many of the studies designed to assess attitudes toward science have been quantitative. One criticism of quantitative attitude studies is that, while useful in identifying the nature of the problem, they do not address the cause of the problem or understanding why the problem persists. To help understand the problem, many researchers turn to qualitative research designs. Qualitative studies offer a richness and depth that cannot be captured by quantitative methodologies. However, only a few researchers have specifically used clinical or group interviews to explore student attitudes (Osborne & Collins, 2000).

Declining Attitudes Toward Science

Recent subject preference research by Colley and Comber (1994) found significant gender differences among 11 and 13-year-old students. Girls favored English and humanities, while boys preferred physical education and science. Other researchers have shown a decline in attitudes toward science starting from about age 11. Attitudes toward science may actually peak around age 9 (Hadden & Johnstone, 1983). In most countries, data suggest that children actually maintain positive attitudes toward science until entering secondary school where attitudes plummet as a result of their experiences with school science. This is particularly true for girls (Kahle & Lakes, 1983). However, during adolescence attitudes toward all subjects seem to decline (Eccles & Wigfield, 1992). On the other hand, attitude measurements gathered for the

TIMSS study (Beaton et al., 1996) suggests that most students reported liking science or liking science a lot. The TIMSS study also suggests that attitudes decline slowly until age fourteen, when the drop in attitudes is rapidly accelerated.

Poor Attitudes Toward School Science

The literature shows a discrepancy between students' attitudes toward science in general and students' attitude toward school science. Although many studies show that attitudes toward school science are low, many other studies show that students' attitudes toward science in general are positive. For example, the Assessment of Performance Unit (1988) showed that the majority of 15-year-old English students believed science to be both interesting and useful. Similarly, Ebenezer and Zoller (1993) found that the majority of 16-year-old United States students reported that science was valuable, and school science was important, but 40% found science classes boring. Ebenezer and Zoller suggested that school science presentation may be part of the problem. They believe science is presented as a topic disconnected from society and should be studied for intrinsic reasons. So, although students may see science as relevant to their lives, the science presented to students in their science classes may not seem relevant. Osborne and Collins (2000) showed that attitudes toward school science vary among the different science domains. For example, biology students seemed to have more positive attitudes because biology has more obvious direct relevance to students' lives than other sciences, such as chemistry. Without relevance, sustaining interest is difficult. In general, there is a decline in attitudes toward school science from age 11 onwards and an accelerated drop off after age 14; however, there is a drop off in attitudes toward all school subjects during adolescence (Osborne *et al.*, 2003).

Environmental Factors

Several studies have attributed classroom learning environment as a contributing factor

toward attitude. Myers and Fouts (1992) examined high school science classroom environments and their effect on the attitude of students toward science. Using cluster analysis, twenty-seven high school science classes were divided into three distinct groups. More positive attitudes toward science were found among students in one of the clusters with a distinctly different environment from the other two. Positive attitudes were found in classrooms with high levels of involvement, high student-to-student affiliation, high teacher support, and low levels of teacher control. Also, negative attitudes were present in classrooms with control oriented teachers. Myers and Fouts believe that teachers may develop and change to enhance science attitudes and science achievement of the students.

Talton and Simpson (1987) reported that the characteristics of teachers, peers and classroom environment affect the affective and cognitive learning of the student among tenth grade biology students. These indicate that while there is a strong relationship between classroom environment and the attitude of the student toward science, the relationship between classroom environment and achievement in science is weak. They suggested that in order to enhance cognitive and affective outcomes, teachers need to develop a positive, supportive climate within the science classroom.

A longitudinal study by Simpson and Oliver (1990) focused on the major influences on attitude toward science and achievement in science among adolescent students in North Carolina. Three major categories of independent variables were related to home, school, and individual characteristics. The two major dependent variables were attitude toward science and achievement in science. They concluded that classroom variables were the strongest influence on attitudes toward science.

Further support for the significance of the teachers' effect on attitudes can be found in a

study by Sundberg and Dini (1994) who examined 2965 college students' attitudes toward science. The authors noted a small, but significant, difference in prior understanding of basic biological concepts between students enrolled in majors' versus nonmajors' introductory biology courses. By the end of the respective courses, nonmajors demonstrated greater improvement in posttest scores than did majors. Furthermore, although initially students in the major course had significantly more positive attitudes toward science, especially in terms of personal comfort with science, by the end of the course this difference between major and nonmajors had disappeared. Following a semester of instruction, the attitudes of nonmajors generally improved, but student attitudes in the majors' classes declined in nearly all categories. They believe that the difference in attitudes was attributed to a significant instructor effect.

The majority of attitude studies conducted in science classrooms have been the comparison of traditional classrooms versus new experimental curriculum materials or instructional techniques. The results have not been conclusive. Osborne et al. (2003) explain in their literature review of attitudes toward science, that these types of studies produce little meaningful results, because researchers often do not analyze the ways in which the traditional and experimental curriculum differ. Therefore, it is not possible to make generalizations about the way in which attitudes or outcome measures are influenced by a particular curriculum feature. Osborne et al. (2003) conclude that teacher variables are the most significant factor determining attitude, not curriculum variables. They also explain that students will hold higher attitudes toward subjects that are more personally relevant to their lives.

Attitude and Achievement

There is a deep literature describing the relationship between attitude and achievement. Some studies conclude that the relationship between these two variables is weak (i.e., Gardner,

1975); however, more recent studies (i.e., Shirgley, 1990; Weinburgh, 1995) show a moderate relationship. Weinburgh (1995) conducted a meta-analysis of the literature which pertaining to gender differences in students attitudes toward science, and correlations between attitudes toward science and science achievement. Results demonstrated that boys show a more positive attitude toward science than girls in all types of science and that a positive attitude results in higher achievement, particularly for low-performing girls. However, Oliver and Simpson (1988) argued that their longitudinal study showed strong relationships between three affective variables (attitudes toward science, motivation to achieve, and self-efficacy for learning and performance) and academic achievement in science. In their study they tracked achievement in science of high school students over time and determined if self-reports of affective constructs could be used to predict that achievement. Also, the comparative achievement of students across content areas was studied. The results identified students whose science achievement was higher or lower than their achievement in other content areas. One other interesting finding was that girls were generally more motivated to achieve than boys, and their achievements tended to be superior to boys, yet boys were more inclined toward science as a career.

Within the literature, there is some contrast about the causal link between attitudes and achievement. Much of the available literature holds that attitudes influence achievement (Fennema & Leder, 1990; Haladyna, Olsen, & Shaughnessy, 1982; Lester & Garofalo, 1987; Papanastasiou & Papanastasiou, 2002; Papanastasiou & Papanastasiou, 2004). However, Millar and Tesser (1990) suggest that *affective* (emotions and feelings) and *cognitive* (attributes and beliefs) components of individuals are often independent of each other. In other words, students may achieve highly even if they have poor attitudes toward science.

Women and Minorities in Science

Recently, Harvard University President Dr. Lawrence Summers argued that women are infrequently tenured in math and science for three reasons. Pollitt, (2005) summarized his three points as follows. First, women typically choose to raise a family rather than dedicate the eighty hours per week necessary for tenure and promotion in those fields. Second, fewer women have the necessary genetic talent to excel in those fields, and third, women are discriminated against. However, he discounted discrimination by explaining that a talented woman unjustly rejected by one university would surely be hired by a rival. His message was clear; women are less successful in math and science because of their lack of commitment and lower intelligence. Dr. Summers created an uproar that triggered a firestorm of explanations as to why he is incorrect and a trend among science educators to investigate why women are so underrepresented in the sciences.

Women are not the only group of people underrepresented in the sciences; minorities are also disproportionately represented. A report released in September of 2000 by the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology (CAWMSET) explains that in most areas of science, there is a large and consistent underrepresentation of women, several racial and ethnic minorities, and people with disabilities (Garelik, 2000). Some of the same types of discrimination plague these groups, but they each have unique barriers of their own that may dissuade them from pursuing math and science careers.

Women in Science

The disparity of women in math and science is not a new topic of debate. Title IX of the 1972 Education Amendments prohibits sex discrimination in the schools, but the treatment of

male and females may still not be equal today. In math and science, the disparities in performance level between males and females have been attributed to genetics (as cited in Tindall & Hamil, 2004). However, the biological differences between men and women have been overturned as a viable explanation (Hyde et al., 1990). Tindall and Hamil (2004) believe that the true reasons for the disparities are environmental and influenced by society. They believe that sexism is built into our culture and society undervalues the role of women. Instead, we place a higher value on the traditional males roles. Therefore, a simple explanation for why women may be underrepresented in math and science is that not enough efforts have been made to recruit and support women. Marks (2005) believes that the deficiencies start at the earliest levels of education and escalate up through college and into academia itself. To explain the lack of women and minorities, he also believes that the current system is biased toward the success of white males. Tindall and Hamil (2004) explain that science classes are traditionally competitive and do not accommodate a variety of learning styles. All of the inequality problems may be compounded by the denial of gender biases in schools and society (Tindall & Hamil, 2004).

Women receive 55% of both bachelor's and master's degrees in most fields (Graham, 2001). However, according to the National Science Foundation (2003) only 37% of the science and engineering doctoral students are women. The Association of American Medical Colleges (Brotherton, Rockey, & Etzel, 2003) states that 44.5% of MD graduates are women and currently, 36% of new faculty hires at academic medical schools are women. Furthermore, only 26% of faculty granted tenure at medical schools are females. Also, women only account for 33% of faculty promoted from assistant to associate professor, 23% promoted from associate to full professor, and currently account for 12% of full professors in science and medicine. In computer science, women hold only 6% of the full professorships (Mervis, 1999). The

Association of American Medical Colleges also points out that only 10 of 126 US medical school deans are women. This obvious lack of women in leadership positions among the sciences is a clear indicator of women's under-representation. The question is why do we find these disproportions and how do we rectify the situation? Marks (2005) believes that older white males are choosing who progresses and they tend to choose other males. The decision to promote more male than females may or may not be conscience choice. Therefore, Marks believes that a simple solution is to simply raise awareness of the lack of diversity. He states that search committees should intentionally work to improve diversity and incentives should be given to schools and departments who demonstrate significant improvement. However, to truly increase the numbers of women in upper level faculty positions, timelines for promotion and tenure need to be extended so having children and raising a family, does not incur such harsh penalties (Marks, 2005). Granting agencies will also need to show leniency.

Socialization

From early childhood, initiative and independence tend to be encouraged in boys, whereas dependence and passive behavior tends to be encouraged in girls (Woolfolk, 1998). Girls focus on the development of verbal, interpersonal, and fine motor skills, while boys tend to focus on physical and spatial understanding. These learned behaviors are carried with them into their educational experiences possibly effecting participation and interest in science classes (Aldridge & Goldman, 2002). As a result, discussion, problem solving, and lab activities tend to be dominated by males while females watch and take notes (Woolfolk, 1998). By the time the students reach the sixth grade, males report that they are more interested in scientific subjects than their female classmates (Jones et al., 2000). At the upper levels, traditional science classes are extremely competitive and do not accommodate a variety of learning styles (Graham, 2001).

The only students who will succeed in the sciences must be comfortable with the traditional teaching methods. Since males may be socialized to learn one way and females may be socialized to learn another way, one explanation for the observed gender differences in math and science is that the preferred teaching methods cater to male learning over female learning.

Gender stereotypes effect on education

Traditional stereotypes encourage females to develop self-images that demote science interests. Female stereotypes emphasize dependence, personal relationships, and feelings (Smith, 1992). According to Adams (1996), these traditional stereotypes promote achievement through conformity and obedience. On the other hand, the masculine stereotypes encouraged in boys promote assertiveness, curiosity, and questioning. These are the behaviors that promote success in the quantitative fields and lead to science being perceived as a masculine discipline (Kahle & Meece, 1994). Adams (1996) also believes that girls may hide their intelligence and develop a distorted perception of their abilities as a result of gender-role socialization. Furthermore, textbooks and teachers may reinforce these stereotypes, attitudes, and beliefs.

According to the American Association of University Women [AAUW] (2002), teachers interact more often and in more detail with males than with females. This seems to be the case from preschool all the way up through college. In fact, by the time females complete high school, they will have received 1,800 fewer hours of attention than males (Woolfolk, 1998). The AAUW also believes that teachers tend to choose class activities that appeal to males' interests more than females and use teaching methods that favors learning in males. Furthermore, the AAUW believes that multiple-choice questions favor males over females and do not reflect an accurate view of females' abilities. This becomes obvious when comparing standardized test scores to grades earned. Despite the fact that females typically receive better grades in school (Evans,

2002), males tend to score higher on the verbal and mathematics sections on the SAT (Tindall & Hamil, 2004). Furthermore, Mewborn (1999) compares male and female performance on the standardized test scores for entrance into graduate school, law school, and medical school. Males outscore females in each case. As a result, these standardized test scores effectively block females from entering into the upper level sciences. The AAUW, also believes that between males and females who score similarly on the SAT, the females tend to do better in college. Clearly, further investigation into the reasons as to why there are gender differences in grades and standardized test scores needs to be examined along with teaching methods that cater to females.

Minorities in Science

Western science has traditionally been very hostile to minorities. As Rey (2001) explains, until fairly recently many scientists believed that most “races” of humans did not have the ability to excel in the sciences. Although blatant discrimination is now illegal, many of the traditional social hierarchies continue to structure academia as well as society in general. Examples of this can be seen today in science and science education. Moore, Jensen, and Hatch (2002) believe that the Americans have created a scientific apartheid.

Although African-Americans and Hispanics comprised 25% of the United States population in 2002, they only earned a combined 13% of the science and engineering bachelor degrees and 7% of the doctorates (Rey, 2001). While some improvements have been noted, minorities remain obviously underrepresented in science and engineering (NSF, 2000). Many minorities drop out of science. Only one-third of the minorities who begin studying the sciences in college end up graduating with a degree in science or engineering. Most switch to some other field. Critics fear minorities may be getting the message that they are not welcome in the

sciences.

According to Moore, Jensen, and Hatch (2002), the most recent approach to multiculturalism is to recruit minorities into science classes. The expectation is that the minorities will conform and assimilate into the existing scientific culture. These efforts have failed because they have placed the burden reform on those who are already alienated by science. This is especially true for students with different cultural backgrounds including women, ethnic minorities, the disabled, and students of lower socioeconomic class. The change must occur not within the marginalized students, but the system that marginalizes them in the first place. Science education must learn to accommodate various learning styles and cultural backgrounds. Incorporating multiculturalism into science courses to enhance learning (Moore, 2001). Furthermore, some scientific theories contribute to destructive stereotypes due to misconceptions by scientists and teachers.

Race

As described by Durodoye (2003), the term “race” is a term that has been misused for many centuries. Prior to the 1500’s it was used to differentiate between distinctly similar groups within the same species. The term was applied to groups of animals with tremendous amounts of genetic diversity. From the 1500’s to the 1800’s it was applied to humans who differed in lineage, customs, and religions. Today we refer to this definition as “culture”. During the scientific shift of the 1800’s, the term race was attributed to human’s physical appearance. Today, most biologists do not recognize the term race as it is applied socially to humans. The genetic diversity among humans is so strikingly minuscule, it is believed that *Homo sapiens* have undergone a genetic bottleneck during their early history. In other words, all humans have extremely similar DNA. In fact the Human Genome Project has confirmed that all humans are

99.9% genetically identical (Human Genome Project Information, 2002). The slight differences that account for differing colors of the eyes and skin are so minute that two “Caucasians” are no more genetically similar than when a “Caucasian” is compared to any other human on Earth (Gould, 1994). Genetically, races do not really exist among humans (Diamond, 1994).

Unfortunately, the scientific community did at one time make distinctions between human races. The famous Carolus Linnaeus, who is credited for our current biological classification system, assigned four races to humans: Americanus, Europaeus, Asiaticus, and Afer (Durodoye, 2003). Early scientists believed that humans originated from the Caucas Mountains of Russia and all other races descended from them, thus confirming the superiority of Caucasians and a hierarchy that placed blacks at the lowest rank. Today we know that this is simply incorrect.

Scientific racism

As described by Durodoye (2003), the first standardized tests for human intelligence was published in 1905. Despite the fact that these exams were culturally biased to favor white students, the results of these exams were used to demonstrate the lower intelligence of minority groups in the United States. This form of testing coincided with the eugenics movement around the turn of the 20th century. It was believed that to improve the gene pool, people of low intelligence should not be allowed to reproduce and that various social and racial groups contained genetic deficiencies. The American Eugenics Society created in 1926 promoted these views. Membership consisted of large numbers of university professors, administrators, researchers, and other white professionals. Many fields of study at U.S. colleges and universities became aligned with the eugenics movement. Educational psychology was especially susceptible because of its dual interests in learning and intelligence. Misinformation about ethnic groups was

created and promoted by these elite circles of whites in the social sciences. Unfortunately, the attitudes generated by these misconceptions may still prevail today in many parts of society despite today's improved understanding of equal intelligences among all ethnic groups.

Over the years, many educators have consumed and disseminated misinformation labeled as "science". Although most negative stereotypes of minorities seem to be diminishing among the general public, some still remain. It is not too difficult to see why some minorities may have poor attitudes towards science or motivation to study it, particularly in the biological sciences.

Summary

In summary, there is considerable research on the relationships between learning environment, attitudes, motivation, and course performance. While much of the research focuses on self-determination, self-regulated learning, the effects of experimental constructivist classrooms or lessons, and the effects of gender and ethnicity on attitudes there is little research describing the combined interaction of the causal relationships between learning environment, attitudes, motivation and course performance in nonmajor biology courses.

CHAPTER III. METHODOLOGY

This chapter describes the research design, participants, data collection instruments, variables, materials, procedures used to collect the data, and data analysis procedures. The source of data is archive data that was collected during the last week of the fall semester of 2007 by an educational research group at Bowling Green State University in a collaborative effort to study the effects of intrinsic and extrinsic motivation on attitudes toward biology and course performance among nonmajor biology students. The research groups study also examined nonmajor biology students' attitudes toward mathematics, self efficacy, and their perceptions of their classroom learning environment. The present study only focuses on biology and uses the data in a very different fashion.

Participants

All students enrolled in the fall 2007 semester of an introductory biology course for nonmajors at a four-year public university in Ohio were asked to participate in the study. Introductory biology is taught using two different formats. Most of the sections (Group A) were taught using a predominantly traditional lecture-style format. Three of the sections (Groups B and C) were taught using a reform-based inquiry format. Regardless of format, students were given only one overall grade in the course. In the lecture format, the lab was taught separately by a graduate student teaching assistant and was worth about one third of the overall grade in the course. Separate grades for both the lecture and the lab were not reported. A faculty member, with graduate student help, taught the reform-based inquiry classes. The lecture and lab were integrated and the student only received one overall grade in the course.

Group A: Participants in this group were enrolled in one of three introductory nonmajor biology lectures taught by three different instructors. Each lecture contained four to six sections

of 25-30 students (approximately 400 total) enrolled in the Fall 2007 semester of an introductory biology course for nonmajors at a four-year public university in Ohio. The three lecture courses were taught using a traditional three hours of lecture per week taught by faculty and two hours of lab per week taught by various graduate student teaching assistants. These courses represent the standard teaching method for large lectures at this particular university.

Group B: Participants in this group were enrolled in one reform-based introductory nonmajor biology courses of 24 students taught by one professor. In this reform-based inquiry course the lecture and lab portions were combined and taught entirely by faculty with a graduate student serving as an assistant. The course met for two 75-minute sessions per week and one 2-hour session per week.

Group C: Participants in this group were enrolled in one reform-based introductory nonmajor biology courses of 24 students taught by one professor. In this reform-based inquiry course the lectures were taught entirely by faculty with a graduate student serving as an assistant. A teaching assistant also taught the lab. The course met for three one-hour sessions and one 2-hour lab per week.

The study site was a mid-sized university located in northwest Ohio with approximately 20,300 students and 860 faculty. About 17,300 of the student body were undergraduates. About 1,680 (8%) were African American, Native American, Hispanic, or Asian American. Most of the students were from nearby locations, but roughly 10 percent came from outside the state, including more than 540 from other countries.

Instrumentation

Demographic questions (gender, ethnicity, academic major) and three instruments totaling 83 Likert-style questions were used in this study. The instruments were (a) Motivated

Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993) (b) Constructivist Learning Environment Survey (CLES) (Aldridge, Fraser, Taylor, & Chen, 2000), and (c) Biology Attitude Scale (Russell & Hollander, 1975). Each instrument is described below.

Motivated Strategies for Learning Questionnaire (MSLQ)

The Motivated Strategies for Learning Questionnaire (MSLQ) is a 31-item Likert-style survey used to measure generic course specific motivation and learning strategies. The scale used in the current study was the Motivation scale of the college version of the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993). The 50-item learning strategies section of the MSLQ was not administered. The MSLQ was designed to measure the goals and value beliefs for a course, students' beliefs about their skills to succeed in a course, and student anxiety about tests. The various scales making up the Motivation Scales include (a) value (intrinsic goal orientation, extrinsic goal orientation, task value); (b) expectancy (control of learning beliefs, self-efficacy for learning and performance); and (c) affect (test anxiety). The Motivation subscales of the MSLQ have demonstrated reliability coefficients (Pintrich et al., 1993) of $\alpha = .74$ (intrinsic goal orientation), $\alpha = .62$ (extrinsic goal orientation), $\alpha = .90$ (task value), $\alpha = .68$ (control of learning beliefs), $\alpha = .93$ (self-efficacy for learning and performance), and $\alpha = .80$ (test anxiety). Validity and reliability were established by Pintrich et al. (1993). Furthermore, the instrument shows adequate predictive validity of course performance of students (Fasko, Earley, & Winseki, 2007). The MSLQ was administered one time and distinctions were not made between the lecture and laboratory portions of the course (see Appendix A).

Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Climate Questionnaire (CLES) is a 30-item Likert style survey designed to measure the students' perceived level of constructivism in the classroom. The

CLES was found to be both valid and reliable for use with secondary students in Australia and Taiwan (Aldridge, Fraser, Taylor, & Chen, 2000). Using Cronbach's alpha, the instrument has been demonstrated to have an internal consistency class mean reliability coefficient of .96 (Australia) and .98 (Taiwan). The five scales that make up the CLES are (a) *personal relevance*: relevance of learning to students lives, $\alpha = .88$ (Australia) and $\alpha = .87$ (Taiwan); (b) *uncertainty of science*: provisional status of scientific knowledge, $\alpha = .76$ (Australia) and $\alpha = .83$ (Taiwan); (c) *critical voice*: legitimacy of expressing a critical opinion, $\alpha = .85$ (Australia) and $\alpha = .73$ (Taiwan); (d) *shared control*: participation in planning, conducting and assessing of learning, $\alpha = .91$ (Australia) and $\alpha = .92$ (Taiwan); (e) *student negotiation*: involvement with other students in assessing viability of new ideas, $\alpha = .91$ (Australia) and $\alpha = .92$ (Taiwan). The CLES was administered one time and distinctions were not made between the lecture and laboratory portions of the course (see Appendix B).

Biology Attitude Scale (BAS)

The Biology Attitude Scale (BAS) is a unidimensional, 22-item survey designed to measure students' attitudes toward biology in terms of like or dislike (Russell & Hollander, 1975). The survey consists of 14 Likert-style questions and 8 semantic differential questions. To test validity and reliability, Russell and Hollander (1975) surveyed three introductory biology courses as well as an education class as a control. Russell and Hollander (1975) explained that the study demonstrated the relative sensitivity of the instrument and that it is both valid and reliable with a demonstrated reliability coefficient of $\alpha = .90$ for the Likert scale and .80 for the semantic scale. Rogers and Ford (1997) also confirmed a Cronbach's alpha reliability coefficient of $\alpha = .95$ for the BAS Likert scale (see Appendix C).

Course Performance

Course performance was measured by securing final course grades from each instructor. To reconcile different grading practices, grades were reported as a percentage and converted to a standardized z-score for each individual course. After standardizing the grades, all of the courses were pooled to make the “Course Performance” variable.

Research Design

A causal (predictive correlational) study design was used to produce descriptive information about factors related to students’ perceptions of their learning environment, attitudes toward biology, motivation, and course performance in an introductory biology course for nonmajors. One hypothesized path model depicting the interrelatedness of the variables was tested and compared to results obtained by the survey. Based on the results an adjusted model was produced. Indirect and direct predictors were investigated. A path model was used to demonstrated the strength of the relationships between the variables measured in the study. Demographics were also compared by causal-comparative design.

Procedures

The data used for this study were acquired as preexisting data from a collaborative educational research group associated with me. After securing approval from the BGSU Human Subjects Review Board and the Department of Biological Sciences, we visited classes to recruit participants and they were read a cover letter explaining why their participation is important, followed by instructions about the survey. Next, we secured signed consent forms from all participants and administered the pretest surveys sequentially during the last week of the semester for each course being studied. Students were given 30 minutes to complete the surveys. Surveys could be not coded to ensure anonymity so final grades could be matched to the correct

students; however confidentiality was and will continue to be maintained. The surveys were not scored until after the end of the semester and the students had received their final grades in the course. No students under the age of 18 participated in the study.

Data Analysis

After committee approval, I analyzed results by path analysis and Pearson-r correlation coefficients. The Statistical Package for Social Sciences (SPSS, version 15.0) was used for statistical analysis. The data were analyzed using descriptive analysis, ANOVA, Pearson correlation, and path analysis. Groups A, B, and C were compared to each other. Since no obvious differences in overall scores on the three surveys were apparent, all analyses were conducted on the combined data set.

Descriptive Statistics

Data collected from the three surveys and demographics were first summarized. These descriptive analyses were used to report the number and percentage of students giving each response. A table of means and standard deviations was constructed for each measured variable. Correlational data were plotted as a scatterplot and a table describing correlations between each pair of linear variables was constructed.

Inferential Statistics

Data were examined by a correlational research design and analyzed by Pearson's correlation coefficients to check for linear relationships. No curvilinear relationships were found. Multiple applications of multiple-regression, including path analysis, were used to estimate direct and indirect causal relations between all continuous variables. Path analysis assumes all of the relationships between variables are recursive. Demographics were compared for each variable using ANOVA to look for significant differences.

Research Questions

In this study, the following research questions were addressed in an undergraduate nonmajor biology course:

- 1) Does the Constructivist Learning Environment Survey (CLES), a multi-dimensional assessment of classroom learning environment, directly predict course performance, self-efficacy, intrinsic goal orientation, or attitudes towards biology?
- 2) Does the Constructivist Learning Environment Survey (CLES), self-efficacy, intrinsic goal orientation, attitudes toward biology, or course performance significantly vary by ethnicity or gender?
- 3) Does self-efficacy, intrinsic goal orientation, or attitudes toward biology directly predict course performance?
- 4) Is the proposed CLEM model — which describes the causal effects among the variables perception of learning environment (CLES), attitudes toward biology, intrinsic goal orientation, self-efficacy for learning and performance, and course performance — consistent with observed correlations among these variables?

Assumptions

This study has many assumptions that must be noted. First, one underlying assumption of this study is that the participants answered all of the survey questions honestly and they understood the meaning of the items on each of the surveys. This study assumes that the scores reported for all of the scales are an accurate measure of beliefs and attitudes and the scores are relative to their peers. In other words, it is assumed that a student scoring higher on the biology attitude scale has more positive attitudes toward biology than a peer scoring lower on the biology attitude scale.

The second assumption deals with statistical analysis. The path analysis statistical technique used in this study assumes that the relationships between the variables on the CLEM model are recursive, meaning the arrows only work in one direction. In other words, perceived learning environment affects attitudes and not the other way around. In truth, all of the studied variables probably have some effect on each other; however, the literature supports a predominant effect in one direction over the other in each case (see Figure 2). Furthermore, a cause and effect may be inferred by considering the dimension of time.

Figure 2. Studies supporting a recursive CLEM model.

Students' overall perceptions of their learning environment, as measured by the CLES, build over the semester and can only be measured at the end. Although it is a self-report survey, one must assume that the results the students provide reflects reality, with a small amount of variance based on perception alone. The CLES is made up of scales such as "Personal Relevance" and "Shared Control" and for one to claim that the grade received in a course has a strong effect on how relevant the material is to that student does not make sense. In other words, the grades given at the end of the semester do not affect the way the course was structured

throughout the semester. Although an instructor may consciously decide to make a course more personally relevant or to offer more shared control to their students after poor performance on an exam, this did not happen with any of the courses studied. In other words, personal relevance and shared control were not consciously altered during the course based on feedback from the students; however, they could be if instructors are trained to look for it and taught to improve it among their students.

The same arguments may be extended to the effects of attitudes toward biology, intrinsic goal orientation, and self-efficacy on the learning environment. No adjustments to the learning environment were made on the instructors' part based on these variables. For example, a student hates biology, but comes to class and the instructor discusses a rare disease that the student's beloved sister has inherited. Assuming that the instructor did not know this fact, the students' attitudes toward biology had no bearing on whether the instructor chose to discuss that personally relevant topic. However, the student's attitudes may improve based on the new perception that particular class is personally relevant.

More legitimate concerns center on the relationships between self-efficacy and course performance, and attitudes toward biology and course performance. Although past experiences of success are known to increase self-efficacy, attitudes influence course performance through their mediating effects on an individual's self-efficacy beliefs (Bandura, 1997). This results in a nonrecursive model, which cannot be handled by simple path-analysis. Structural equation modeling can handle nonrecursive models and may offer a more suitable analysis.

The third assumption centers on the participants' interpretation of their learning environment in Group A. For three consecutive semesters prior to this study, the faculty lab coordinator participated in a learning community that focused on teaching and learning in the

biological sciences. The faculty lab coordinator is responsible for overseeing the graduate student teaching assistants. The primary function of the faculty lab coordinator is to explain the weekly laboratory lessons to the graduate student teaching assistants. The faculty lab coordinator is also responsible for pedagogical training and has conveyed constructivist-based pedagogy to the graduate student teaching assistants. Although the curriculum is identical for each lab section and the lab activities come directly from a lab manual, it is expected that the graduate student teaching assistants have incorporated varying degrees of constructivist-based pedagogy into their teaching, resulting in a moderate range of learning environments.

On the other hand, the lecture portion of the course is primarily taught by traditional lecture-style, with faculty presenting the material. Various constructivist-based activities were sporadically scattered throughout the course by each instructor. Although the curriculum was similar for each lecture course, they were not identical. As expected, faculty have incorporated varying degrees of constructivist-based pedagogy into their teaching, resulting in a moderate range of learning environments. It is important to note that this study does not distinguish between the lecture and the laboratory portions of the course. Because the introductory biology course under study is one course, the results are assumed to reflect the participants' impressions of the course overall. Groups B and C were added to the study to provide more variability in CLES_TOTAL scores.

Limitations

The first limitation in this study is the aforementioned recursive assumption of the variables. Once again, it is acknowledged that all of the studied variables probably have some effect on each other, but the literature suggests directional effects. Second, the data will be collected at the end of the semester after students have had success or failure in the particular

course they are reporting on. This may lead to exaggerated correlations with self-efficacy for learning and performance, and course performance. However, this study is only concerned with students' mind-sets immediately after completing the course and these correlations will reflect the mind-set at that particular point in time. Third, students' prior knowledge and experiences as well as future aspirations may influence motivation, attitudes, and course performance regardless of perceived classroom learning environment. There are many scenarios where a student may have poor attitudes toward a subject and still perform well in a related course and vice versa. However, this study is testing a model of general trends to make predictions, not identify cause and effect relationships.

Two other limitations to this study are population validity and internal validity. The former is the degree to which the sample represents the population and the latter is the degree to which the results of the study can be attributed to the treatment and not some other variables. To address these limitations, a large sample size was used, and path analysis expects outside influence and can account for this. The chosen design ensures good internal validity. The chosen design will help provide adequate control over history, maturation, testing, and regression threats as well as providing increased protection from differential subject characteristics. Internal validity may be vulnerable to mortality, location, and differential subject threats. Therefore, incomplete cases will be dropped from the study. This study also depends on the validity and reliability of the surveys. However, all instruments used in the study have been shown to be valid and reliable and all data was examined by factor analysis.

Delimitations

This study specifically examined nonmajor biology students at one mid sized, state university located in the Midwestern United States during one academic semester. This study is

also delimited by not measuring students' previous experiences with science and science learning. This study also did not consider students' academic ability or levels of cognitive development.

CHAPTER IV. RESULTS

Introduction

In this dissertation the following questions were addressed: Is there a relationship between students' perceptions of their learning environment and course performance, and what roles do motivation and attitudes play in mediating that relationship? The purpose of this study was to test the Constructivist Learning Environment and Motivation (CLEM) model (see Figure 1). The CLEM model is a mediated model that explains the causal relationships among aspects of the learning environment as defined from a constructivist perspective (shared control, student negotiation, personal relevance, critical voice and uncertainty of science; depicted as *CLES_TOTAL* in figure 1), motivation constructs (intrinsic goal orientation and self-efficacy for learning and performance), attitudes toward biology, and course performance in a large undergraduate biology course for nonmajors. No educational researchers have previously included these particular variables into a single model. The CLEM model has incorporated the ideas of Bandura's (1981) Self-Efficacy Theory, Fraser and Wallberg's (2005) view of the constructivist-learning environment, Dorman and Adams' (2004) views on the relationships between classroom environment, academic efficacy, and grades, Palmer's (2005) ideas of incorporating motivation and constructivism, Osborne, Simon, Collins' (2003) views on attitudes toward science and motivation, and Deci and Ryan's (1985) views on Self-Determination Theory and intrinsic motivation. The CLEM model was created by the author of this dissertation and was assessed by path analysis. This chapter is organized into four sections: (1) introduction, (2) sample demographics, (3) instrument reliability, and (4) analysis of research questions.

Sample Demographics

The sample for this study was drawn from 499 students enrolled in an introductory biology course for nonmajors during the Fall term of 2007. A survey was voluntarily completed by 318 students or about 63% of the registered students in the participating classes. The students ages in years were 18 (30%), 19 (34%), 20 (23%), 21-22 (8%), and 23 and over (4%). The median age was 19. The gender composition of the participants was 66% female 31% male, and about 3% unreported. The ethnicities reported were 77% Caucasian, 12% African- American, 2% Hispanic, <1% Asian-Pacific Islanders, and 7% Others. The number of high school or college science courses students completed before taking the current course was 2 (5%), 3 (21%), 4 (38%), 5 (21%), 6 or more (14%). The median number of high school or college science courses taken prior to the current course was 4. The academic major for most of the students was Education (25%), Health and Human Services (22%), Undecided (8%), Business (7%), Biology (5%) and other Arts and Sciences-nonmathematics/nonscience (31%).

Instrument Reliability

The reliabilities for the various scales used to measure the variables were analyzed by Chronbach's alpha. The two scales used from the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993) were Self-Efficacy (MSLQ_SE) ($\alpha=.919$) and Intrinsic Goal Orientation (MSLQ_IGO) ($\alpha=.652$). The measures collected from the unidimensional Biology Attitudes Scale (Russell & Hollander, 1975) were the Likert portion of the scale (BAS_Likert) ($\alpha=.954$) and the Semantics Differential portion of the scale (BAS_Semantic) ($\alpha=.856$). The total of the two portions together (BAS_TOTAL) provided a reliability of $\alpha=.905$. Since the semantic differential portion of the scale lowered the reliability of the scale it was not used in the study and only the Likert portion of the scale was used for all calculations. Rogers and Ford (1997)

only used the Likert portion of the scale in their study as well. The multidimensional Constructivist Learning Environment Survey (CLES) (Aldridge, Fraser, Taylor, & Chen, 2000) consisted of five scales with the following reliabilities: Personal Relevance (CLES_PR) ($\alpha=.806$); Uncertainty of Science (CLES_US) ($\alpha=.893$); Critical Voice (CLES_CV) ($\alpha=.744$); Shared Control (CLES_SC) ($\alpha=.893$); and Student Negotiation (CLES_SN) ($\alpha=.846$). The total of all of the scale together (CLES_TOTAL) had a reliability of $\alpha=.836$. All of the variables used in this study were reliable (see Table 1). Table 1 includes reliabilities, means, standard deviations, scale minimums, and scales maximums for each scale used in the study.

Table 1

Reliabilities, Means, Standard Deviations, Scale Range, and Frequencies for All Scales

Instrument	Scale	Abbreviation	Chronbach's	Mean	SD	Min	Max	N
Motivated	Self-efficacy	MSLQ_SE	.919	29.0	6.3	8	40	318
Strategies for	Intrinsic	MSLQ_IGO	.652	13.5	2.7	4	20	318
Learning	Goal							
	Orientation							
Biology	Likert	BAS_Likert	.954	45.0	12.8	14	70	318
Attitudes	Semantic	BAS_Semantic	.856	20.1	5.8	8	40	318
Scale	Differential*							
	Total*	BAS_TOTAL	.905	64.8	9.4	22	110	318
Constructivist	Personal	CLES_PR	.806	22.0	4.1	6	30	318
Learning	Relevance							
Environment	Uncertainty	CLES_US	.893	22.6	2.9	6	30	318
Survey	of Science							
	Critical	CLES_CV	.744	22.5	3.5	6	30	318
	Voice							
	Shared	CLES_SC	.893	16.0	4.9	6	30	318
	Control							
	Student	CLES_SN	.846	21.9	4.4	6	30	318
	Negotiation							
	Total	CLES_TOTAL	.836	105	13.6	30	150	318

Analysis of Research Questions

Data for this study were compiled from the surveys returned by students. Numerous statistical tests were conducted to analyze the information. This analysis was conducted in the order that the research questions were proposed in Chapter 1.

Research Question 1

One of purposes of this study was to examine the level of contribution each scale of the Constructivist Learning Environment Survey (CLES) contributes to the CLES_TOTAL's correlation with motivation, attitudes, and course performance. Question 1 states: Does the Constructivist Learning Environment Survey (CLES), a multi-dimensional assessment of classroom learning environment, directly predict course performance, self-efficacy, intrinsic goal orientation, or attitudes toward biology? Multiple-regression was used to examine the amount of variability explained by each scale of the CLES on the other variables.

CLES predicts course performance

Standard multiple regression was conducted to determine the accuracy of the independent variables (Personal Relevance [CLES_PR]; Uncertainty of Science [CLES_US]; Critical Voice [CLES_CV]; Shared Control [CLES_SC]; and Student Negotiation [CLES_SN]) predicting course performance. Data screening led to the elimination of six cases. Regression results indicate that these particular variables significantly predict course performance, $R^2=.036$, $R^2_{adj}=.021$, $F(5, 306)=2.305$, $p<.001$. These particular variables accounts for 3.6% of variance in course performance. A summary of regression coefficients is presented in Table 2 and indicates that only one (Personal Relevance) of the five variables contributes to course performance.

Table 2

Regression Analysis Summary for Constructivist Learning Environment Variables Predicting Course Performance

Variable	<i>B</i>	<i>SE B</i>	β
CLES_PR	.033	.016	.137*
CLES_US	-.003	.024	-.007
CLES_CV	.026	.017	.093
CLES_SC	-.014	.013	-.069
CLES_SN	.015	.015	.067

Note. $R^2 = .036$ ($N = 312$, $p < .01$).

* $p < .05$

CLES predicts self-efficacy

Standard multiple regression was conducted to determine the accuracy of the independent variables (Personal Relevance [CLES_PR]; Uncertainty of Science [CLES_US]; Critical Voice [CLES_CV]; Shared Control [CLES_SC]; and Student Negotiation [CLES_SN]) predicting self-efficacy. Data screening led to the elimination of no cases. Regression results indicate that these particular variables significantly predict self-efficacy, $R^2 = .247$, $R^2_{adj} = .235$, $F(5, 312) = 20.515$, $p < .001$. These particular variables accounts for 24.7% of variance in self-efficacy. A summary of regression coefficients is presented in Table 3 and indicates that only two (Personal Relevance and Critical Voice) of the five variables contribute to self-efficacy.

Table 3

Regression Analysis Summary for Constructivist Learning Environment Variables Predicting Self-Efficacy

Variable	<i>B</i>	<i>SE B</i>	β
CLES_PR	.489	.090	.326*
CLES_US	.028	.134	.013
CLES_CV	.308	.095	.173*
CLES_SC	.120	.072	.094
CLES_SN	.117	.085	.080

Note. $R^2 = .247$ ($N = 318$, $p < .01$)

* $p < .05$

CLES predicts intrinsic goal orientation

Standard multiple regression was conducted to determine the accuracy of the independent variables (Personal Relevance [CLES_PR]; Uncertainty of Science [CLES_US]; Critical Voice [CLES_CV]; Shared Control [CLES_SC]; and Student Negotiation [CLES_SN]) predicting intrinsic goal orientation. Data screening led to the elimination of no cases. Regression results indicate that these particular variables significantly predicts intrinsic goal orientation, $R^2 = .235$, $R^2_{adj} = .222$, $F(5, 312) = 19.136$, $p < .001$. These particular variables accounts for 23.5% of variance in intrinsic goal orientation. A summary of regression coefficients is presented in Table 4 and indicates that only two (Personal Relevance and Shared Control) of the five variables contribute to intrinsic goal orientation.

Table 4

Regression Analysis Summary for Constructivist Learning Environment Variables Predicting Intrinsic Goal Orientation

Variable	<i>B</i>	<i>SE B</i>	β
CLES_PR	.191	.039	.292*
CLES_US	.033	.058	.034
CLES_CV	-.025	.041	-.032
CLES_SC	.144	.031	.264*
CLES_SN	.016	.037	.026

Note. $R^2 = .235$ ($N = 318$, $p < .01$).

* $p < .05$

CLES predicts attitudes toward biology

Standard multiple regression was conducted to determine the accuracy of the independent variables (Personal Relevance [CLES_PR]; Uncertainty of Science [CLES_US]; Critical Voice [CLES_CV]; Shared Control [CLES_SC]; and Student Negotiation [CLES_SN]) predicting attitudes toward biology. Data screening led to the elimination of no cases. Regression results indicate that these particular variables significantly predicts attitudes toward biology, $R^2 = .180$, $R^2_{adj} = .167$, $F(5, 312) = 13.674$, $p < .001$. These particular variables accounts for 18.0% of variance in attitudes toward biology. A summary of regression coefficients is presented in Table 5 and indicates that only one (Personal Relevance) of the five variables contribute to attitudes toward biology.

Table 5

Regression Analysis Summary for Constructivist Learning Environment Variables Predicting Attitudes Toward Biology

Variable	<i>B</i>	<i>SE B</i>	β
CLES_PR	1.336	.193	.428*
CLES_US	-.537	.285	-.118
CLES_CV	-.020	.202	-.005
CLES_SC	.111	.153	.042
CLES_SN	.172	.181	.058

Note. $R^2 = .180$ ($N = 318$, $p < .01$).

* $p < .05$

Research Question 2

Another purpose of this study was to determine if demographic differences account for significant differences in the variables examined in this study. Research question 2 states: Does the Constructivist Learning Environment Survey (CLES), self-efficacy, intrinsic goal orientation, attitudes toward biology, or course performance significantly vary by ethnicity or gender? These variables were examined by one-way Analysis of Variance.

CLES_TOTAL by gender

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but eight cases did not report gender. A univariate ANOVA was conducted; a summary of results are presented in Tables 6 and 7. Main effects revealed that CLES_TOTAL was not significantly different among males and females, $F(1, 308) = .143$, $p =$

.706, partial $\eta^2=.000$. Estimates of effect size revealed low strength in associations. Results reveal CLES_TOTAL did not significantly differ by gender.

Table 6

Frequencies, Means, Standard Deviations, Scale Minimums, and Scale Maximums for the Effect of Gender on CLES_TOTAL, Self-Efficacy, Intrinsic Goal Orientation (IGO), Attitudes Toward Biology, and Standardized Grades (Z_Grade)

Scale	Gender	Mean	SD	Min	Max	N
CLES_TOTAL	Female	104.70	13.77	6	30	211
	Male	105.33	13.90	6	30	99
	TOTAL	104.90	13.72	6	30	310
Self-Efficacy	Female	28.24	6.41	8	40	211
	Male	30.09	5.92	8	40	99
	TOTAL	28.83	6.31	8	40	310
IGO	Female	13.15	2.64	4	20	211
	Male	14.29	2.66	4	20	99
	TOTAL	13.52	2.70	4	20	310
Attitudes	Female	43.91	13.45	14	70	211
	Male	46.72	11.59	14	70	99
	TOTAL	44.80	12.93	14	70	310
Z_Grade	Female	.0945	.9854	-1.00	1.00	205
	Male	-.1787	.9778	-1.00	1.00	99
	TOTAL	.0056	.9897	-1.00	1.00	304

Table 7

ANOVA Summary Table for the Effect of Gender on CLES_TOTAL, Self-Efficacy, Intrinsic Goal Orientation, Attitudes Toward Biology, and Course Performance

Scale	Gender	df	SS	MS	F	Part. η^2
CLES_TOTAL	Between Groups	1	26.91	26.91	.143	
	Within Groups	308	58154.19	188.81		
	TOTAL	309	58181.10			
Self-Efficacy	Between Groups	1	230.42	230.42	5.877*	.019
	Within Groups	308	12076.86	39.211		
	TOTAL	309	12307.28			
IGO	Between Groups	1	87.77	87.77	12.52***	.039
	Within Groups	308	2159.65	7.01		
	TOTAL	309	2247.419			
Attitudes	Between Groups	1	532.81	532.81	3.208	
	Within Groups	308	51148.19	166.07		
	TOTAL	309	51681.00			
Z_Grade	Between Groups	1	4.98	4.98	5.16*	.024
	Within Groups	302	291.82	.97		
	TOTAL	303	296.81			

* $p < .05$ ** $p < .01$. *** $p < .001$.

Self-efficacy by gender

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but eight cases did not report gender. A univariate ANOVA was conducted; a summary of results are presented in Tables 6 and 7. Main effects revealed that self-efficacy was significantly different between males and females, $F(1, 308) = 5.877$, $p = .016$, partial $\eta^2 = .019$. Estimates of effect size revealed low strength in associations. Since gender only consists of two groups, a post hoc test was not conducted. Results reveal that self-efficacy for males was significantly higher than females. Effect size was small.

Intrinsic goal orientation by gender

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but eight cases did not report gender. A univariate ANOVA was conducted; a summary of results are presented in Tables 6 and 7. Main effects revealed that intrinsic goal orientation was significantly different between males and females, $F(1, 308) = 12.517$, $p = .000$, partial $\eta^2 = .039$. Estimates of effect size revealed low strength in associations. Since gender only consists of two groups, a post hoc test was not conducted. Results reveal that intrinsic goal orientation was significantly higher for males than females. Effect size was small.

Attitudes toward biology by gender

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but eight cases did not report gender. A univariate ANOVA was conducted; a summary of results are presented in Tables 6 and 7. Main effects revealed that attitudes toward biology were not significantly different between males and females, $F(1, 308) = 3.208$, $p = .074$, partial $\eta^2 = .010$. Estimates of effect size revealed low strength in associations. Results reveal that attitudes toward biology did not significantly differ by gender.

Course performance by gender

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but eight cases did not report gender. A univariate ANOVA was conducted; a summary of results are presented in Tables 6 and 7. Main effects revealed that course performance was significantly different between males and females, $F(1, 308) = 5.157$, $p = .024$, partial $\eta^2 = .017$. Estimates of effect size revealed low strength in associations. Since gender only consists of two groups, a post hoc test was not conducted. Results reveal that females grades were significantly higher than males.

CLES_TOTAL by ethnicity

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but nine cases did not report ethnicity. A univariate ANOVA was conducted; a summary of results are presented in Tables 8 and 9. Main effects revealed that CLES_TOTAL was not significantly different among ethnicities, $F(4, 304) = .259$, $p = .904$, partial $\eta^2 = .003$. Estimates of effect size revealed low strength in associations. Results reveal CLES_TOTAL did not significantly differ by ethnicity.

Table 8

Frequencies, Means, and Standard Deviations for the Effect of Ethnicity on CLES_TOTAL, Self-Efficacy, Intrinsic Goal Orientation, Attitudes Toward Biology, and Course Performance

Scale	Ethnicity	Mean	SD	Min	Max	N
CLES_TOTAL	African- American	104.54	13.37	6	30	37
	Asian-Pacific Islander	109.00	2.83	6	30	2
	Caucasian	105.04	13.95	6	30	244
	Hispanic	100.00	18.26	6	30	6
	Other	104.20	11.17	6	30	20
	TOTAL	104.85	13.72	6	30	309
Self-Efficacy	African- American	26.46	6.22	8	40	37
	Asian-Pacific Islander	31.50	2.12	8	40	2
	Caucasian	28.89	6.38	8	40	244
	Hispanic	29.83	5.98	8	40	6
	Other	31.90	4.76	8	40	20
	TOTAL	28.83	6.32	8	40	309
IGO	African- American	13.27	2.97	4	20	37
	Asian-Pacific Islander	16.50	.71	4	20	2
	Caucasian	13.45	2.67	4	20	244
	Hispanic	13.83	2.99	4	20	6
	Other	14.40	2.50	4	20	20
	TOTAL	13.51	2.70	4	20	309

Scale	Ethnicity	Mean	SD	Min	Max	N
Attitudes	African- American	41.86	11.97	14	70	37
	Asian-Pacific Islander	41.50	.71	14	70	2
	Caucasian	44.68	13.17	14	70	244
	Hispanic	50.67	9.58	14	70	6
	Other	50.40	11.96	14	70	20
	TOTAL	44.51	12.95	14	70	309
Z_Grade	African- American	-.4831	1.04	-1.00	1.00	36
	Asian-Pacific Islander	-.8905	.00	-1.00	1.00	2
	Caucasian	.0920	.94	-1.00	1.00	239
	Hispanic	-.9443	1.26	-1.00	1.00	6
	Other	.1806	1.11	-1.00	1.00	20
	TOTAL	.0025	.99	-1.00	1.00	303

Table 9

ANOVA Summary Table for the Effect of Ethnicity on CLES_TOTAL, Self-Efficacy, Intrinsic Goal Orientation, Attitudes Toward Biology, and Course Performance

Scale	Ethnicity	df	SS	MS	F	Part. η^2
CLES_TOTAL	Between Groups	4	196.47	49.12	.26	
	Within Groups	304	57755.98	189.99		
	TOTAL	308	57952.45			
Self-Efficacy	Between Groups	4	417.45	104.36	2.67*	.034
	Within Groups	304	11885.11	39.10		
	TOTAL	308	12302.56			
IGO	Between Groups	4	37.45	9.36	1.288	
	Within Groups	304	2209.74	7.27		
	TOTAL	308	2247.18			
Attitudes	Between Groups	4	1177.97	294.49	1.773	
	Within Groups	304	50502.38	166.13		
	TOTAL	308	51680.35			
Z_Grade	Between Groups	4	18.01	4.5	4.828***	.061
	Within Groups	298	227.92	.93		
	TOTAL	302	295.93			

* $p < .05$ ** $p < .01$. *** $p < .001$.

Self-Efficacy by ethnicity

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but nine cases did not report ethnicity. A univariate ANOVA was conducted; a summary of results are presented in Tables 8 and 9. Main effects revealed that self-efficacy was significantly different among ethnicities, $F(4, 304) = 2.669$, $p = .033$, partial $\eta^2 = .034$. Estimates of effect size revealed low strength in associations. Scheffe's post hoc test was conducted to determine which ethnic groups were significantly different in self-efficacy. Results reveal that self-efficacy for African-Americans was significantly lower than individuals who reported that they were in an ethnic group other than the selections provided on the survey. The effect size was small. All other ethnicities examined in the study did not significantly differ from each other.

Intrinsic goal orientation by ethnicity

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but nine cases did not report ethnicity. A univariate ANOVA was conducted; a summary of results are presented in Tables 8 and 9. Main effects revealed that intrinsic goal orientation was not significantly different among ethnicities, $F(4, 304) = 1.288$, $p = .275$, partial $\eta^2 = .017$. Estimates of effect size revealed low strength in associations. Results reveal that intrinsic goal orientation did not significantly differ by ethnicity.

Attitudes toward biology by ethnicity

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but nine cases did not report ethnicity. A univariate ANOVA was conducted; a summary of results are presented in Tables 8 and 9. Main effects revealed that intrinsic goal orientation was not significantly different among ethnicities, $F(4, 304) = 1.773$, $p =$

.134, partial $\eta^2=.023$. Estimates of effect size revealed low strength in associations. Scheffe's post hoc test was conducted to determine which ethnic groups were significantly different in self-efficacy. Results reveal that Attitudes toward biology did not significantly differ by ethnicity.

Course performance by ethnicity

Data were screened to ensure that the assumptions of one-way ANOVA were fulfilled. No outliers were eliminated, but nine cases did not report ethnicity. A univariate ANOVA was conducted; a summary of results are presented in Tables 8 and 9. Main effects revealed that self-efficacy was significantly different among ethnicities, $F(4, 304) = 4.828$, $p = .001$, partial $\eta^2=.061$. Estimates of effect size revealed low strength in associations. Scheffe's post hoc test was conducted to determine which ethnic groups were significantly different in self-efficacy. Results reveal that course performance for African-Americans was significantly lower than Caucasians. All other ethnicities examined in the study were not significantly different from each other.

Research Question 3

Another purpose of this study was to confirm the relationships between motivation and attitudes on course performance. Question 3 states: Does self-efficacy, intrinsic goal orientation, or attitudes toward biology directly predict course performance? Bivariate-regression was used to examine the amount of variability explained by each variable.

Self-efficacy predicts course performance

Bivariate regression was conducted to determine the accuracy of the independent variable self-efficacy predicting course performance. Data screening led to the elimination of no cases. Regression results indicate that this particular variable significantly predicts course performance, $R^2=.303$, $R^2_{adj}=.301$, $F(1, 302)=131.526$, $p<.001$. This variable accounts for 30.3% of variance in

course performance. A summary of regression coefficients is presented in Table 10 and indicates a standardized coefficient of $\beta=.551$. As self-efficacy increases by a standardized unit of 1, course performance increases by .551.

Table 10

Self-Efficacy Predicts Course Performance

Variable	<i>B</i>	<i>SE B</i>	β
MSLQ_SE	.087	.008	.551*

Note. $R^2 = .303$ ($N = 318$, $p < .01$).

* $p < .05$

Intrinsic goal orientation predicts course performance

Bivariate regression was conducted to determine the accuracy of the independent variable intrinsic goal orientation predicting course performance. Data screening led to the elimination of no cases. Regression results indicate that this variable significantly predicts course performance, $R^2 = .015$, $R^2_{adj} = .012$, $F(1, 302) = 4.607$, $p < .001$. This variable accounts for 1.5% of variance in course performance. A summary of regression coefficients is presented in Table 11 and indicates a standardized coefficient of $\beta = .123$. As intrinsic goal orientation increases by a standardized unit of 1 course performance increases by .123.

Table 11

Intrinsic Goal Orientation Predicts Course Performance

Variable	<i>B</i>	<i>SE B</i>	β
MSLQ_SE	.045	.021	.123*

Note. $R^2 = .015$ ($N = 318$, $p < .01$).

* $p < .05$

Attitudes toward biology predicts course performance

Bivariate regression was conducted to determine the accuracy of the independent variable attitudes toward biology predicting course performance. Data screening led to the elimination of no cases. Regression results indicate that this variable significantly predicts course performance, $R^2 = .142$, $R^2_{adj} = .139$, $F(1, 302) = 49.815$, $p < .001$. This variable accounts for 14.2% of variance in course performance. A summary of regression coefficients is presented in Table 12 and indicates a standardized coefficient of $\beta = .376$. As attitudes toward biology increases by a standardized unit of 1 course performance increases by .376.

Table 12

Attitudes Toward Biology Predict Course Performance

Variable	<i>B</i>	<i>SE B</i>	β
MSLQ_SE	.029	.004	.376*

Note. $R^2 = .142$ ($N = 318$, $p < .01$).

* $p < .05$

Research Question 4

The primary purpose of this study was to test the Constructivist Learning Environment and Motivation (CLEM) model. Question 4 states: Does self-efficacy, intrinsic goal orientation, or attitudes toward biology directly predict course performance? Path analysis was used to test the model.

A path analysis was conducted to determine the causal effects among the variables perception of learning environment (*CLES_TOTAL*, Z_1), intrinsic goal orientation (*IGO*, Z_2), self-efficacy (*MSLQ_SE*, Z_3), attitudes toward biology (*BAS_Likert*, Z_4), and course performance (*Grade_Z_Score*, Z_5). Prior to analysis, seven cases were removed because one was an outlier and grades could not be matched to 6 cases. The initial model, presented in Figure 3, was consistent with the empirical data. However, one of the reproduced correlations exceeded a difference of .05. Furthermore, the strong correlation between variables may have caused three *negative net suppressor variable phenomena*. This phenomenon is identified by two variables having a significant positive correlation and a significant negative standardized beta (path coefficients) or vice versa (Davis, 1985) (see Figures 3 and 4). The negative beta should not be interpreted as a negative relationship. One interesting note is that this phenomenon may dramatically increase the standardized beta (path coefficient) with a common third variable; note

the zero-order correlation (.565) between self-efficacy and course performance in Figure 3 and the higher standardized beta (path coefficient) (.667) in Figure 4.

* = $p < .05$ level (2-tailed). ** = $p < .01$ level (2-tailed)

Figure 3. The initial Constructivist Learning Environment and Motivation (CLEM) Model depicting Pearson correlations followed by reproduced correlations.

* = $p < .05$ level (2-tailed). ** = $p < .01$ level (2-tailed)

Figure 4. The initial Constructivist Learning Environment and Motivation (CLEM) Model depicting path coefficients.

The non-significant path of *BAS_Likert* to *Grade_Z_Score* created another small problem for the model, but that particular path could not be removed from the model. Removing the variable *BAS_Likert* from the model caused the reproduced correlations to move further away from the zero-order correlations, but still within .05 units. This indicates that attitudes toward biology are an important component of the model. However, removing the variable

Grade_Z_Score produced an improved model, though one negative net suppressor variable phenomenon remained. Although unnecessary, a revised model was generated and is presented in Figures 5 and 6. Recomputation of reproduced correlations for the revised model indicated consistency with the empirical correlations as no reproduced correlations exceeded a difference of .05 (see Figure 5).

* = $p < .05$ level (2-tailed). ** = $p < .01$ level (2-tailed)

Figure 5. The revised Constructivist Learning Environment and Motivation (CLEM) Model depicting Pearson correlations followed by reproduced correlations.

* = $p < .05$ level (2-tailed). ** = $p < .01$ level (2-tailed)

Figure 6. The revised Constructivist Learning Environment and Motivation (CLEM) Model depicting path coefficients.

All path coefficients for both the initial and revised models were significant at the .05 level, with the exception of the path from attitude towards biology to course performance in the initial model. The direct, indirect, and total causal effects of the initial model are presented in Table 13. The outcome of primary interest was self-efficacy (.583). The remaining determinants of course performance as indicated by total causal effect were attitudes toward biology (.488),

learning environment (CLES_TOTAL) (.136), and intrinsic goal orientation (.115). This model explained approximately 36.0% of variance in course performance. The primary determinant of attitudes toward biology was self-efficacy (.674) with intrinsic goal orientation (.483) and perceptions of learning environment (CLES_TOTAL) (.288) following. Approximately 51.6% of variance in attitudes toward biology was explained by the model. The two determinants of self-efficacy were nearly equal: Intrinsic goal orientation (.471) and learning environment (CLES_TOTAL) (.461). Approximately 30.5% of variance in self-efficacy was explained by the model. The only determinant of intrinsic goal orientation was learning environment (CLES_TOTAL). Approximately 18.3% of variance in intrinsic goal orientation was explained by the model. In both models $n=309$.

Table 13

Summary of Causal Effects for Initial CLEM Model

Outcome	Determinant	Causal Effects		
		Direct	Indirect	Total
Intrinsic Goal ($R^2=.183$)	CLES_TOTAL	.428*	—	.428
Self-Efficacy ($R^2=.305$)	CLES_TOTAL	.318*	.143	.461
	Intrinsic Goal	.335*	.136	.471
Attitudes ($R^2=.516$)	CLES_TOTAL	-.102*	.390	.288
	Intrinsic Goal	.335*	.251	.483
	Self-Efficacy	.628*	.046	.674
Course Performance ($R^2=.360$)	CLES_TOTAL	-.111*	.247	.136
	Intrinsic Goal	-.174*	.289	.115
	Self-Efficacy	.667*	-.084	.583
	Attitudes	.046	.442	.488

*Direct effect is significant at the .05 level.

Table 14

Summary of Causal Effects for Revised CLEM Model

Outcome	Determinant	Causal Effects		
		Direct	Indirect	Total
Intrinsic Goal ($R^2=.183$)	CLES_TOTAL	.428*	—	.428
Self-Efficacy ($R^2=.305$)	CLES_TOTAL	.318*	.143	.461
	Intrinsic Goal	.335*	.136	.471
Attitudes ($R^2=.516$)	CLES_TOTAL	-.102*	.390	.288
	Intrinsic Goal	.335*	.251	.483
	Self-Efficacy	.628*	.046	.674

*Direct effect is significant at the .05 level.

Summary

Statistical analyses of the data support several significant findings. The summarized findings and educational conclusions will be presented in Chapter V along with a discussion of the direct implications for instructors and educational leadership in higher education.

In Research Question 1, the five scales of the CLES predict course performance, self-efficacy, intrinsic goal orientation, and attitudes toward biology. However, Personal Relevance was the only significant contributor to the course performance and attitudes toward biology models; while Personal Relevance and Critical Voice were the only significant contributors to the self-efficacy model; and Personal Relevance and Shared Control were the only significant contributors to the intrinsic goal orientation models. Personal Relevance was the primary contributor in each model.

In Research Question 2, CLES_TOTAL and attitudes toward biology do not significantly differ by gender. Self-efficacy and intrinsic goal orientation for males are significantly higher than they are for females, but course performance for males is significantly lower than it is for females. The effect size for all significant findings was small. CLES_TOTAL, intrinsic goal orientation, and attitudes toward biology do not significantly differ by ethnicity. However, Self-efficacy for African-Americans is significantly lower than it is for individuals who reported that they were in an ethnic group other than the selections provided on the survey. All other ethnicities examined in the study were not significantly different from each other. Research Question 2 also showed that course performance for Caucasians was significantly higher than course performance for African-Americans, with a small effect size.

In Research Question 3, self-efficacy, intrinsic goal orientation, and attitudes toward biology all predict course performance. Self-efficacy accounts for 30% of variance and as self-efficacy increases by a standardized unit of one, course performance increases by .551. Intrinsic goal orientation accounts for 1.5% of variance and as intrinsic goal orientation increases by a standardized unit of one, course performance increases by .123. Attitudes toward biology accounts for 14.3% variance and as attitudes toward biology increases by a standardized unit of 1 course performance increases by .376.

In Research Question 4, Both the initial and revised CLEM models, presented in Figure 3 and Figure 4, were consistent with the empirical data. The initial model explained approximately 36.0% of variance in course performance and the outcome of primary interest was self-efficacy. The relationship between self-efficacy and course performance increased from a zero-order correlation of .565 to a standardized beta of .667 when the other variables are added to the model. The initial and revised models contained negative net suppressor variables.

CHAPTER V. DISCUSSION AND CONCLUSION

Introduction

One purpose of this study was to test the Constructivist Learning Environment and Motivation (CLEM) model (see Figure 1). The CLEM model is a mediated model that explains the causal relationships among aspects of the learning environment as defined from a constructivist perspective (shared control, student negotiation, personal relevance, critical voice and uncertainty of science; depicted as *CLES_TOTAL* in figure 1), motivation constructs (intrinsic goal orientation and self-efficacy for learning and performance), attitudes toward biology, and course performance in a large undergraduate biology course for nonmajors. No other educational researcher has previously included these particular variables into a single model. The CLEM model has incorporated the ideas of Bandura's (1981) self-efficacy theory, Fraser and Wallberg's (2005) view of the constructivist-learning environment, Dorman and Adams' (2004) views on the relationships between classroom environment, academic efficacy, and grades, Palmer's (2005) ideas of incorporating motivation and constructivism, Osborne, Simon, and Collins' (2003) views on attitudes toward science and motivation, and Deci and Ryan's (1985) views on self-determination theory and intrinsic motivation. The CLEM model was created by the author of this dissertation and was assessed by path analysis. This chapter is organized into five sections: 1) introduction, 2) summary of statistical findings, 3) discussion, 4) implications instructors and leaders in higher education, and 5) implications for further research.

This study was designed to examine several research questions, including:

- 1) Does the Constructivist Learning Environment Survey (CLES), a multi-dimensional assessment of classroom learning environment, directly predict course performance, self-efficacy, intrinsic goal orientation, or attitudes towards biology?

- 2) Does the Constructivist Learning Environment Survey (CLES), self-efficacy, intrinsic goal orientation, attitudes toward biology, or course performance significantly vary by ethnicity or gender?
- 3) Does self-efficacy, intrinsic goal orientation, or attitudes toward biology directly predict course performance?
- 4) Is the proposed CLEM model — which describes the causal effects among the variables perception of learning environment (CLES), attitudes toward biology, intrinsic goal orientation, self-efficacy for learning and performance, and course performance — consistent with observed correlations among these variables?

Summary of Statistical Findings

Although the data were collected using three instruments focusing on classroom learning environment, attitudes toward biology, and motivation, the statistical findings were organized around the previously described research questions. Following this method, each of the following four sections will present conclusions based on the research questions.

Research Question 1

- The CLES predicts course performance, accounting for 3.6% of variance. Only Personal Relevance contributes to the model.
- The CLES predicts self-efficacy, accounting for 24.7% of variance. Only Personal Relevance and Critical Voice contribute to the model. Personal Relevance is the primary contributor.
- The CLES predicts intrinsic goal orientation, accounting for 23.5% of variance. Only Personal Relevance and Shared Control contribute to the model. Personal Relevance is the primary contributor.

- The CLES predicts attitudes toward biology, accounting for 18.0% of variance.
Only Personal Relevance contributes to the model.

Research Question 2

Gender

- CLES_TOTAL did not significantly differ by gender.
- Self-efficacy for males was significantly higher than it was for females. Effect size was small.
- Intrinsic goal orientation was significantly higher for males than it was for females. Effect size was small.
- Attitudes toward biology did not significantly differ by gender.
- Course performance for males was significantly lower than it was for females. Effect size was small.

Ethnicity

- CLES_TOTAL did not significantly differ by ethnicity.
- Self-efficacy for African-Americans was significantly lower than it was for individuals who reported that they were in an ethnic group other than the selections provided on the survey. All other ethnicities examined in the study did not significantly differ from each other.
- Intrinsic goal orientation did not significantly differ by ethnicity.
- Attitudes toward biology did not significantly differ by ethnicity.
- Course performance for African-Americans was significantly lower than it was for Caucasians. All other ethnicities examined in the study were not significantly different from each other.

Research Question 3

- Self-efficacy predicts course performance, accounting for 30.3% of variance. As self-efficacy increases by a standardized unit of 1, course performance increases by .551.
- Intrinsic goal orientation predicts course performance, accounting for 1.5% of variance. As intrinsic goal orientation increases by a standardized unit of 1 course performance increases by .123.
- Attitudes toward biology predict course performance, accounting for 14.3% variance. As attitudes toward biology increases by a standardized unit of 1 course performance increases by .376.
- Question 1 determined that the CLES accounts for 3.6% of variance in course performance.

Research Question 4

- Both the initial and revised CLEM models, presented in Figure 3 and Figure 4, were consistent with the empirical data.
- The initial model explained approximately 36.0% of variance in course performance and the outcome of primary interest was self-efficacy. The relationship between self-efficacy and course performance increased from a zero-order correlation of .565 to a standardized beta of .667 when the other variables are added to the model. The initial and revised models contained negative net suppressor variables.

Discussion

Research Question 1

The CLES is successful in predicting course performance, but it only explains a very small amount of variance (3.6%). However, the CLES does explain a fair amount of variance in self-efficacy (24.7%), intrinsic goal orientation (23.5%), and attitudes toward biology (18%), each of which help predict course performance. The CLES is used to assess student's perceptions of their learning environment on five scales. The five scales that make up the CLES are (a) *personal relevance*: relevance of learning to students lives; (b) *uncertainty of science*: provisional status of scientific knowledge; (c) *critical voice*: legitimacy of expressing a critical opinion; (d) *shared control*: participation in planning, conducting and assessing of learning; and (e) *student negotiation*: involvement with other students in assessing viability of new ideas (Taylor et al., 1994).

In Research Question 1, the results clearly show that personal relevance is either the largest or the only contributor among the five scales on the CLES for all of the variables examined. This adds support to stressing the importance of constructivist pedagogy in course design. The cornerstone of constructivism is assessing students' prior knowledge and building on that foundation (Piaget, 1954). If (a) students make sense of the world in relation to the knowledge which they have already constructed (Fraser, 1998); and (b) social constructivism (Vygotsky, 1978) stresses the significance of society, culture, and language (Lemke, 2001), where knowledge is socially constructed and acquired in specific social and cultural contexts; then (c) a student who finds a subject meaningful to his or her life is likely to be more highly motivated to study that subject and hold higher attitudes toward studying that subject. It makes sense for a student to devote more time and resources to a course her or she views as personally

relevant, thus the higher motivation to pursue it, and if a student is surrounded by a culture that highly values that subject the student will naturally have higher attitudes toward studying it.

Personal relevance is important. However, it may be often overlooked when developing a course. Personal relevance seems to be a good way to build self-efficacy and should be a central goal of a constructivist, motivation-minded, reform-based course.

It is worth noting that personal relevance may have been such a large contributor to the models because the study asked for perception and this scale could potentially provide the largest variability among the variables, since the others were primarily dependent on the instructor and personal relevance is partially dependent on the student's personal background. However, this was not the case. The highest standard deviations were found among shared control and student negotiation, with personal relevance ranking third.

The other significant contributors to the models in research question one include 1) critical voice, which contributes to self-efficacy and 2) shared control, which contributes to intrinsic goal orientation. These results support the findings of Osborne, Simon, and Collins (2003) as well as Black and Deci (2000) and may be explained by the students' perceptions of their personal autonomy. Osborne, Simon, and Collins (2003) recommended that educators increase students' personal autonomy. Personal autonomy refers to students' desires to be self-governing and involved in their lessons. Black and Deci (2000) describe autonomy support as the level of self-determination a teacher allows a student so the student may attach his or her behavior to personal goals, interests, and values. In other words, choice and decision making are important to motivation and attitudes.

A study conducted by Black and Deci (2000) with college level organic chemistry students revealed that students' perceptions of a more autonomy-supportive instructor predicted

increases in autonomous self-regulation, higher perceived competence, and higher interest in the course. Self-regulation refers to “planning and managing time; attending to and concentrating on instruction; organizing, rehearsing, and coding information strategically; establishing a productive environment; and using social resources effectively” (Schunk & Zimmerman, 1997, p. 195). The resulting change in students’ autonomous self-regulation was successfully used to predict students’ performance in the course. Furthermore, instructor autonomy support directly predicted student performance for students who reported initially low levels of autonomous self-regulation. Instructor autonomy support also predicted student performance when controlling for student ability. The course performance variable was measured as the final grade received in the course. In the current study, if student ability were controlled for, the relationship between the CLES and course performance may have been stronger.

In this study, students who reported higher levels of shared control reported higher intrinsic goal orientation, and students who reported higher levels of critical voice reported higher levels of self-efficacy. As defined by Taylor et al. (1994), shared control and critical voice are attributes of personal autonomy (Deci & Ryan 2002), and the perception of a more autonomy-supportive instructor leads to increases in autonomous self-regulation, higher perceived competence, and higher interest in the course (Black and Deci, 2000). Therefore, it is no surprise that a student who perceives his or her learning environment as autonomy supportive and has the opportunity to voice their opinions (critical voice) will report higher levels of self-efficacy. Furthermore, students who perceive more shared control and critical voice (personal autonomy) in the classroom will be more likely to participate in class activities and to persist on their own without the need for high levels of extrinsic motivators. Intrinsic motivation involves being impulsively attracted to activities that provide the best possible challenge, chances for

unbound action, and the possibility of “testing one’s skills with a reasonable chance of success” (Deci & Ryan, 2000, p 100). Therefore, it is the need for competence that combines with autonomy to influence intrinsic motivation (Koestner, Weinberger, & McClelland, 1991). That need for competence may be satisfied through shared control.

It is important to note that just because the uncertainty of science and student negotiation scales in the CLES were not significant contributors to the variables in this study, does not mean they are not important. The CLEM model is concerned with attitudes and motivation. Course performance may be considered an indirect measure of learning, but it is more of a measure of persistence, self-regulation, and past experiences. Previous knowledge is not controlled for when assigning final course grades in a college biology course, yet previous knowledge may have an effect on final course grade. Students who were better prepared for college biology courses by their high school experiences will have an easier time earning a higher grade in college, but not necessarily. They still must put in some effort, although not as much effort as a student whose high school experiences left him or her ill prepared for college biology. Had one of the variables in this study been a direct measure of learning achieved in their college course, perhaps uncertainty of science or student negotiation would have been significant contributors to that variable as predicted by the constructivist paradigm.

Research Question 2

The results from question two are inconclusive. Although statistical significance was found among males and females for self-efficacy, intrinsic goal orientation, and course performance, the effect size in each case was small. This indicates that there may be a difference, but it is not pronounced. The significant differences may be due to the large sample size. However, the literature does report disparities between males and females in the sciences derived

from environmental and societal factors (Tindall & Hamil, 2004). In fact, according to the American Association of University Women [AAUW] (2002), teachers interact more often and in more detail with males than with females. This seems to be the case from preschool all the way up through college. In fact, by the time females complete high school, they will have received 1,800 fewer hours of attention than males (Woolfolk, 1998). This could explain the higher self-efficacy found in males in this study. The AAUW have found that teachers tend to choose class activities that appeal to boys' interests more than girls and use teaching methods that favors learning in boys. This may explain why males have higher intrinsic goal orientation toward studying biology in this study.

The differences in male and female course grades in this study are consistent with the findings of Evans (2002) who compared male and female standardized test scores to grades earned. They explain that despite the fact that females typically received better grades in school, males tended to score higher on the verbal and mathematics sections on the SAT. In addition, Mewborn (1999) compared male and female performance on the standardized test scores for entrance into graduate school, law school, and medical school. Males outscore females in each case. The AAUW (2002) maintains that between males and females who score similarly on the SAT, females tend to receive better grades in college. It seems that males are better at standardized achievement tests, while females are better at course performance. A study that controls for gender may produce an improved model. However, given the very small effect size found in this study, it seems that this particular study does not adequately identify the disparities between males and females or the cause of disparity between them.

Self-efficacy for African-Americans was significantly lower than individuals who reported that they were in an ethnic group other than the selections provided on the survey

(Others). All other ethnicities examined in the study did not significantly differ from each other. It seems that this question was poorly designed, because 6.5% of the respondents reported belonging to the “others” category. People who referred to themselves as “others” may have been of middle-eastern or Indian descent. Another possibility is that some respondents may have been philosophically opposed to reporting their ethnicity. Either way, since it is unknown who the “Others” are, conclusions cannot be drawn about them or why they differed from African-Americans.

Course performance for African-Americans was significantly lower than Caucasians with a small effect size. The results are inconclusive and perhaps ethnicities should be compared by number of prior science courses completed. A study that controls for ethnicity may produce an improved model. However, given the very small effect size found in this study, it seems that this particular study does not adequately identify the disparities between ethnicities or the causes of disparity between them.

Research Question 3

Question 3, along with Question 1, demonstrate that intrinsic goal orientation and the CLES are significant predictors of course performance, but they account for very small amounts of variance (1.5% and 3.6%, respectively). This indicates that although they are significantly related to course performance they do not have particularly strong total effects. This agrees with the findings of Talton and Simpson (1987) who reported that the relationship between classroom environment and course performance is weak. They suggested an affective mediator was involved. Self-efficacy and attitudes account for larger amounts of variance (30.3% and 14.3%, respectively) and stronger total effects on course performance. The value of this research question is in its contributions to interpreting the results of Research Question 4.

Research Question 4

The CLEM model is consistent with the empirical data and explains 36% of variance in course performance. This is not surprising since the model was based on known relationships found throughout the science education literature. While the model does provide some interesting results there is much room for improvement. The most obvious conclusions that may be drawn from the initial model, are that the CLES_TOTAL has a moderate direct effect on intrinsic goal orientation (.428) and a moderate total effect on self-efficacy (.461). Therefore, learning environment is important to these variables. For example, if teachers wish to increase intrinsic goal orientation in their students, they will provide personal relevance and opportunities for shared control. If teachers wish to increase student self-efficacy, they will provide personal relevance and opportunities for critical voice. The causal relationships between these variables may be confirmed through controlled experimentation.

Looking at Table 13 a little more closely will reveal that the CLES_TOTAL has a significant, but weak direct effect on course performance (negative net suppressor) and a moderate indirect effect (.247). The worth of the CLES_TOTAL becomes even more important when examining its relationship with attitudes. Again, there is a very weak direct effect (negative net suppressor) and a moderate indirect effect (.390). This indicates a moderator between CLES_TOTAL and course performance, as well as CLES_TOTAL and attitudes. More specifically, self-efficacy is the moderator between these variables, with a moderate total effect between CLES_TOTAL and self-efficacy (.461) as well as a strong direct relationship between self-efficacy and grades (.667). The sum of these two paths equals .307, indicating a moderate mediator. In other words, in a particular class a student perceives as personally relevant and where he or she is given opportunities for critical voice, self-efficacy will increase and in turn so

will course performance. Remember, the CLES_TOTAL accounted for 24.7% variance in self-efficacy and self-efficacy explained 30.3% of variance in grades. Therefore, to increase course performance, a teacher may try to build student self-efficacy. One way to build self-efficacy is to provide personal relevance and opportunities for critical voice. Again, this may be confirmed through controlled experimentation.

One interesting relationship revealed by the CLEM model is the relationship between self-efficacy and course performance. The zero order correlation between self-efficacy and course performance is moderate (.565), but when the other variables are added to the model, it actually increases to a standardized beta of .667 and the relationships between CLES_TOTAL and course performance, as well as intrinsic goal orientation and course performance, change from positive to negative. This is the result of a negative net suppressor variable phenomenon. The negative betas should not be interpreted as negative relationships, but they do indicate relatively weak relationships compared to the very strong relationship between self-efficacy and course performance. Since the relationships between CLES_TOTAL and self-efficacy, as well as intrinsic goal orientation and self-efficacy are moderate, this provides support to the relationship of self-efficacy as a mediator between course performance and these two variables. In other words, if an instructor increases personal relevance, opportunities for critical voice, and intrinsic goal orientation, then self-efficacy will increase, and in turn so will course performance.

Perhaps the most interesting relationship revealed by the CLEM model is the relationship between self-efficacy, attitudes toward biology, and course performance. Self-efficacy is believed to be a strong determinant of behavioral and emotional processes, such as course performance and attitudes. In fact, Bandura (1997) felt that attitudes influence course performance through their mediating effects on an individual's self-efficacy beliefs. Although the

significant zero-order correlation between attitudes and course performance in the present study is moderate (.390), and a large body of literature supports this relationship (Fennema & Leder, 1990; Haladyna, Olsen, & Shaughnessy, 1982; Lester & Garofalo, 1987; Mattern & Schau, 2002; Papanastasiou & Papanastasiou, 2002; Papanastasiou & Papanastasiou, 2004; Shrigley, 1990; Weinburgh, 1995), the standardized beta becomes an insignificant .046 when self efficacy is added to the model. Usually an insignificant relationship should be removed from a path-analysis model, unless a large amount of literature supports that relationship. Due to the large amount of literature supporting this relationship, it was not necessary to remove it from the model.

Table 13 indicates that the indirect relationship between attitudes and course performance is moderate (.442) and removing attitudes from the model creates problems, indicating that it is indeed important. The total relationship between self-efficacy and attitudes was high (.674) and the direct relationship between self-efficacy and course performance was also high (.667). This indicates that self-efficacy is a mediator between attitudes toward biology and course performance; and not the other way around as suggested by Bandura (1997). Perhaps, the recursive relationship between self-efficacy and attitudes needs to be reconsidered through structured equation modeling, which can accommodate non-recursive relationships.

Whether attitudes towards biology is positioned properly in the model or not, it is clear that attitudes has an important indirect relationship with course performance. In other words, if a teacher would like to improve course performance, one potential way to do this is to increase attitudes, which will in turn increase self-efficacy and thus course performance. Once again, this may be confirmed through controlled experimentation.

One final note. Logically, there will always be a strong correlation between self-efficacy and course performance at the end of a course, because students have already performed in the

course and smaller successes along the way should have increased self-efficacy, thus a double arrow should be represented between these two variables representing a non-recursive relationship. Remember, this model only represents what students are leaving this particular introductory biology course with. The relationships among all of the psychometrics examined in this study may change throughout the semester. Again, this model should be examined by structural equation modeling, which can accommodate non-recursive relationships.

Implications for Instructors and Educational Leaders in Higher Education

Instructors

As described in the previous section, this model has many implications for biology instructors teaching nonmajor introductory biology courses and a few common themes have emerged. First, instructors concerned with disparities among genders or ethnicities should ensure that all students are given equal time and attention as well as equal opportunities to build self-efficacy. Secondly, this model demonstrates the importance of constructivist pedagogy in course design and the need to increase students' personal autonomy. To increase course performance, a teacher may try to build student self-efficacy. A few ways to build self-efficacy are to make the course personally relevant to students' lives, provide opportunities for students to express a critical opinion of the subjects discussed within the course, and increase intrinsic goal orientation. If self-efficacy increases, so will course performance. If a teacher wishes to increase intrinsic goal orientation in their students, that teacher will provide personal relevance and opportunities for students to participate in the planning, conducting and assessing of learning. An increase in students' attitudes toward biology may lead to higher self-efficacy, but further research is needed.

Bandura (1997) suggested four ways to increase self-efficacy: mastery experiences,

vicarious experiences, verbal persuasion, and physiological/affective state. *Mastery experiences* are previous experiences of success with a task and will result in higher self-efficacy of that task. Therefore, students should be given series of short-term proximal goals to steadily increase or maintain self-efficacy (Pajares, 2002). *Vicarious experiences* occur when students watch a teacher or other students successfully perform a task and the student feels as if he/she could just as easily perform that task. This results in higher self-efficacy. In addition, if the teacher openly and honestly admits making mistakes, students will understand that mistakes are acceptable and can be overcome (Pajares, 2002). *Verbal persuasion* occurs when students receive positive feedback for success and effort. This feedback will help persuade students to do the desired behavior, such as earn higher grades. This too will result in higher self-efficacy. *Physiological/affective state* refers to a student's awareness and interpretation of their physiological responses to stressful situations. If students treat this response as a normal process rather than as a sign of inability, self-efficacy will increase.

Table 15 (below) provides suggestions for a reform-based motivation-minded undergraduate biology course. The column on the far left lists the constructs important to building motivation in the classroom: personal relevance, critical voice, shared control, attitudes toward biology, and self-efficacy. The middle column lists the conditions found in a generalized "traditional classroom", while the column on the right lists reform-based motivation-minded alternatives. The first suggestion for each construct is provided by Brandsford, Brown, and Cocking (2000). Their work is based on a synthesis of many rigorous empirical studies and the present study fully supports their findings and suggestions. The other suggestions in Table 15 come from findings of the present study and other pertinent literature.

The first set of recommendations deals with personal relevance. Problem 2 states

“Assumes prerequisites were acquired in high school” with the recommendation of “Assess prior knowledge and use it to build new knowledge”. For a list of ways to assess prior knowledge see Angelo and Cross’ (1993) book entitled *Classroom Assessment Techniques*. Other ways to make a class more personally relevant to students are to use local newspaper articles or articles in popular science magazines such as *Scientific American* to help frame the curriculum.

Furthermore, class projects should contribute to the local community. Even if students come from far away hometowns, many of them live in the local community while attending college.

To make classes personally relevant instructors should work with local entities such as the humane society, water treatment, Marine Fisheries, or U.S. Fish and Wildlife. Problem-based learning may be used to address local problems. To encourage critical voice in even a large lecture, discussion boards may be used. To ensure critical voice, allow students to play “devil’s advocate” or other similar roles where they can express concerns with what they are being taught. Students may also be encouraged to reply to their peers’ posts with critique or support. Shared control and attitudes may be addressed by allowing students to choose among various projects and to work in teams on problem-based or inquiry-based projects. Students should be involved in the design of the project. Self-efficacy may be addressed by allowing students to form organized concept maps and providing peer and instructor feedback by formative assessments. These techniques may help students organize and test their knowledge. For other methods to increase student self-efficacy see Bandura (1997). Formative assessment and problem-based learning may also increase student intrinsic goal orientation.

Table 15

Suggestions for a Reform-Based Motivation-Minded Undergraduate Biology Course

Motivational Construct	Traditional Biology Undergraduate Course (Generalized)	Reform-Based Biology Undergraduate Course (Motivation Minded)
Personal Relevance	<ol style="list-style-type: none"> 1. Lecture topics not clearly linked to students lives 2. Assumes prerequisites were acquired in high school. 3. Textbook dictates curriculum 4. Curriculum static over time 5. Projects are simulations contained within the classroom. 6. Low levels of situational interest 7. Little opportunities for decision making. 8. Promote performance goals 	<ol style="list-style-type: none"> 1. <i>Community centered environments</i> establish norms where students are not afraid to take academic risks and make mistakes. Courses should link classroom learning to other aspects of students' lives to promote personal relevance (Brandsford, Brown, & Cocking, 2000). 2. Assess prior knowledge and use it to build new knowledge. 3. Local problems frame the curriculum. 4. Curriculum dynamic from year to year. 5. Class projects contribute to the local community (Brandsford, Brown, & Cocking, 2000). 6. Lessons that actively involve students and are relevant to students' lives will bring about situational interest (Mitchell, 1997); Flowerday, Schraw, and Stevens (2004) demonstrated that situational interests increase the level of engagement among students. 7. Students will feel that they have ownership in classroom activities if allowed to make relevant decisions. 8. Maximize goal achievement by providing some classroom autonomy. Materials should be meaningful and relevant to the students so they will perceive the comprehension of course concepts as beneficial, thus promoting the development of mastery goals (Ames, 1992).
Critical Voice	<ol style="list-style-type: none"> 9. No opportunities to voice disagreement with instructor 	<ol style="list-style-type: none"> 9. <i>Community centered environments</i> establish norms where students are not afraid to take academic risks and make mistakes. Students should build a critical voice where they may express critical opinions (Brandsford, Brown, & Cocking, 2000).
Shared Control	<ol style="list-style-type: none"> 10. Teacher centered; Instructor determines all aspects of course 	<ol style="list-style-type: none"> 10. <i>Student centered environments</i> encourage students to make connections between previous knowledge and their current academic engagements by providing students with shared control in the planning, conducting, and

Motivational Construct	Traditional Biology Undergraduate Course (Generalized)	Reform-Based Biology Undergraduate Course (Motivation Minded)
Attitudes	11. Students compete against each other 12. Traditional lecture format 13. Controlling Environment	<p>assessment of learning (Brandsford, Brown, & Cocking, 2000).</p> 11. <i>Community centered environments</i> establish norms where students are not afraid to take academic risks and make mistakes. The classroom should promote intellectual camaraderie and positive attitudes toward learning that build a sense of community within the classroom (Brandsford, Brown, & Cocking, 2000). 12. High levels of student involvement, high student-to-student affiliation, high teacher support, and low levels of teacher control (Myers & Fouts, 1992). 13. Autonomy-supportive environments are associated with more positive influence on attitudes than controlling environments (Ryan & Grolnick, 1987).
Self-Efficacy	14. Passive learners 15. Little or no feedback from instructors	14. <i>Knowledge centered environments</i> provide developmentally appropriate lessons that present well-organized knowledge that is accessible in appropriate contexts, which will in-turn encourage learning and problem solving. Organize knowledge into clusters that are much easier to retrieve for problem solving, and mastery of concepts facilitates learning to new problems. Teach students to monitor their understanding and progress in problem solving (Donovan, Brandsford, & Pellegrino, 1999); Students should be actively thinking about what is being presented (Angelo, 1990). 15. Instructors provide mastery experiences, vicarious experiences, verbal persuasion, and physiological/affective state (Bandura, 1997); Instructors use scaffolding to provide step-wise successes (Vygotsky, 1978); Encouraging feedback from instructor (Tuckman and Sexton, 1991).

Motivational Construct	Traditional Biology Undergraduate Course (Generalized)	Reform-Based Biology Undergraduate Course (Motivation Minded)
Intrinsic Goal Orientation	<p>16. High stakes accountability schemes</p> <p>17. Controlling authority; Extrinsic rewards for success; threat, deadlines, directives, and competition pressure</p> <p>18. Do not do scientific investigation (Romberg, 1998)</p>	<p>16. <i>Assessment centered environments</i> use formative assessments that allow students opportunities to revise and improve their thinking, and help teachers identify misconceptions that need to be addressed. Successes achieved at the appropriate level, or zone of proximal development, provide the intrinsic motivation for further learning (Donovan, Brandsford, & Pellegrino, 1999); Challenge set at correct level (Lepper & Hodell, 1989).</p> <p>17. Autonomy supportive classrooms offer choice and opportunities for self-direction. Instructors should take student's perspective, show empathy, provide relevant information for decision making, and offer opportunities for decision making (Ryan & Deci, 2002).</p> <p>18. Inquiry-based curriculum; Use discrepant events demonstrations to temporarily raise intrinsic motivation (Nussbaum & Novick, 1982).</p>

Educational Leaders

Introduction

Many instructors teaching introductory biology courses for nonmajors are probably not aware of postsecondary science education reform efforts at the local, state, and national levels. An instructor with little or no training in pedagogy may not even be aware of constructivism. Instructors may not know that personal relevance, critical voice, and intrinsic motivation are important factors that may account for as much as 30% of the variability in their students' self-efficacy toward performing in their class. In the same vein, instructors may not be aware that student self-efficacy alone accounts for as much as 30% of the variance in course performance. Many instructors are probably not aware that self-efficacy may be increased among students over

a semester. Some instructors may not be aware that the resulting increase in self-efficacy could potentially increase their students' course performance and perhaps academic achievement in that subject area. Simply, instructors will not know these things are important unless they are taught that they are important. Even if an instructor is aware of such things, he or she may not change the way he or she teaches unless there is incentive to do so. There are costs, such as time commitment, involved with making any type of course change and the costs must not outweigh the perceived benefits. Most importantly, faculty must be viewed as students of pedagogy and all of the recommendations aimed at instructors using constructivist methods to increase student self-efficacy apply equally well to administrators using constructivist methods to increase faculty self-efficacy for implementing constructivism in their classes. The following recommendations are inspired by the findings of this dissertation, but go beyond the scope of this particular study and apply to a broad range of issues and educational settings.

Managing change

It is the job of educational leaders to influence the behaviors of their faculty, staff, and student body, individually and in groups (Hersey, Blanchard, & Johnson, 2001). Influence means changing from one behavior to another. Therefore, when discussing science reform efforts leaders must be effective change managers. To be effective change managers, leaders must have good diagnostic skills to analyze the demands of the environment and develop the means to change some or all of the pertinent situational variables (Hersey, Blanchard, & Johnson, 2001).

Change managers may follow the Map of the Change Process developed by Beckhard and Harris (1977). The first step is to diagnose the problem and to articulate why change is necessary. The diagnosis may come from within the college or university or it may be external. Preferably, the diagnosis is made by someone who is fully cognizant of the problems and related

issues. The diagnosis of the problem should be based in empirical research. Currently many problems have been identified in the literature surrounding nonmajor introductory biology courses. The problem identified and analyzed in this dissertation deals with student attitudes and motivation to increase course performance, which also may be interpreted as faculty members' failure to foster positive attitudes and motivation to their students. In the current study the body of literature surrounding this problem was reviewed and causal variables were identified. Rensis Likert (1961) describes causal variables as independent variables that can be altered or changed by the organization or its management. The results of this study show that the problem of poor course performance among biology students may be articulated as a self-efficacy issue among students. Self-efficacy is a variable that may be changed with little resources and minimal effort. Furthermore, changes in self-efficacy could potentially make a large impact in student course performance.

A leader may wish to thoroughly assess the current state of faculty teaching methods, student motivation, or some other desired characteristic among faculty and students in nonmajor introductory biology courses, and weigh it against a desired and realistic future state. If a leader has evidence that the identified issue is a problem worth addressing (i.e., benefit outweighs cost), there are not more pressing issues that need to be addressed first, and there is indeed a need for change, then that leader may progress to the next stage of change management.

The second step in the Beckhard and Harris (1977) Map of the Change Process is implementation. Kurt Lewin (1947) identified three phases of the change process: 1) unfreezing, 2) changing, and 3) refreezing. In the unfreezing phase, the aim is to motivate and prepare individuals or groups for change. In higher education, this may be very difficult to do, because of the high level of autonomy afforded to instructors in their course design. In fact, the best time to

do this is when instructors sit down to design a new course that he or she has never taught before. One solution is to provide pedagogical guidance before and during the course design process, however pedagogical guidance may be effective after a course has been designed as well. It is important to include chairs, deans, provosts, and university presidents in the unfreezing process, because their support will be needed for change.

During the changing phase, change may occur through identification or internalization. Identification occurs when models are provided in the environment and faculty may learn by emulating the new behavior. This is ideal for higher education. Internalization usually occurs when individuals are placed in a survival situation where the new behavior is demanded of them, such as a military boot camp. This is less than ideal for higher education, but may work in some instances. Refreezing occurs when the new behavior becomes integrated into the faculty member's way of thinking and behavior patterns. However, if change is brought about by identification, the refreezing process may only persist as long as the faculty member maintains a relationship with the original influence model or new surrogate models. Social support and reinforcement may help in these situations. This may be achieved through educational learning communities where faculty periodically convene with a pedagogical expert knowledgeable in a similar discipline of the faculty members to discuss teaching and learning. However, change managers should strive for internalization of new ideas among faculty. This may be approached by all of the same mechanisms used by faculty to teach their students a new discipline, such as introductory biology (see Table 15 above). All of the same ideas apply if administrators view their faculty as students of pedagogy. If the results of the current study are applied to leadership, constructivist reform-based teaching methods should be modeled and taught to faculty using constructivist methods. Therefore, motivation and attitudes are a concern. Personal relevance is

one way to increase motivation and attitudes. Specifically, self-efficacy for faculty to implement constructivism in their classrooms should be considered a top priority. This new model may be tested among faculty by replacing the variable “course performance” from the current study to “implementation of constructivism” in a future study.

Kurt Lewin (1947) also developed a technique called Force Field Analysis to assess the driving and restraining forces affecting change. Lewin warns that the driving forces must outweigh the restraining forces. If this is not the case, the restraining forces should be minimized or eliminated while maintaining the driving forces. This approach may be very time consuming and moving on to a different problem may be the best course of action in some situations. In line with the thinking of Lewin, Schein’s (1968) idea of Psychological Safety explains that the fear of not changing (anxiety 2) must outweigh the fear of changing (anxiety 1). He explains that this balance should be addressed during the unfreezing process and anxiety 2 issues should be addressed first.

Hersey, Blanchard, and Johnson (2001) describe two types of change cycles: participative change and directive change. Directive change is a top down model of change where the new behavior is imposed on the group by administration. This type of change is most effective while managing groups of unambitious workers. Participative change is a bottom-up type of change where new knowledge is made available to faculty. It is hoped that, with participative change, the faculty will accept the new information and develop positive attitudes toward the desired change. Next, the new commitment is translated into individual and group behavior. This type of change is most effective with individuals and groups who are “achievement-motivated, seek responsibility, and have a degree of knowledge and experience that may be useful in developing new ways of operating” (p. 390). In higher education, participative change should be used. The

new information may be presented in faculty meetings and learning communities, and the new information may be reinforced during evaluation periods. Hersey, Blanchard, and Johnson (2001) also warn that faculty must recognize the problem as their own and faculty should be given a sense of urgency so they prioritize the desired change above other pressing issues. This may be accomplished through the constructivist teaching of faculty (Sirum, Madigan, & Klionsky, in review).

Summary

There are reform efforts at the local, state, and federal level directed toward higher education, based on empirical research, such as this dissertation. Effective leaders in higher education must educate themselves on these issues and pass that information on to their faculty. The new information may be disseminated during new course design and reinforced through learning communities and faculty meetings. Leaders must carefully assess driving and restraining forces and eliminate the restraining forces while cultivating the driving forces. Finally, faculty should be instilled with a sense of urgency to help facilitate the change.

Implications for Further Research

If an adequate sense of urgency is established among faculty to incorporate contemporary pedagogical techniques into their classrooms, they will want to change and they will want more information. The current study may have uncovered some interesting relationships, but the true value of this dissertation may come from its implications for further research and an improved CLEM model based on analysis of the current study.

Improving the CLEM Model

The recursiveness of the model needs to be reexamined. Although the model is consistent with the empirical data, a few relationships may be better defined as nonrecursive. This may be

examined through structural equation modeling and analyzed with causal modeling software such as LISREL. Also, the positioning of the “attitudes toward biology” variable may be examined at that time. In addition, to improve the usefulness of the model, course performance should be replaced with direct measures of learning to determine if the model can be used to explain motivation for learning, instead of motivation to receive a favorable grade in a particular course.

In a future study, changes in students’ CLES_TOTAL, intrinsic goal orientation, attitudes toward biology, self-efficacy, and course performance over the course of the term may also help explain the results found by testing the model. These variables could be measured periodically throughout the term. If changes in self-efficacy correlate strongly with course performance at each test time and not with changes in the other variables, perhaps course performance is a significant contributor to self-efficacy.

In a future study, covariates should be used. First, if student ability were controlled for, the relationship between CLES_TOTAL and course performance may be stronger as indicated by Black and Deci (2000). Second, males had significantly higher self-efficacy and intrinsic goal orientation, yet females had significantly higher grades. In a future study, gender should be used as a covariate of course performance, self-efficacy, and intrinsic goal orientation. This covariate may strengthen the results of the study by eliminating these gender differences. Ethnicity should also be used as a covariate of course performance. In the current study, grades for African-Americans were significantly lower than Caucasians and this difference should be eliminated as well. These covariates could be used with the current dataset. In addition, ethnicity should also be compared by number of prior science courses completed to examine the cause of this

difference. The causes of gender and ethnicity differences may need to be uncovered through qualitative studies.

One more improvement of the model could be a demonstration of its usefulness in the field of leadership. A new CLEM Leadership model may be tested among faculty by replacing the variable “course performance” from the current study to “implementation of constructivist pedagogy”. The other variables may be modified as well. The CLES may be adapted to assess faculty’s professional development learning environment and the other variables may be worded to assess faculty attitudes and motivation toward learning the new material.

Controlled Experiments

Controlled experiments may be used to test the conclusions drawn from the current study. The current study suggests that in order to increase course performance, a teacher may try to build student self-efficacy. One way to build self-efficacy is to provide personal relevance and opportunities for critical voice. Two similar classes may be used to test whether teacher provided personal relevance and opportunities for critical voice produce higher levels of self-efficacy among students. One class may serve as a control while the other serves as the experimental group. The experimental group is presented with a course specifically designed to provide these variables. At the conclusion of the course, the two classes may be compared. If many classes are available, perhaps a multivariate design may be used where one experimental group focuses on personal relevance, a second experimental group receives a focus on opportunities for critical voice, and a third experimental group receives a focus on both variables. All of the classes may be compared to a control group and each other. Similar types of studies could be designed to assess whether personal relevance and shared control really build intrinsic motivation or to

determine if intrinsic goal orientation builds self-efficacy. Other controlled experiments could be used to determine if attitudes build self-efficacy.

A more useful experiment may be the design of an experimental group who receives personal relevance, opportunities for critical voice, intrinsic goal orientation, and all of the self-efficacy building recommendations suggested by Bandura (1981): mastery experiences, vicarious experiences, verbal persuasion, and physiological/affective state. At the conclusion of the course, learning should be assessed and compared to a control group. Learning may be assessed by a pretest and posttest design, where the results of the pretest are used to control for the results of the posttest. If significant differences in self-efficacy and learning differences exist between the control group and the experimental group, the importance of self-efficacy in learning will be confirmed. Currently, a good biological leaning inventory that can be agreed upon by most biologists is not in circulation. However, learning inventories are being developed and a few are in use in the other sciences, such as the Force Concept Inventory (FCI) (Hestenes et al.,1992); Halloun et al., 1995).

Conclusions

Although the classroom learning environment has a small direct impact on course performance, there is a moderate total effect on self-efficacy and intrinsic goal orientation. The classroom learning environment also had a moderate indirect effect on attitudes toward biology. However, attitudes have a moderate direct effect on course performance and self-efficacy has a strong direct effect on course performance and attitudes toward biology. Each of these constructs is important in its own right and instructors and leaders in higher education should strive to enhance them among their students and faculty. Self-efficacy seems to be particularly important. If students are to learn using constructivist methods they need the proper motivation and positive

attitudes to encourage them to prepare for class and to participate in class activities.

Administrators may also model constructivist teaching methods for their faculty or at least arrange for someone else to do it. This is important, because faculty too need the proper motivation and positive attitudes to change familiar methods of teaching to pedagogy that may seem foreign to them and their students. By enhancing attitudes and motivation of both faculty and students, the recommendations from this study may be step forward in addressing the critical problems of relatively low scientific literacy among students entering college (AAAS, 1990; Beatty, 1997; Campbell, 1997, Ohio Board of Regents, 2006a), the need for more students to pursue science related careers (Daempfle, 2004; Montgomery, 2005; Ohio Board of Regents, 2006a; Yoder, 2006), and poor attitudes toward studying science among students (Osborne, 2003).

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APPENDIX A

Motivated Strategies for Learning Questioner (MSLQ)

Item	Statement
1.	In a class like this, I prefer course material that really challenges me so I can learn new things.
2.	If I study in appropriate ways, then I will be able to learn the material in this course
3.	When I take a test I think about how poorly I am doing compared with other students.
4.	I think I will be able to use what I learn in this course in other courses.
5.	I believe I will receive an excellent grade in this class.
6.	I'm certain I can understand the most difficult material presented in the readings for this course.
7.	Getting a good grade in this class is the most satisfying thing for me right now.
8.	When I take a test I think about items on other parts of the test I can't answer.
9.	It is my own fault if I don't learn the material in this course.
10.	It is important for me to learn the course material in this class.
11.	The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.
12.	I'm confident I can learn the basic concepts taught in this course.
13.	If I can, I want to get better grades in this class than most of the other students.
14.	When I take tests I think of the consequences of failing.
15.	I'm confident I can understand the most complex material presented by the instructor in this course.
16.	In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.

17. I am very interested in the content area of this course.
18. If I try hard enough, then I will understand the course material.
19. I have an uneasy, upset feeling when I take an exam.
20. I'm confident I can do an excellent job on the assignments and tests in this course.
21. I expect to do well in this class.
22. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
23. I think the course material in this class is useful for me to learn.
24. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.
25. If I don't understand the course material, it is because I didn't try hard enough.
26. I like the subject matter of this course.
27. Understanding the subject matter of this course is very important to me.
28. I feel my heart beating fast when I take an exam.
29. I'm certain I can master skills being taught in this class.
30. I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.
31. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

APPENDIX B

Constructivist Learning Environment Survey (CLES)

Item	Statement
IN THIS CLASS...	
32.	I learn about the world outside of school.
33.	I learn that science cannot provide perfect answers to problems.
34.	It's OK for me to ask the teacher "Why do I have to learn this?"
35.	It's OK for me to question the way I'm being taught.
36.	I help the teacher to plan what I'm going to learn.
37.	I help the teacher to decide how well I am learning.
38.	I get the chance to talk to other students.
39.	My new learning starts with problems about the world outside of school.
40.	I learn that science has changed over time.
41.	It's OK for me to complain about teaching activities that are confusing.
42.	I help the teacher to decide which activities are best for me.
43.	I talk with other students about how to solve problems.
44.	I explain my understandings to other students.
45.	I learn how science can be part of my out-of-school life.
46.	I learn that science is influenced by people's values and opinions.
47.	It's OK for me to complain about anything that prevents me from learning.
48.	I help the teacher to decide how much time I spend on learning activities.
49.	I ask other students to explain their thoughts.
50.	I get a better understanding of the world outside of school.
51.	I learn about the different sciences used by people in other cultures.
52.	It's OK for me to express my opinion.
53.	I help the teacher to decide which activities I do.
54.	Other students ask me to explain my ideas.

- 55. I learn interesting things about the world outside of school.
- 56. I learn that modern science is different from the science of long ago.
- 57. It's OK for me to speak up for my rights.
- 58. I help the teacher to assess my learning.
- 59. Other students explain their ideas to me.
- 60. What I learn has nothing to do with my out-of-school life.
- 61. I learn that science is about creating theories.

APPENDIX C

Biology Attitude Survey (BAS)

Item	Statement
62.	Biology is very interesting to me.
63.	I don't like biology, and it scares me to have to take it.
64.	I am always under a terrible strain in a biology class.
65.	Biology is fascinating and fun.
66.	Biology makes me feel secure, and at the same time is stimulating.
67.	Biology makes me feel uncomfortable, restless, irritable, and impatient.
68.	In general, I have a good feeling toward biology.
69.	When I hear the word "biology," I have a feeling of dislike.
70.	I approach biology with a feeling of hesitation.
71.	I really like biology.
72.	I have always enjoyed studying biology in school.
73.	It makes me nervous to even think about doing a biology experiment.
74.	I feel at ease in biology and like it very much.
75.	I feel a definite positive reaction to biology; it's enjoyable.

Semantic Differential Scale

Below are some scales on which we would like you to rate your feelings toward biology. On each scale, you can rate your feelings toward biology as an A, B, C, D, or E. There are no correct answers. Also, some of the scales seem to make more sense than others. Don't worry about it. Just rate your feelings toward biology on these scales as best you can. Please don't leave any scales blank.

PLEASE NOTE THE NEW RESPONSE SCALE!!

BIOLOGY IS...

76.	Good	A	B	C	D	E	Bad
77.	Clean	A	B	C	D	E	Dirty
78.	Worthless	A	B	C	D	E	Valuable
79.	Cruel	A	B	C	D	E	Kind
80.	Pleasant	A	B	C	D	E	Unpleasant
81.	Sad	A	B	C	D	E	Happy
82.	Nice	A	B	C	D	E	Awful
83.	Fair	A	B	C	D	E	Unfair

APPENDIX D

Demographics

Item	Statement
106.	Gender: <ul style="list-style-type: none">a. Femaleb. Male
107.	Age: <ul style="list-style-type: none">a. 18b. 19c. 20d. 21-22e. 23+
108.	What is your ethnicity? <ul style="list-style-type: none">a. African-Americanb. Asian-Pacific Islanderc. Caucasiand. Hispanice. Other
109.	How many high school or college <u>science</u> courses have you completed (not including this one). <ul style="list-style-type: none">a. 2b. 3c. 4d. 5e. 6 or more
110.	How many high school or college <u>mathematics</u> courses have you completed (not including this one). <ul style="list-style-type: none">a. 2b. 3c. 4d. 5e. 6 or more

111. What Biology course are you enrolled in?
- a. BIOL104 large lecture
 - b. BIOL104 small active learning
 - c. BIOL204
 - d. BIOL205
 - e. None of the above

Please answer Part A, B, AND C. Please respond to all three questions.

112. Intended Major **[Part A]:**
- a. Biology
 - b. Education, Science (ex. Science Education, 4-9 or 7-12)
 - c. Education, Nonscience (ex. Early childhood education, pK-3)
 - d. None of these. See next questions**
113. Intended Major **[Part B]:**
- a. Health and Human Services
 - b. Science, Non-biology (ex. psychology, sociology, geology)
 - c. Undecided
 - d. None of these. See previous/next question**
114. Intended Major **[Part C]:**
- a. Business
 - b. Mathematics
 - c. Technology
 - d. Other Arts & Science, nonmath/nonscience (ex. history, music)
 - e. None of these. See previous questions**