1-6-2012

Predictors of Science Success: The Impact of Motivation and Learning Strategies on College Chemistry Performance

Shari B. Obrentz

ACCEPTANCE

This dissertation, PREDICTORS OF SCIENCE SUCCESS: THE IMPACT OF MOTIVATION AND LEARNING STRATEGIES ON COLLEGE CHEMISTRY PERFORMANCE, by SHARI B. OBRENTZ, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty. The Dean of the College of Education concurs.

Nannette Commander, Ph.D.
Committee Chair

Catherine J. Brack, Ph.D.
Committee Member

Catherine Y. Chang, Ph.D.
Committee Member

Daphne Greenberg, Ph.D.
Committee Member

Date

Gwendolyn T. Benson, Ph.D.
Associate Dean of School and Community Partnership
Interim Chair, Department of Educational Psychology and Special Education

R.W. Kamphaus, Ph.D.
Dean and Distinguished Research Professor
College of Education

AUTHOR'S STATEMENT

Shari B. Obrentz

NOTICE TO BORROWERS

All dissertations deposited in the Georgia State University library must be used in accordance with the stipulations prescribed by the author in the preceding statement. The author of this dissertation is:

Shari B. Obrentz
885 Briarcliff Road
Apartment 40
Atlanta, GA 30306

The director of this dissertation is:

Dr. Nannette Commander
Department of Educational Psychology and Special Education
College of Education
Georgia State University
Atlanta, GA 30303-3083

CURRICULUM VITAE

Shari B. Obrentz

ADDRESS:

885 Briarcliff Road
Apartment 40
Atlanta, GA 30306

EDUCATION:

Ph.D.	2011	Georgia State University Educational Psychology
M.S.	2005	Georgia State University Professional Counseling
B.A.	2001	Washington University in St. Louis Psychology, Spanish

PROFESSIONAL EXPERIENCE:

2005-Present	Director, Learning Programs & Learning Specialist Emory College of Arts & Sciences, Atlanta, GA
2005-Present	Independent Learning Strategies Consultant Atlanta, GA
2005	GSU 1050 Discussion Group Leader Georgia State University, Atlanta, GA
2005	Study Abroad Graduate Assistant Office of International Affairs Georgia State University, Atlanta, GA
2004- 2005	Counseling Intern & Stress Management Consultant Counseling Center Georgia State University, Atlanta, GA
2003-2005	Life Skills Lab Manager Counseling Center Georgia State University, Atlanta, GA

PROFESSIONAL SOCIEITIES, ORGANZIATIONS AND CERTIFICATIONS:

2010-2011	American Educational Research Association
2010-Present	Tutor Certification Committee Member (ATP)
2006-Present	Learning Disabilities Association of Georgia
2006-Present	The Association for the Tutoring Profession (ATP)
2006-Present	Certified Master Tutor Trainer (ATP)
2005-Present	American Counseling Association
2005-Present	National Certified Counselor (NCC) National Board for Certified Counselors (NBCC)

PRESENTATIONS AND PUBLICATIONS:

Obrentz, S. B. & Nikopoulos, B. (2011, March) *Why testing works*. Presented at The Association for the Tutoring Profession Conference, Orlando, FL.

Nikopoulos, B. & Obrentz, S. B. (2011, March) *Types of Memory*. Presented at The Association for the Tutoring Profession Conference, Orlando, FL.

Obrentz, S. B. (2011, March) *Tutor training: Do's and don'ts, beginning and ending sessions, and session planning*. Presented at The Association for the Tutoring Profession Conference, Orlando, FL.

Obrentz, S. B., Commander, N., & Greenberg, D. (2010). *Supplemental Instruction and High-Achieving Undergraduate Students: Who Benefits the Most?* (Unpublished residency project). Georgia State University, Atlanta, GA.

Obrentz, S. B. (2009, April) *Do academic support programs really work? Evaluating peer-tutoring and SI programs controlling for academic preparedness.* Presented at The Association for the Tutoring Profession Conference, Albuquerque, NM.

Obrentz, S. B. & Fields, T. L. (2007, April) *Who are we serving? How supplemental instruction and peer tutoring programs work together to serve the undergraduate community*. Presented at The Association for the Tutoring Profession Conference, Orlando, FL.

Newby, W. L. & Obrentz, S. B. (2006, March) *Linking assessment to intervention: Targeting goals and structuring tutoring support for students with special needs.* Presented at The Association for the Tutoring Profession Conference, San Antonio, TX.

Brack, G. L., Hill, M. B., & Obrentz, S. B. (2004). *Conflict resolution and negotiation*. Department of Counseling and Psychological Services, Georgia State University, Atlanta, GA.

ABSTRACT

PREDICTORS OF SCIENCE SUCCESS: THE IMPACT OF MOTIVATION AND LEARNING STRATEGIES ON COLLEGE CHEMISTRY PERFORMANCE

by

Shari B. Obrentz

As the number of college students studying science continues to grow, it is important to identify variables that predict their success. The literature indicates that motivation and learning strategy use facilitate science success. Research findings show these variables can change throughout a semester and differ by performance level, gender and ethnicity. However, significant predictors of performance vary by research study and by group. The current study looks beyond the traditional predictors of grade point averages, SAT scores and completion of advanced placement (AP) chemistry to consider a comprehensive set of variables not previously investigated within the same study. Research questions address the predictive ability of motivation constructs and learning strategies for success in introductory college chemistry, how these variables change throughout a semester, and how they differ by performance level, gender and ethnicity. Participants were 413 introductory college chemistry students at a highly selective university in the southeast. Participants completed the Chemistry Motivation Questionnaire (CMQ) and Learning Strategies section of the Motivated Strategies for Learning Questionnaire (MSLQ) three times during the semester. Self-efficacy, effort regulation, assessment anxiety and previous achievement were significant predictors of chemistry course success. Levels of motivation changed with significant decreases in self-efficacy and increases in personal relevance and assessment anxiety. Learning strategy use changed with significant increases in elaboration, critical thinking, metacognitive self-regulation skills and peer learning, and significant decreases in time and study management and effort regulation. High course performers reported the highest levels of motivation and learning strategy use. Females reported lower intrinsic motivation, personal relevance, self-efficacy and critical thinking, and higher assessment anxiety, rehearsal and organization. Self-efficacy predicted performance for males and females, while self-determination, help-seeking and time and study environment also predicted female success. Few differences in these variables were found between ethnicity groups. Self-efficacy positively predicted performance for Asians and Whites, and metacognitive self-regulation skills negatively predicted success for Other students. The results have implications for college science instructors who are encouraged to collect and utilize data on students' motivation and learning strategy use, promote both in science classes, and design interventions for specific students who need more support.

PREDICTORS OF SCIENCE SUCCESS: THE IMPACT OF MOTIVATION AND LEARNING STRATEGIES ON COLLEGE CHEMISTRY PERFORMANCE

by
Shari B. Obrentz

A Dissertation

Presented in Partial Fulfillment of Requirements for the
Degree of
Doctor of Philosophy
in
Educational Psychology
in
the Department of Educational Psychology and Special Education
in
the College of Education
Georgia State University

Atlanta, GA
2011

ACKNOWLEDGMENTS

It is a pleasure to thank those who made the completion of this dissertation possible. I owe deepest gratitude to my committee chair and advisor Dr. Nannette Commander, who spent countless days in the relentless pursuit of perfection; her advising and editing skills are second to none. She is an extraordinary mentor, and continues to inspire me to pursue higher education initiatives.

I also thank my committee members Dr. Cathy Brack, Dr. Catherine Chang and Dr. Daphne Greenberg, who supported me throughout this process. Their professional knowledge and feedback have challenged my thinking and strengthened the quality of this project.

Thank you friends and colleagues at Emory University. Dr. Wendy Newby is an unbelievable supervisor, mentor, and friend who encouraged me to apply to this Ph.D. program and supported me throughout the process of obtaining this degree. Professors Tracy Morkin, Douglas Mulford and Jeremy Weaver are the Introductory Chemistry professor who discussed research ideas with me and provided access to their classes and students.

Finally, thank you family and friends for your patience, encouragement and belief in me. You have all earned a portion of this degree.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

ABBREVIATIONS

AX	Anxiety about chemistry assessment
CMQ	Chemistry Motivation Questionnaire
CT	Critical Thinking
EL	Elaboration
EM	Extrinsic motivation to learn chemistry
ER	Effort regulation
GPA	Grade Point Average
HS	Help-seeking
IM	Intrinsic motivation to learn chemistry
MET	Metacognitive self-regulation skills
MSLQ	Motivated Strategies for Learning Questionnaire
NAEP	National Assessment of Educational Progress
ORG	Organization
PL	Peer learning
PR	Relevance of learning chemistry to personal goals
RE	Rehearsal
SD	Self-determination to learn chemistry
SE	Self-efficacy for learning chemistry
SRL	Self-regulated learning
TSE	Time and study environment management

CHAPTER 1

MOTIVATION, LEARNING STRATEGIES AND SCIENCE LEARNING IN COLLEGE: A REVIEW OF THE LITERATURE

Although studied for decades (Robbins et al., 2004; Tai, Sadler, & Loehr, 2005), predicting academic success in college warrants continuous research because student populations are constantly changing, the criteria for academic success varies at each institution, and expectations differ by course and professor (Burton & Ramist, 2001). Moreover, the significant body of work that documents the consistent relationship between academic performance and retention underlines the need for examining variables that influence student achievement (Robbins, Allen, Casillas, Peterson, & Le, 2006; Robbins et al., 2004). Awareness of these variables can inform professors and administrators about student characteristics that influence who may succeed and those at risk to fail. Such information allows for shaping instructional delivery and/or designing support programs that foster student success and increase retention.

In a review of college success, Burton and Ramist (2001) found the strongest academic predictors to be a combination of high school records and combined SAT scores. Robbins et al. (2004) reported these factors "account for approximately 25% of the variance when predicting first-year college GPA" (p. 262). Although high school grades and SATs are considered strong predictors of college success, Prus, Hatcher, Hope, and Grabiel (1995) noted that "70-80% of the variance in academic performance is *not* predicted by these traditional measures" (p. 8). Additional variables that predict academic success should be considered. Two important areas of research that paint a more complete picture for predicting general academic success are motivation and learning strategies (Robbins et al., 2004).

Determining what predicts college success in the specific discipline of science is a more focused area of research that is increasingly important. It is now typically expected that all college students "become scientifically literate citizens who are able to understand the scientific issues… that confront them" (Glynn, Taasoobshirazi, & Brickman, 2009, p. 128) in the rapidly changing world of the 21st century. Students should also be able to solve basic real world problems using scientific principles (Smith, Gould, & Jones, 2004). Yet, science performance for 12th graders on the National Assessment of Educational Progress (NAEP) decreased between1996 and 2005 (National Center for Education Statistics, 2009). In addition, the Program for International Student Assessment (PISA) indicates that U.S. 15 year olds' science literacy scores were below average in 2006 (National Center for Education Statistics, 2009) and only reached the average level in 2009 (National Center for Education Statistics, 2010).

As the number of students interested in studying science in college continues to grow (Aud et al., 2010), identifying variables that predict success becomes more important for retaining students in the sciences. A challenge for identifying these variables is that students' levels of interest in science vary, and many lack conceptual understanding of scientific ideas and/or essential learning strategies (Bao et al., 2009; Bleicher, Romance, & Haky, 2002; Schuss, 1999). Previous academic achievement, measured by math SAT scores and/or high school grade point average (GPA), is a significant predictor of college science success (Spencer, 1996; Tai et al., 2005). Another measurement of previous academic achievement is students' exposure to in-depth science topics in high school which prepare them for more meaningful college science learning (Schwartz, Sadler, Sonnert, & Tai, 2008). Because measures of previous achievement do not change, additional factors need to be considered once students matriculate in college (Singh, Granville & Dika, 2002). Motivation and learning strategies in college science courses can help fill the gaps in measurement of success left by math SAT scores, high school GPAs or exposure to in-depth science material.

When studying motivation and learning strategies as predictors of college science success, gender issues may provide additional valuable information. The gender gap in academic science achievement has narrowed considerably since the 1970s, though differences in achievement (Britner, 2008; Freeman, 2004), as well as stereotypes about science courses being more favorable for males, still exist (DeBacker & Nelson, 2001; Miyake et al., 2010; Nosek et al., 2009). Although female students enroll in more advanced high school science courses (Freeman, 2004), they are less likely to enjoy them (Freeman, 2004; Meece, Glienke, & Burg, 2006; Weinburgh, 2000). Males also outperform females in elementary, middle and high school, and between 1996 and 2005 only small gains in science achievement were made by females ("Gender Differences in Science," 2009; National Center for Education Statistics, 2009). In 2007, scores from the American College Test (ACT) indicated females were less prepared for college science courses ("Gender Differences in Science," 2009). This discrepancy between male and female science achievement continues in postsecondary education where women are less likely to major in science disciplines (Britner, 2008; Freeman, 2004; "Gender Differences in Science," 2009; Miyake et al., 2010). Previous achievement, gender stereotypes and interest in the discipline may all affect how females approach studying science as well as motivation to pursue degrees or careers in the field.

Ethnicity may also provide valuable information when studying motivation and learning strategies as predictors of college science success. The discrepancy in science performance by ethnicity is well documented (Barton, 2002; Bruschi & Anderson, 1994; Stedman, 2009), and few gains have been made over the past decade to close the gaps that still remain (Steadman, 2009). The NAEP science scores between 1996 and 2000 recorded differences between White and minority students averaging 37 points nationally, more than one standard deviation, with a range in difference from 19-41 points with Whites earning the highest scores (Barton, 2002). Stedman (2009) also reviewed NAEP science achievement from 1969-1999 reporting the Black-White gap in science in 1999 remained almost as large as it was in 1969, again with Whites earning higher scores. Similar patterns have been found between White and Hispanic students (Stedman, 2009). In 2005, ethnicity trends indicated Whites earned higher science scores than Blacks and Hispanics at all grade levels, with no gains by the non-White groups by grade 12 from 1996-2005 (National Center for Education Statistics, 2009). Although statistics continue to show differences in performance in elementary and secondary settings, ethnic minorities are studying science in college in greater numbers than ever before. The number of earned science degrees increased for almost all ethnic groups. Moreover, the demographic information for students intending to major in science fields is rising for Asian and Hispanic students and is stable for Black and American Indian students (National Science Board, 2010). Identifying how levels of motivation and learning strategy use contribute to success can only help with retaining minorities in the sciences, one of the major themes and goals in science education (Freeman et al., 2007).

This literature review discusses and critiques previous research on motivation constructs and learning strategy use as predictors of successful college science learning. The research on general academic success, a more robust area, is presented as the foundation for predictors of college science success. Highlights include strengths of science research that investigated both motivation and learning strategies within the same study. Research that addresses levels of motivation and learning strategy use by gender and ethnicity is also presented and critiqued. Finally, instructional considerations and implications for future research are addressed.

Motivation and Science Learning

Motivation is one of the states that drives and sustains behaviors. In order for students to be motivated to learn in any discipline, they must participate in activities that are personally meaningful and worthwhile (Glynn & Koballa, 2006). By middle school, students' motivation to learn science is one of the most important predictors of science course success (Britner & Pajares, 2006). In a study with 8^{th} graders, motivation strongly influenced science achievement (Singh et al., 2002). This trend continues in college. Glynn, Taasoobshirazi, and Brickman (2007) investigated the relationship between overall motivation to learn science and science GPA. Most students reported they were motivated to study science not only because they thought it would be helpful for a career, but also because they "found it relevant to their health, life and understanding of the world" (p. 1098). When students found science courses were relevant to their careers, both their motivation and science GPA were higher (Glynn, Taasoobshirazi, & Brickman, 2007). Another study found when college students reported lower motivation in science courses their performance was lower as well (Glynn et al., 2009). Both studies concluded that motivation to learn science positively related to college science performance. There are many motivational constructs that could relate to academic success in college science. However, researchers have identified intrinsic and extrinsic motivation, goal orientation, task value, self-determination, self-efficacy and assessment anxiety as important constructs for science learning (Glynn & Koballa, 2006; Glynn et al., 2009).

Intrinsic and Extrinsic Motivation

Motivation orientation, defined as intrinsic or extrinsic motivation, explains how rewards affect students engagement with particular learning activities (Eccles & Wigfield, 2002). Intrinsic motivation refers to performance of a task rewarded by completing the task itself, whereas extrinsic motivation refers to performance of a task in order to receive an external reward (Covington, 2000b; Murphy & Alexander, 2000; Pittman & Boggiano, 1992; Ryan & Deci, 2000). Ryan and Deci stated that "intrinsically motivated activities . . . provide satisfaction of innate psychological needs" (p. 57). When intrinsically motivated, students engage in an activity because the task itself is interesting or they feel rewarded by completing the task. In academic situations, intrinsic motivation leads to deeper processing, greater mastery and better implementation of learning strategies (Covington, 2000b). Intrinsically motivated students are also more likely to persist with challenging tasks and other positive classroom behaviors as well as perform better academically (Walker, Greene, & Mansell, 2006).

Extrinsic motivation generally drives behaviors when students complete tasks for an external outcome (Walker et al., 2006). Research from the 1970s revealed that extrinsic rewards diminished intrinsic motivation. When rewards were given to students for completing tasks that they were once intrinsically motivated to complete, their motivation orientation shifted from intrinsic to extrinsic (Pittman & Boggiano, 1992). If students are rewarded for participating in an intrinsically motivated task, they may begin to think that a reward is necessary to complete that task and not persist unless the reward is present. It has also been suggested that if rewards are given in a competitive environment, e.g., to the best or fastest, students are rewarded for the wrong reasons (Covington, 2000b).

Although early research concluded that extrinsic motivation was detrimental to intrinsic motivation and performance, more recent research suggested that extrinsic motivation is more complex. Ranging on a continuum from passive compliance to active personal commitment, extrinsic motivation depends on whether a student wants to avoid a negative consequence or sees value in the outcome that may be obtained (Ryan & Deci, 2000). As people mature in school and work environments more external rewards are offered. It is often difficult to separate motivation orientation as many learning activities have extrinsic rewards attached to them (Ryan & Deci, 2000). Extrinsically motivated students who fall closer to active personal commitment on the continuum may be driven to act primarily because of the reward. However, these rewards may also have some intrinsic elements, (e.g. receiving an ‘A’ makes the student feel good).

Orientations seem to fall on opposite ends of one continuum. Students however, can be simultaneously intrinsically and extrinsically motivated (Kaufmann, Agars, & Lopez-Wagner, 2008; Lin, McKeachie, & Kim, 2002; Watson, McSorely, Foxcraft, & Watson, 2004). Studying general academic success, Kaufman, Agars, and Lopez-Wagner

(2008) investigated whether intrinsic and extrinsic motivation separately predicted first quarter college cumulative GPAs. Intrinsic and extrinsic motivation correlated with and predicted first quarter GPAs differently. A significant positive relationship between intrinsic motivation and GPA was found, and there was a negative relationship between extrinsic motivation and GPA (Kaufman et al., 2008). Instead of measuring global academic success, Watson, McSorely, Foxcraft, and Watson (2004) studied the effects of both intrinsic and extrinsic motivation on a specific college final course grade. They found that higher levels of both motivation orientation variables positively correlated with higher course grades (Watson et al., 2004).

Connecting motivation orientation to science performance, Garcia (1993) found both intrinsic and extrinsic motivation positively predicted final course grades in organic chemistry. In contrast, Yu (1999) found that intrinsic motivation negatively predicted course performance in college chemistry. However, Lin, McKeachie, and Kim (2002) evaluated whether different levels of intrinsic and extrinsic motivation affected final course grades in several courses including college biology. Based on self-reports, students were placed in a low, medium or high category for both intrinsic and extrinsic motivation. Students with high intrinsic and medium extrinsic motivation outperformed their peers with either low or high extrinsic motivation.

Goal Orientation

Goal orientation refers to the direction or type of achievement goals students set. Achievement goals are influenced by the purpose for learning and can determine what behaviors will be implemented to meet these goals, ultimately affecting achievement (Covington, 2000a). Covington (2000a) stated, “all actions are given meaning, direction, and purpose by the goals that individuals seek out and the quality and intensity of behavior will change as these goals change" (p. 174). Achievement goals are typically divided into two orientations of learning and performance (Ames, 1992; Covington, 2000a; Eccles & Wigfield, 2002; Eppler & Harju, 1997; McGregor & Elliot, 2002).

Students who are learning goal-oriented want to increase their competence and reach their goals by mastering new material (Murphy & Alexander, 2000) or improving skills (Elliott & Dweck, 1988). In addition, students with high learning goals are more likely to try or persist in using self-regulatory strategies (Ames, 1992) and participate in more challenging tasks, even if they do not perceive they have the ability to complete them (Dweck, 1986). Since these students are driven by effort rather than ability, it is believed that learning goals support intrinsic motivation (Dweck, 1986).

Students who are performance goal-oriented either want to receive positive or avoid negative judgments about their competence (Murphy & Alexander, 2000). Public recognition is also extremely important to students with performance goals, especially when students receive praise for performing well or better than peers (Ames. 1992). This goal orientation does not always encourage learning, since perception of ability must remain high in order to continue with learning tasks. If performance goal-oriented students receive negative feedback or feel threatened, they will not continue with a task (Dweck, 1986).

Learning and performance goals are independent from each other and should be considered separate variables. Research consistently supported that learning goals positively relate to academic success in college (Eppler & Harju, 1997; Ironsmith, Marva, Harju, & Eppler, 2003; Schraw, Horn, Thorndike-Crist, & Bruning, 1995). The role of performance goals, however, sometimes yielded unexpected results and also led to positive academic outcomes (Harackiewicz, Barron, & Elliot, 1998). Harackiewicz, Barron, and Elliot, (1998) proposed that adopting both learning and performance goals may actually lead to more success in college. Work by Ironsmith, Marva, Harju, and Eppler (2003), supported that college students would be well served to adopt both learning and performance goals. They found students who earned the best grades reported high learning goals. Interestingly, students with both high learning and performance goals and those with just high performance goals had no significant differences in final grades. Finally, students who earned the lowest grades reported both low learning and performance goals. Thus while having high learning goals is associated with high performance, having high levels of either goal is better for performance than low achievement goals in both areas (Ironsmith et al., 2003).

Schraw, Horn, Thorndike-Crist, and Bruning (1995) studied whether college biology course performance differed by achievement goal orientation. Results indicated that prior academic achievement accounted for most of the variance in final course grades. However, when prior achievement was removed from the prediction model, students with high learning versus performance goals earned higher final course grades. These students also reported more strategy use than those with low learning goals, which could explain why their performance was higher. The level of performance orientation goals was not related to course achievement (Schraw et al., 1995). Zusho, Pintrich, and Coppola (2003) found that while learning goals significantly correlated with final course grades in college chemistry, no significant relationship was found with performance goals. Additionally, learning goals did not predict final course grades.

Task Value

Task value explains whether course material or learning activities are personally relevant to the student (Eccles & Wigfield, 2002) and provides interpretation for why the task is interesting, important or useful. Attainment and utility are two key components that influence whether a student values a task (Bonney, Klempter, Zusho, Coppola, & Pintrich, 2005). Attainment describes why performing well on a task is important to the student while utility qualifies whether tasks are useful, practical, or relevant (Eccles & Wigfield, 2002). Interest in material also influences task value (Garcia & Pintrich, 1996).

Task value is essential for academic success as it can influence course selection and learning activities which also influence performance (Pintrich, 2004). Students must identify why performing well on a task is important and determine whether learning tasks can support their personal or professional goals (Eccles & Wigfield, 2002). When task value is high, students make the connection between learning and their present or future personal goals, engage with material, put forth more effort, and ultimately reach higher achievement (Bonney et al., 2005; Walker et al., 2006).

Pokay and Blumenfeld (1990) investigated the relationship between task value and high school course achievement. While they did not find task value predicted course success, it was positively correlated with self-concept and expectancy to perform. They also found when task value was higher, students used more learning strategies. Garcia and Pintrich (1996) investigated the relationship between task value and college course achievement. Although it was not a significant predictor of course success, high task value early in the semester predicted higher intrinsic motivation later in the semester.

DeBacker and Nelson (2001) investigated how task value impacted high school science performance. They found that higher achieving students valued science more. Several studies reported that college science students' task value decreased during a semester (Garcia, 1993; Yu, 1999; Zusho et al., 2003). Garcia (1993) and Yu (1999) did not find task value significantly predicted success in organic chemistry or general chemistry respectively. Zusho et al. (2003) however, reported task value not only significantly predicted college chemistry success but was a stronger predictor than previous achievement.

Self-determination

Academic self-determination is defined by how much control a student perceives he or she has over learning (Glynn & Koballa, 2006). Self Determination Theory (SDT) suggests that people innately strive for optimal stimulation, feeling competent and being self-determinant, or having a sense of control over their behaviors (Eccles & Wigfield, 2002; Pittman & Boggiano, 1992). Lavigne, Vallerand, and Miquelon (2007) explained that self-determination is comprised of both a perception of autonomy in the learning environment and competence in the ability to perform a task.

Research with medical students enrolled in a practical doctor-patient interviewing course provides an example of the impact of self determination (Williams & Deci, 1996). When medical students felt more autonomous in the course, they reported stronger psychosocial beliefs and more competencies about their interviewing skills. When these students perceived that instructors supported their autonomy, they engaged in more autonomous self-regulated learning and performed better with simulated patients (Williams & Deci, 1996).

For success in science courses, Lavigne et al. (2007) argued that self-determination plays a significant role in students' overall motivation to learn science and increases the likelihood of pursuing academic or professional careers in science. The relationship between autonomy, motivation orientation, and college academic performance was studied by Garcia and Pintrich (1996) in several disciplines, including biology. Although not directly related to course achievement, they found that a sense of autonomy was the strongest predictor of end of semester motivation orientation (Garcia & Pintrich, 1996).

Black and Deci (2000) tested the relationship between self-determination and performance in organic chemistry. In a self-report study, those students who perceived greater autonomy at the beginning of the semester also perceived more competence and interest in the course, as well as lower anxiety. Although starting autonomy levels did not predict course achievement, students who gained a sense of autonomy throughout the course earned higher grades. When students perceived that group leaders supported autonomy, their own sense of autonomy, competence, and interest increased. Perceived group leader support of autonomy was a stronger predictor of grades than ability (Black & Deci, 2000).

Self-efficacy

Self-efficacy describes whether a student believes he or she can successfully perform a specific task. Although similar to other expectancy constructs like self-concept which explain students' expectations about performance, "self-efficacy is defined in terms of individuals' perceived capabilities to attain designated types of performances and achieve specific results" (Pajares, 1996, p. 546). When self-efficacy is high, students believe tasks can be accomplished and are more likely to proceed with the task. When self-efficacy is low, or beliefs about successful completion are not present, tasks are avoided (Bandura, 1997). Self-efficacy regulates the perception of difficulty and the amount of effort and persistence for completing a task (Pajares, 1996). Pajares (2002) summarized that self-efficacy is often more strongly related to performance than ability, possibly because students with higher self-efficacy practice more self-regulation including persistence, monitoring and adjustment of strategies.

For college students, self-efficacy can directly and indirectly affect academic performance (Pajares, 1996). Self-efficacy is directly related to both expectations about performance and academic performance itself for first year students (Chemers, Li-tze, & Garcia, 2001). Although success in college is often measured by final course grades, student achievement may also be defined by students' ability to effectively solve problems. In a study testing a model of successful problem-solving, researchers found that high self-efficacy was a contributing factor to successful problem-solving (Taasoobshirazi & Glynn, 2009).

Research supports that self-efficacy is related to science achievement at all grade levels including college (Britner & Pajares, 2006). Decades ago, Lent, Brown and Larkin (1984) found that college students with higher self-efficacy earned higher grades and persisted in technical/scientific majors. Andrew (1998) studied the effects of self-efficacy on science course performance, finding self-efficacy predicting nearly 18-24% of the variance in final grades for nursing students. Both Yu (1999) and Zusho et al. (2003) found self-efficacy to be a significant predictor of final chemistry grades, even beyond previous achievement.

Assessment Anxiety

Assessment anxiety occurs when the student fears the testing situation. Although many models explain this anxiety through drives, attention, skill deficit, self-regulation and self-worth, there is no one comprehensive model that includes all of the factors that contribute to assessment anxiety (Chapell et al., 2005). Some reasons for the existence of assessment anxiety include that the test taker is unsure about the testing situation, fears the unknown and/or failure, or believes that tests are unfair (Berkley & Sproule, 1973).

Cassady and Johnson (2002) explained that assessment anxiety exists on two dimensions; emotionality and worry. Emotionality pertains to the awareness of physical symptoms (sweat, nausea, dizziness, heart racing, etc.) during or around the testing situation. Worry or cognitive test anxiety pertains to the thoughts people have before, during and after an evaluation. Examples of these thoughts include comparing performance to others, considering the consequences of failing, having low levels of confidence, general worry about the evaluation, feeling like performance will disappoint a parent, feeling unprepared for an evaluation, and/or losing self-worth (Cassady & Johnson, 2002).

Although some anxiety can be motivating and help students reach academic goals, having too much or too little can be detrimental to learning and ultimately negatively affect performance (Glynn & Koballa, 2006). Yerkes and Dodson (1908) explained that the relationship between arousal or anxiety and performance is curvilinear. Some arousal or anxiety helps performance but eventually hits a threshold and then begins to hurt performance. In addition, when arousal is either too weak or too strong, performance can suffer. There is an optimal amount of arousal for different tasks which will change for individuals and for tasks (Yerkes & Dodson, 1908).

Since first identified in the 1950s, many studies have investigated the relationship between assessment anxiety and academic performance (Cassady & Johnson, 2002; Hembree, 1988). In contrast to the motivation constructs that generally have positive relationships with academic performance, assessment anxiety consistently negatively correlated with academic performance from elementary to graduate school (Chapell et al., 2005), even when controlling for ability (Berkley & Sproule, 1973).

Students studying science are not exempt from assessment anxiety or the negative effects it can have on science performance. Garcia (1993) reported that assessment anxiety negatively predicted final course grades in organic chemistry. Lin et al.'s (2002) study with undergraduates that included biology students, found those who earned the highest final course grades had low assessment anxiety. In a large study with 4,000 undergraduates including nearly 22% science majors, Chappell et al. (2005) found a significant negative relationship between test anxiety and GPA. They concluded that test anxiety is one of the motivation factors that negatively relates to academic performance.

Critique of Motivation and Science Learning Literature

A critique of motivation and science learning literature reveals several methodological issues that exist across disciplines. It is important to take note of these criticisms when interpreting results about what influences science learning. First, studies do not always consider motivation constructs in conjunction with other related constructs. There is a need to consider the affect of multiple aspects of motivation when investigating college science success (Glynn & Koballa, 2006). Second, motivation is usually measured by self-reports which assumes science students can accurately identify and report how they are feeling and what they are doing. Evaluating motivational constructs over the course of a semester, or through several science courses, may reveal whether students' motivation to learn science is consistent or whether their self-opinions change over time.

As the demographics of college science students continue to change, determining differences in motivation for groups of students is necessary. Although some studies have looked at differences in science motivation by gender (Yu, 1999) or ethnicity (Garcia, 1993), demographic variables are not always included (Zusho et al., 2003). Sample selection and analyses by group within the sample could determine whether results are applicable to all science students or just to specific populations.

Research needs to consider how both intrinsic and extrinsic orientations affect science success and whether their predictive abilities are positive or negative. Because science success is often measured by final course grades, an extrinsic reward, the role of intrinsic motivation may not always be positive for science courses. Both learning and performance goal orientations also have independent relationships with science course grades. While learning goals positively relate to science success, the effect of performance goals is still unclear (Schraw et al., 1995; Zusho et al., 2003). Additional research considering both learning and performance goals in science courses is needed to determine if in fact performance goals positively or negatively predict science performance. Research may also consider whether the science classroom promotes learning or performance goals.

There is a clear positive relationship between task value and other motivational constructs that relate to science success, but it is unclear whether task value can consistently predict science success. Because task value depends on students' current and future goals, researchers need to consider why students enroll in science courses and whether that reason affects task value. Several studies reported a decline in task value throughout the semester (Garcia, 1993; Yu, 1999; Zusho et al., 2003). Future research may compare task value of science courses between science and non-science majors to determine if the decline is related to the types of students enrolled in the class.

Like task value, the direct relationship between self-determination and science performance is less conclusive than other motivational constructs. Garcia and Pintrich (1996) found self-determination was related to motivation orientation. Black and Deci (2000) reported change in self-determination over the course of the semester was important, especially for predicting other motivation constructs. More research at the college level with specific science courses is needed on whether self-determination is a significant factor in predicting success and its relationship to other constructs. As self-determination deals with students' sense of control over the learning situation, it would be worthwhile to study its relationship to effort regulation or time and study management.

The research consistently reported that self-efficacy is one of the strongest predictors of science performance. Measuring the changes in self-efficacy over the course of a semester as well as identifying factors that increase or decrease self-efficacy could determine when it is most important. Britner and Pajares' (2006) also called for investigating science self-efficacy considering more demographic variables such as age, ethnicity and socioeconomic level. Finally, because differences in self-efficacy have been reported within specific science disciplines at the high school level (Britner, 2008), additional research could investigate whether these differences continue in college.

Assessment anxiety is a motivational construct that most often negatively related to science course performance. Because science students are constantly assessed and there are techniques to reduce assessment anxiety, this motivation construct should not be ignored. Future research needs to address whether assessment anxiety is more prevalent in particular science courses, or with specific groups of students such as women or minorities (Garcia, 1993; Yu, 1999). It is not clear whether assessment anxiety in science courses is present from the beginning of the semester or develops over time.

Learning Strategies and Science Learning

Motivation constructs answer many questions about why students are driven to learn but do not always explain the specific actions students take or perform to reach learning objectives. Understanding which learning strategies relate to academic success can add to the discussion on predictors of science achievement in college. Unlike motivation constructs that at times seem innate and unchangeable, learning strategies may be changed based on environment, task, or demands. Learning strategies can also be taught in conjunction with course content (Bleicher et al., 2002), thus providing interventions that would support academic success in specific classes.

Learning strategies are essential for science learning because they assist students in mastering the foundation knowledge necessary for advancing within the discipline (Miyake et al., 2010). In science courses students must retain basic information in order to learn new and advanced material (Bleicher et al. 2002). Students are expected to not only understand concepts, but also apply content to problem-solving and scientific inquiry (Taasoobshirazi & Glynn, 2009). Using strategies that develop and encourage scientific ability helps students in their college science courses and prepare them to solve real-life problems and tasks (Bao et al., 2009).

Self-Regulated Learning

Self-Regulated Learning (SRL), the process by which students practice metacognitive skills or are aware of their cognition (Rickey & Stacy, 2000), includes four phases of forethought, planning and activation, monitoring, and reflection (Schunk, 2005). SRL is an ongoing process in which strategies change as learning environments and expectations change. SRL skills include, but are not limited to, self-evaluating, organizing, goal-setting and planning, seeking information, keeping records, monitoring, environmental structuring, implementing self consequences, rehearsing, memorizing, and seeking assistance from teachers, peers and others (Young & Ley, 2005).

When students are self-regulated learners, they monitor what they learn and implement study strategies at different stages in the learning process. This allows them to remember information as well as connect new and previously learned material (Corno & Randi, 1999; Pintrich, 2004). It is difficult to identify which SRL strategies are most effective for every student, as defining adaptive and maladaptive strategies depends on the student or learning situation. Students who self-regulate have a bank of strategies they can modify to fit new information or complete a variety of academic tasks (Corno & Randi, 1999; Zimmerman, 2008). Additionally, individual students can implement different strategies and still reach the same result (Ablard & Lipschultz, 1998).

Prus et al. (1995) explored whether specific SRL strategies predicted freshmen GPA. Of the strategies examined, time management, study aids, self testing, and test strategies significantly correlated with GPA. In conjunction with attitude, motivation, and concentration, these strategies helped explain 12% of the variance in GPA. The presence of learning strategies had important predictive value above and beyond the traditional factors such as high school GPA and SAT scores (Prus, Hatcher, Hope, & Grabiel, 1995).

Although students who displayed more adaptive SRL strategies demonstrated higher learning motivation, research indicated that students did not implement skills consistently or even at all (Schunk, 2005). Zeegers (2001) found that first year college students did not always implement strategies that will best support learning, but rather chose strategies that fit their demanding schedules and help them keep up with their workload. Students' motivation as well as their ability to set and follow through with goals also affects whether self-regulation occurs (Wolters, 1998). Bandura (1997) warned that, "self-regulatory skills will not contribute much if students cannot get themselves to apply them persistently in the face of difficulties, stressors, and competing attractions" (p. 233).

Persistently applying self regulation strategies in science courses is crucial as, "failure on the part of students to examine their conceptual understanding and cognitive processes that produce understanding cannot lead to learning scientific knowledge of a conceptual nature" (Chin & Brown, 2000, p. 112). Because many science students have not been taught active learning strategies beyond memorization, they may perform well on rote tasks, but little else (Modell, 1996). If science instructors expect students to use self-regulated skills, they may actually have to teach them as well as promote their use. In order for science students to consistently use SRL strategies, they must be motivated to use them.

Yu (1999) investigated whether a variety of self-regulation strategies predicted performance in college chemistry. The study found that effort regulation (staying on task even if there are distractions or interest fades) predicted final course grades (Yu, 1999). Chen (2002) studied whether different self-regulation and study strategies predicted success in a college lecture course with a lab component. For the lecture, only effort regulation predicted final course grades. For the lab, only time and environment management (when, how long, and where the student studied) predicted success (Chen, 2002). Zusho et al.'s (2003) analyses of learning strategy use reported the highest performing college chemistry students implemented more rehearsal and elaboration than both low and average performers.

Deep and Surface Learning

The use of specific SRL strategies can lead to deep or surface learning. Deep or meaningful learning relies on the students' ability to connect new material to previously learned material, while surface learning allows students to memorize and recall information without making connections (Ausubel, 1963). Deep learning approaches often correlate with intrinsic motivation because of the emphasis on connecting new information to what the learner personally knows. Surface learning approaches relate to extrinsic motivation and focus on completing tasks without any attempt to make personal connections (Chin & Brown, 2000).

Because learning occurs in many contexts, differences in approaches exist for specific disciplines and tasks. However, students can only reach meaningful learning in all disciplines when information is organized in a hierarchy which affords easy access as needed (Ausubel, 1963; Bleicher et al., 2002). Without organizational skills, students do not engage in the process of changing thoughts or ideas, resulting in unlearned material and hindering future learning (Ausubel, 1963; Chin & Brown, 2000). It is also true for science that in order for students to reach meaningful learning, they must practice a variety of self-regulation skills for not only learning the material but reflecting on what they understand (Chin & Brown, 2000).

Science courses require students to recall many facts and then connect old and new concepts. Students often rely on surface strategies for memorizing facts (Zeegers, 2001) without any focus on content comprehension or connection. This poses a problem for college science, because, if meaningful learning does not occur, students may not truly understand the material and ultimately make necessary connections for solving problems (Cavallo, Potter, & Rozman, 2004; Chin & Brown, 2000). The absence of meaningful learning may be due to the manner in which material is presented or to the lack of awareness of actual skills needed to reach meaningful learning levels (Bleicher et al., 2002).

BouJaoude and Giuliano (1994) tested the relationship between two learning approaches in college chemistry. They explored Meaning Orientation (MO), a deep approach where students related ideas and had intrinsic motivation. They also examined Reproducing Orientation (RO), a surface approach where students were bound to the syllabus and had extrinsic motivation. MO scores were significant predictors of final course grade, helping explain 32% of the variance in final exam scores. Because MO scores predicted final course grades, the specific strategy of relating ideas was identified for success in a science course. Interestingly, students with higher scores on both the MO and RO scales earned higher final exam scores than students with lower scores.

BouJaoude and Giuliano suggested that having a balance of MO and RO, or a combination of deep and surface strategies, is most beneficial for science success.

Zeegers' (2001) longitudinal study identified specific approaches to learning in college science. He measured students' deep approach (understanding by connecting material to broader contexts) and surface approach (learning through memorization) over three years and found changes over time. During the first year of the study, students' surface learning approach increased while their deep learning approach decreased. The deep approach returned to the students' starting level between the second and third years, while the surface approach remained stable. A positive significant relationship was found between the deep approach and yearly GPA, and a small negative correlation was found between surface learning and annual GPA (Zeegers, 2001). Although the surface approach was used more by students, it did not prove to support successful science learning.

Critique of Learning Strategies and Science Learning Literature

A critique of learning strategy use and science learning literature revealed methodological issues that also exist in other disciplines. It is clear that science students employ many deep and surface self-regulating strategies. While some researchers test surface and deep learning approaches (BouJaoude & Giuliano, 1994; Zeegers, 2001), others test specific strategies (Chen, 2002) or a cluster of strategies (Yu, 1999; Zusho et al., 2003). As there are many skills that fall under the categories of deep and surface learning, researchers need to identify the specific skills they are testing, so that it is clear which need promotion or use.

There is also variability in how science performance is measured. Measuring performance via global GPA (Zeegers, 2001) or specific science course grade (BouJaoude & Giuliano, 1994; Yu, 1999; Zusho et al., 2003) investigates two different research questions. The former tests how skills relate to overall science success, while the latter tests skills needed for a specific science course. The results could have different implications for which skills instructors promote in different courses.

Although some researchers investigated and found differences in learning strategy use in science courses by gender and ethnicity (Garcia, 1993; Yu, 1999), more studies are needed to determine if these differences consistently affect science performance. Because age and experience influence strategy use, researchers may want to consider these factors when measuring performance (Linder & Harris, 1992; Zeegers, 2001). Considering learning strategy use over time will help identify when skills develop or they are beneficial to particular groups.

Finally, strategy use is often measured in isolation. Zeegers (2001) cautions researchers that many factors impact strategy selection and students are often motivated to implement only those strategies they think will lead to success. As motivation seems to be a necessary but not sufficient factor for implementing learning strategies (Vollmeyer & Rheinberg, 2006; Wolters, 1998), it is difficult to tease out whether SRL predicts academic performance without considering motivational constructs that promote use of certain strategies.

Studies Investigating Both Motivation and Learning Strategies

Investigating both motivation and learning strategies within the same study allows researchers to interpret how they interrelate and jointly predict success. Two sentinel studies by Pintrich and De Groot (1990) and Pokay and Blumenfeld (1990) measured levels of motivation and learning strategy use with middle and high school students respectively. Pintrich and De Groot found that motivation, cognitive engagement and performance are connected. High self-efficacy and intrinsic motivation were related with greater use of cognitive strategies and higher achievement for all graded tasks. High test-anxiety was correlated with lower achievement on test scores (Pintrich & De Groot, 1990). Pokay and Blumenfeld found positive correlations between self-concept, perceived value, and expectancies, which all related to course grades. They also found that motivation and use of strategies at different times of the semester predicted performance differently. They concluded that strategy use may need to change as the demands of the course change (Pokay & Blumenfeld, 1990).

At the college level, researchers have investigated the predictive value of several motivation constructs and learning strategies in science courses. Garcia (1993) surveyed organic chemistry students at the beginning and end of the semester. While prior achievement, mastery orientation and effort regulation were the strongest predictors of final course grade, different variables predicted success at the beginning and end of the semester. At the beginning of the semester, prior achievement (high school GPA, verbal SAT and chemistry placement) and effort regulation positively predicted performance, while rehearsal had a negative relationship with performance, explaining 26% of variance in final course grade. At the end of the semester, both intrinsic and extrinsic goal orientation and effort regulation positively predicted performance while test anxiety negatively predicted performance, explaining 34% of the variance of final course grade.

Task value, rehearsal, metacognitive self-regulation strategies and time and study environment management were not significant predictors of course success.

Yu (1999) investigated the predictive ability of motivation and learning strategy use on final course grades in general chemistry. By the end of the semester, self-efficacy was the strongest predictor of final course grade. Additionally, effort regulation also positively predicted and intrinsic motivation negatively predicted final course grade. When considered with previous achievement, motivation and learning strategies accounted for 53% of the variance in final course grade. Task value, test anxiety, deep processing skills and self-regulation were not significant predictors of course success.

Zusho et al. (2003) studied the changes in motivation, cognitive and metacognitive self-regulation skills to determine what predicted final course grades in college chemistry. Self-reports were collected at three times throughout the semester, and results indicated that self-efficacy, task-value, performance goals, rehearsal and elaboration decreased, while organization and metacognitive skills increased. Self-efficacy, task value and rehearsal were significant predictors of final course grade and explained 31% of the variance in final course grade when considered with previous achievement. Mastery and performance goals, organization, elaboration and metacognitive self-regulation skills did not predict performance. Students who earned the highest final grades also reported higher self-efficacy, task value, mastery goals and deep processing strategies.

Gender Differences in Motivation and Learning Strategy Use

Over 40 years of science research has produced different theories of why gender differences in levels of motivation and strategy use occur. While early research concluded that women were afraid of success, by the 1970s, attribution theory explained that girls did not attribute their success to ability, but to effort and hard work (Meece et al., 2006). Meece, Glienke, and Burg (2006) explain that gender differences in competency beliefs begin at an early age. Self-efficacy research also has shown that males are more efficacious than females in science, even when females perform better (Pajares, 2002). The differences in motivation to learn science between males and females actually may exist because of stereotypes and socio-cultural factors rather than gender (Meece et al., 2006; Miyake et al., 2010: Nosek, 2009; Pajares, 2002).

Additional factors that may lead to gender differences in strategy use in science are modeling and expectation by both parents and teachers (Meece et al., 2006). Parents' perceptions of the child's ability can influence the child's perception of ability, even if achievement is controlled. When students perceive their ability to be low, they will not persist or try new skills, which can perpetuate poor performance (Meece & Jones, 1996). Although not as gender biased as they once were, teachers still may have different expectations for males and females. For example, math teachers have been found to emphasize the effort females put into their work. As a result, females may conclude that their success is due to effort rather than ability (Meece et al., 2006).

DeBacker and Nelson (2001) investigated gender differences in high school science. Females scored higher on measures of future value and teacher pleasing goals than males. However, it is interesting that females still scored lower on perceived ability, even if their science performance was not actually lower. Differences in motivation levels were also found for those who chose to continue to higher levels of science. These results suggest that if students do not believe they have the ability to succeed, they will not continue in the sciences (DeBacker & Nelson, 2001).

Britner (2008) also studied gender differences in motivation in several high school science subjects. Differences in self-efficacy by gender and science course subject were found. In earth sciences, females reported higher self-efficacy and earned higher grades. In life science, females earned higher grades, but reported lower self-efficacy and more anxiety. In physical science, there were no gender differences in grades or self-efficacy, but females reported more anxiety. Self-efficacy scores predicted science grades for males and females. Britner concluded that self-efficacy, although a strong predictor of science achievement may need to be examined differently for males and females. These findings suggest that females may need support in understanding academic successes and achievements, as well as techniques to reduce anxiety (Britner, 2008).

Cavallo, Potter, and Rozman (2004) investigated differences in learning approaches and motivational goals between male and female students enrolled in college physics. Males earned significantly higher final course grades, and analyses of the motivation constructs indicate gender differences as well. Although there was an increase in all students' learning goals, performance goals and concept understanding, males' performance goals and concept understanding began and remained at higher levels than females'. While self-efficacy did not significantly change from the beginning of the study to the end, males' scores were again always higher (Cavallo et al., 2004).

Zeyer (2010) explored the relationship between high school students' cognitive style and motivation to learn science. Cognitive styles include systemizing, the drive to analyze rules of a system and empathizing, the drive to understand someone else's mental state. Although a significant relationship between motivation to learn science and higher systemizing scores was reported, no gender differences in cognitive style or motivation to learn science were found. Chapell et al. (2005) analyzed gender differences with reported test anxiety and college academic performance. Even though females reported higher test anxiety, they earned higher GPAs. Glynn et al. (2007) found no gender differences in motivation to learn science, or science GPA for non-science majors. In another study by Glynn et al. (2009) overall motivation did not differ by gender but females reported more self-determination as well as lower self-efficacy and greater assessment anxiety. Thus, results about how gender and motivation relate to each other are mixed.

Research on differences by gender in science learning strategy use is also complex. Meece and Jones (1996) summarized several studies that found approaches to learning science differ by gender, but results were not consistent. Early research reported females favored surface approaches (arbitrary and not connecting new ideas), while males' approaches were deep (deliberately relating new information to what is known) (Meece & Jones, 1996). However, more recent research reported females were in fact using strategies that led to meaningful learning (Meece & Jones, 1996). Pajares (2002) also found females more efficacious in using self-regulation skills. Contrary to both of these studies, Zeegers' (2001) reported that while college science students' changed their strategies over time, gender did not affect the change.

Several studies have considered the impact of gender on both motivation and learning strategy use in science. Meece and Jones (2006) investigated differences in achievement levels, motivation and learning strategy use of 5^{th} and 6^{th} grade students. Findings indicate that male and female high achievers reported higher confidence in learning science. Interestingly, low and average achieving males also reported high confidence. Differences in achievement levels showed differences in motivation and strategies use, most notably in the low achievement group where males reported more mastery goals and females reported lower motivation. Average achieving females used more active learning than the average achieving males. Although the females reported lower confidence in their ability, there were no differences in actual performance (Meece & Jones, 1996).

Garcia (1993) evaluated motivation and learning strategies for organic chemistry. Males reported higher scores in extrinsic goals and females reported more learning strategies and test anxiety. There were also differences in the change of motivation over the course of the semester. While all students' intrinsic goals, task value and learning strategies decreased, only males' extrinsic goals increased. Gender did not predict final course grades (Garcia, 1993).

Yu's (1999) evaluation of motivation and study strategies in college chemistry found that males earned significantly higher course grades than females. Motivation also differed by gender, with males reporting higher self efficacy and females reporting higher task value, test anxiety, deep processing skills and self-regulation. No significant gender differences were found for intrinsic goal orientation or effort regulation. Gender was a significant predictor of final course grades, with females scoring lower, until motivation and learning strategies were considered. Although significant gender differences appeared, motivation and learning strategies were stronger predictors of course grade than both gender and prior knowledge (Yu, 1999).

Cavallo et al. (2004) also found differences in learning approaches and motivation in college physics by gender. Females used fewer meaningful approaches to studying than males, although there were no significant differences in the use of rote learning strategies. For female students, negative relationships were reported between meaningful learning, rote learning and performance goals, as well as between learning and performance goals. For both male and female students, a positive correlation between self-efficacy, meaningful learning and learning goals was reported. These factors also had different predictive ability of final course grade by gender. For males, self-efficacy predicted higher concept understanding, but learning goals and rote learning negatively predicted course performance. For females, higher self-efficacy and reasoning ability predicted higher concept understanding, and both higher self-efficacy and reasoning predicted higher course performance. Although changes in motivation and learning strategies were reported by all students, males and females did not begin the semester with the same level of understanding or self-efficacy (Cavallo et al., 2004).

Ethnic Differences in Motivation and Learning Strategy Use

While differences in science performance by ethnicity are often reported (Barton, 2002; Bruschi & Anderson, 1994; Stedman, 2009), explaining why these differences exist is difficult. There is less research on how motivation and learning strategy use vary by ethnicity than by gender. While some ethnicity studies focus on why group differences in motivation and learning strategy use exist, others measure if differences impact science performance.

Differences in motivation to learn science may be a result of less exposure to science beginning in high school. For example, reports indicate African-Americans were less likely to enroll in courses such as chemistry or physics (Weinburgh, 2000). Lewis and Connell (2005) acknowledge that the number of science classes taken in high school influences college major selection and taking advanced science classes in college is one of the strongest predictors of pursuing a science career. In order for students to enroll in higher level science courses, they must have interest in or motivation to learn the subject matter (Lewis & Connell, 2005).

In an exploratory study with African-American high school students enrolled in advanced science courses, 72% indicated interest in at least one science related career. Over half in the advanced courses site their reason for enrolling as interest in the subject (which can be interpreted as intrinsic motivation), career/college preparation, or to learn more about the discipline. Students explained that their interest in science was present before they enrolled. After attending the class, 36% gained interest in the subject while only 12% lost interest. These results suggest that interest in science may also increase motivation to pursue advanced courses, which may ultimately help students succeed (Lewis & Connell, 2005).

Nelson (1996) warned that while poor achievement is often blamed on lower family income or lack of preparation or motivation, differences in performance may actually be linked to the learning strategies students implement. Black and Hispanic students may perceive that particular strategies, such as working with peers or in groups, are only necessary for students who struggle. They may also perceive these actions insinuate cheating or are socially undesirable. In contrast, Asian-American students may perceive that working in groups and helping others actually improves social status. Some Black and Hispanic students with more preparation and higher family income often perform worse than expected in college science courses. Since low performance is not a result of lack of preparation, results support the hypothesis that these students are not using strategies, such as working with others (Nelson, 1996).

Weinburgh (2000) studied differences in motivation to learn science with White and African-American middle school students. Although there were not significant differences in motivation to learn science, White students' reported higher scores on measurements of positive perceptions of the teacher, value of science, science self-concept and enjoyment of science. Results also indicated Whites had lower anxiety scores than African-Americans (Weinburgh, 2000).

Garcia's (1993) study explored changes in organic chemistry students' motivation and learning strategy use as well as differences between Caucasian, Asian and grouped African-American/Hispanic students. Caucasian and Asian students reported higher pervious achievement scores and earned higher final course grades than African-American and Hispanic students. Differences in motivation and strategy use were also found. Caucasians reported the lowest extrinsic goal scores, as well as the lowest test anxiety at the end of the semester. While intrinsic goals, task value, and learning strategy use decreased, extrinsic goals increased for Caucasians. Asians reported lower metacognitive strategies at the beginning of semester. Similar to Caucasian students, their task value and learning strategies decreased during the semester. Interestingly, Asians' task value was not a factor in predicting their performance, as grades were similar whether they valued the class or not. For African-American/Hispanic students, the only significant change in learning strategy was a decrease in rehearsal. While differences in motivation were found between the groups, contrary to expectations, ethnicity was not a significant predictor of course performance (Garcia, 1993).

Critique of Research on Motivation and Learning Strategies by Gender and Ethnicity

Mixed results on the relationship between science performance, motivation and learning strategies by gender and ethnicity make interpretation of the data difficult. Gender does not always predict science performance once motivation and learning strategies are considered in prediction models (Garcia, 1993; Yu, 1999). However, differences by gender are consistently reported (Cavallo et al., 2004; Garcia, 1993; Yu, 1999). Because gender stereotypes and thoughts about science ability develop at an early age (Meece et al., 2006), more research needs to explore whether motivation and strategy use influence science performance more than gender itself (Miyake et al., 2010) or if thoughts about ability influence motivation and strategy use. Researchers need to be sensitive to the relationship between motivation and learning strategies with particular science courses before drawing conclusions that differences are caused by gender. They may also want to consider whether differences are consistent between science subjects.

For the studies that consider ethnicity, comparisons are difficult because there is little consistency in how groups are defined or how many groups are investigated. While these differences are often attributed to ethnicity, they may actually be a result of exposure to science material or strategies in middle and high school (Neslon, 1996). Since more ethnic minorities are studying science at the college level than ever before (National Science Board, 2010), continued study investigating group differences in motivation and learning strategy use is needed. These studies will help determine if increases in motivation and learning strategy use can help reduce the gap in performance.

Discussion

Both motivation and learning strategies are associated with success in science learning and predict performance at the college level. It is important to understand in what ways students with higher levels of motivation and effective learning strategies perform better in college science courses. Also, there are many questions about how motivation constructs and learning strategies affect science success by gender and ethnicity. This review provides information essential to both instructors who deliver content and college administrators who design academic support programs. Additionally, analysis of previous studies investigating motivation and learning strategies as predictors of college science success guides future research in significant ways.

Implications for Practice

Research on the relationship between motivation, learning strategies and science performance represents a loud call for courses delivery to promote active learning (Allen & Tanner, 2005; Anderson et al., 2010; Bao et al., 2009; Eberlin et al., 2008; Ebert-May, Batzli, & Lim, 2003). When active learning occurs in the classroom, "the student's level of motivation, curiosity, and attention are high" (Wood 2009, p. 97), and engagement with the material increases (Gauci, Dantas, Williams, & Kemm, 2009). Thus, promoting motivation and learning strategy use that supports active learning enhances student performance.

The literature highlights intrinsic and extrinsic motivation, goal orientation, task value, self-determination, self-efficacy and assessment anxiety as key factors for consideration (Glynn & Koballa, 2006). Instructors can create many activities that foster both intrinsic and extrinsic motivation inside and outside of the classroom, from creating excitement with demonstrations and experiments to encouraging students' participation in science related activities on their own time. When students are allowed to choose paper or project topics they discover or gain interest in new areas of science. In addition, instructors may reward participation in a problem-solving group or attendance of a professional lecture or conference. Exposure to science topics outside of the classroom also could pique in-class content interest.

Instructors can foster learning and performance goals by clearly explaining their own goals for the class (Wood, 2009). If expectations of learning outcomes are transparent and students understand what it will take to succeed in the course (Wood, 2009), they may be encouraged to reflect on their own learning and performance goals. Instructors may ask students to identify their goals at the beginning of the semester in order to compare them to the course goals. Having both learning and performance goals may support student success (Harackiewicz et al., 1998), but students should understand the course goals and whether their own goals are in line with those expectations.

Task value will increase when students understand why learning material or participating in activities assist in achieving their own current and future goals. Instructors can encourage students to identify their career goals, visit the career center on campus or meet science professionals. Instructors may consider using problem-based learning or case studies to highlight why science learning is relevant to all students, even those not pursuing a science career.

For self-determination to impact learning, students must have a sense of control over the environment. “Instructors must give up the widely held transmissionist view that students must be told everything they need to know” (Wood, 2009, p. 105) and afford students opportunities to learn some on their own. Posing discussion questions, allowing for student led presentations, and setting up peer-led team learning groups (Allen & Tanner, 2005) can support students’ autonomy and increase self-determination.

Self-efficacy can be improved with good instruction (Bonney et al., 2005). Instructors can create circumstances where students actively experience learning and are able to self-evaluate their understanding or performance. For instance, instructors can foster efficacious beliefs by providing standards of science learning so that students can compare how they are performing to others (Pajares, 1996). Instructors should promote both competence and confidence (Pajares, 2002). Providing more formative feedback, via smaller assignments, daily quizzes, or other learning activities (Allen & Tanner, 2005; Wood, 2009), are easy ways for students to check whether they are on track and prepared to succeed. If successful with these tasks, students may feel more self-efficacious for larger or summative evaluations.

Instructors can help reduce assessment anxiety by teaching test preparation and test taking skills specific for science exams. Referrals to campus workshops or support services that teach these skills can also be made throughout the semester. Providing more feedback through smaller, formative assessments could also help students build confidence in their test-taking skills. Such assessments provide opportunities for understanding the evaluation process so students can have more realistic expectations and better prepare.

All students are not explicitly taught how and when to use learning strategies, or even how to reflect on their own learning (Bao et al., 2009). While strong students often learn skills that allow them to reach deeper learning independently, “many students, for whom studying means highlighting phrases in their textbooks and memorizing disconnected facts, fail to develop effective learning skills and consequently learn very little” (Wood, 2009, p. 98). Students need guidance in developing the skills necessary for meaningful science learning.

Rickey and Stacy (2000) suggested that professors weave instruction of metacognitive skills into their content delivery. While it may be challenging to convince students to use new strategies, informing them that the strategies they used in the past may not be effective for more complex college science courses (Modell, 1996). Building time in for activities such as individual discussions with peers, practice with problem-solving, or reflection on a new concept, provides modeling of the deeper strategies students should be implemented. These activities also support increased content understanding and ultimately facilitate science literacy (Bliecher et al., 2002; Cavallo et al., 2004; Eberlein et al., 2008; Wood, 2009; Zeegers, 2001). Instructors also could ask students to share their most effective strategies with peers so that they are exposed to new ideas that have proven helpful to others in the same learning environment. By incorporating these activities into a lecture, students gain experience with the necessary strategies for success and may be more likely to continue practicing these skills outside of class.

Group differences in motivation and strategy use by gender and ethnicity indicate that some may have a greater need for explicit instruction of the factors that lead to science success (Britner, 2008; Nelson, 1996). Instructors may consider setting up study groups facilitated by successful students who could teach those lacking in strategies. Formative assessment could measure whether participation in the study groups impact learning outcomes.

If time constraints limit interactive techniques during class time, professors can simply explain how and why motivation and strategy use support science learning. Instructors can encourage active learning outside of the classroom in a variety of ways (Modell, 1996; Wood, 2009). For instance, if support programs or offices with learning professionals, tutoring or other academic support are available, ways to connect students to these services include class announcements, information on the syllabus, or electronic reminders.

Instructors should approach teaching college science in the same manner as a research study. They can begin their class by making hypotheses, collecting and analyzing data about their students, and then make decisions about how to proceed with instruction based on their analyses (Ebert-May et al., 2003; Freeman et al., 2007). Data from formal and informal instruments on motivation and learning strategy use may help instructors understand who is enrolled in their courses and whether promotion of constructs or instruction of specific skills is needed. As different skills are needed throughout a semester by different students, instructors could benefit from understanding if and when students are using particular strategies as well as identifying which students are in need of learning them.

Administrators should also be aware that while the promotion of motivation and learning strategies support active learning environments (Allen & Tanner, 2005; Wood, 2009), implementing such techniques causes extra work for instructors. Instructors therefore need time to incorporate learning theory into practice, as well as implement new teaching methods (Anderson et al., 2011). For instructors to be motivated to change their instructional design and practice, they need support from colleagues, their departments and administrators (Anderson et al., 2011).

Implications for Future Research

Future research should expand on previous studies and consider multiple motivation constructs and learning strategies. Investigating a broad range of variables within one study provides a clear picture of how motivation constructs and learning strategies predict success in college science courses. Levels of motivation and learning strategy use need to be evaluated by area or department, because each discipline may require different skills. Researchers also could consider measures of performance such as homework problems, tests, and related lab assignments in order to definitively determine the motivation and learning strategies necessary for the class. Comparisons of motivation and strategy use between science subjects will help determine whether there are universal variables necessary for science success, or whether they are subject specific.

Students' motivation to learn science and strategy use change over the course of a semester (Garcia, 1993; Yu, 1999; Zusho et al., 2003) but the differences in results about which variables change and when these changes occur invite continued study. Timing of self-reports should also be considered in future research. Students must have some experience in the class before they can accurately answer questions about their motivation and strategy use. While data at the beginning or end of a course allow for pre/post test comparison, the possibility for changes throughout the semester is often overlooked. Data collected throughout the semester could be used as an early alert system to identify students considering withdrawal or those at-risk for failure. Longitudinal research on how motivation and learning strategies change from introductory to advanced courses or in a variety of science major courses will help determine which variables are most important throughout a science student's educational career.

While we know students report differences in motivation and learning strategy use based on gender and ethnicity, these results are inconsistent. Future studies need to include a comprehensive set of motivation constructs and learning strategies to determine which have the strongest affect on performance. Studies must continue to include gender and ethnicity when exploring the predictive ability of different variables that affect college science success.

Motivation and learning strategy use, "have the potential of being enhanced and modified by new and innovative curricular and instructional approaches to teaching and learning" (Singh et al., p. 324). Identifying specific teaching techniques or support interventions that significantly increase motivation and learning strategy use may encourage both instructors and administrators to make changes.

This review presents studies that explain when and why motivation and learning strategies affect science learning. Challenges to effective science learning persist as educators face student populations and demographics that are constantly changing. Instructional implications are highlighted along with areas of research that need more attention. This material contributes toward an understanding of how certain variables predict science success, essential information for both professors and administrators who continue the important work of college science learning.

References

Ablard, K. E., & Lipschultz, R. E. (1998). Self-regulated learning in high-achieving students: Relations to advanced reasoning, achievement goals and gender. *Journal of Educational Psychology, 90(1)*, 94-101.

Allen, D., & Tanner, K. (2005). Infusing active learning into the large-enrollment Biology class: Seven strategies, from the simple to complex. *Cell Biology Education, 4,* 262-268. doi: 10.1187 / cbe.05-08-0113

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84,* 261-271.

Anderson, W. A., Banerjee, U., Drennan, C. L., Elgin, C. R., Epstein, I. R., Handelsman, J., … Warner, I. M. (2011, January). Changing the culture of science education at research universities. *Science, 331,* 152-153.

Andrew, S. (1998). Self-efficacy as a predictor of academic performance in science. *Journal of Advanced Nursing, 27*, 596-603.

Aud, S., Hussar, W., Planty, M., Snyder, T., Bianco, K., Fox, M., … Drake, L. (2010). *The Condition of Education 2010* (NCES 2010-028). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Ausubel, D. P. (1963). *The psychology of meaningful learning.* New York: Grune & Stratton.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman and Company.

Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., … Wu, N. (2009, January). Learning and scientific reasoning. *Science, 323*, 586-87.

Barton, P. (2002). A deeper look at NAEP science results. *ETS Policy Notes, 11,* 2-10.

Berkley, C. S., & Sproule, C. F. (1973). Test-anxiety and test-unsophistication: The effects, the cures. *Public Personnel Management, January-February*, 55-59.

Black, A. E., & Deci, E. L (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education, 84,* 740-756. doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3

Bleicher, R. E., Romance, N., & Haky, J. (2002, January). *Curriculum by design: Improving student learning in college chemistry and biology*. Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science: Charlotte, NC.

Bonney, C., Klemper, T., Zhusho, A., Coppola, B. P., & Pintrich, P. R. (2005). Student learning in science classrooms: What role does motivation play? In S. Alsop (Ed.), *Beyond Cartesian dualism: Encountering affect in the teaching and learning of science* (pp. 83-97). Dordrecht, The Netherlands: Springer.

BouJaoude, S. B., & Giuliano, F. J. (1994). Relationships between achievement and selective variables in a chemistry course for nonmajors. *School Science and Mathematics, 94*, 296-302.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching, 45*, 955-970.

Britner, S. L., & Pajares, P. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43*, 485-499.

Bruschi, B. & Anderson, B. T. (1994, February). *Gender and ethnic differences in science achievement of nine-, thirteen-, and seventeen-year-old students*. Paper presented at the Annual Meeting of the Eastern Educational Research Association, Sarasota, FL.

Burton, N. W., & Ramist, L. (2001). Predicting success in college: SAT studies of classes graduating since 1980. *College Board Research Report No. 2001-2*. 1-32.

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology, 27,* 270-295. doi: 10.1006/ceps.2001.1094

Cavallo, A.M. L., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong college physics course for life science majors. *School Science and Mathematics, 104*, 288-300.

Chapell, M. S., Blanding, Z. B, Silverstein, M. E., Takahashi, M., Newman, B., Gubi, A., & Mccann, N. (2005). Test anxiety and academic performance in undergraduate and graduate students. *Journal of Educational Psychology, 97,* 268-274. doi:10.1037/0022-0663.97.2.268

Chemers, M. M., Li-tze, H, & Garcia, B. F. (2001). Academic self-efficacy and first-year college performance and adjustment. *Journal of Educational Psychology, 93,* 55-64.

Chen, C. S. (2002). Self-regulated learning strategies and achievement in an introduction to information systems course. *Information Technology, Learning, and Performance Journal, 20*, 11-25.

Chin, C., & Brown, D. E. (2000). Learning in science: A comparison of deep and surface approaches. *Journal of Research in Science Teaching, 37*, 109-138.

Corno, L. & Randi, J. (1999). A design theory for classroom instruction in self-regulated learning? In C.M. Reigeluth (Ed.), *Instructional theories in action: Lessons illustrating selected theories and models.* (pp. 293-318). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Covington, M. V. (2000a). Goal theory, motivation and school achievement: An integrative review. *Annual Review of Psychology, 51,* 171-200.

Covington, M. V. (2000b). Intrinsic versus extrinsic motivation in schools: A reconciliation. *American Psychological Society*, *9*(1), 22-25.

DeBacker, T. K., & Nelson, R. M. (2001). Motivation to learn science: Differences related to gender, class type, and ability. *The Journal of Educational Research, 93,* 245-254.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41,* 1040-1048.

Eberlein, T., Kampmeier, J., Minderhout, V., Moog, R. S., Platt, T., Varma-Nelson, P., & White, H. B. (2008). Pedagogies of engagement in science. *Biochemistry and Molecular Biology Education, 36*, 262-273. doi: 10.1002/bmb.20204

Ebert-May, D., Batzli, J., & Lim, H. (2003). Disciplinary research strategies for assessment of learning. *BioScience, 53,* 1221-1228.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values and goals. *Annual Review of Psychology, 53,* 109-132.

Elliott, E. S, & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54,* 5-12.

Eppler, M. A., & Harju, B. L. (1997). Achievement motivation goals in relation to academic performance in traditional and nontraditional college students. *Research in Higher Education, 38,* 557-573.

Freeman, C. E. (2004). *Trends in Educational Equity of Girls & Women: 2004 (NCES 2005–016)*. Retrieved from Washington, DC: U.S. Government Printing Office: http://nces.ed.gov/pubs2005/2005016.pdf

Freeman, S., O’Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., …Wenderoth, P. (2007). Prescribed active learning increases performance in introductory biology. *CBE-Life Sciences Education, 6,* 132-139. doi: 10.1187/cbe.06–09–0194

Garcia, T. (1993, April). *Women and minorities in science: Motivational and cognitive correlates of achievement*. Paper presented at the Annual Meeting of the American Educational Research Association. Atlanta, GA.

Garcia, T., & Pintrich, P. (1996). The effects of autonomy on motivation and performance in the college classroom. *Contemporary Educational Psychology, 21,* 477-486.

Gauci, S. A., Dantas, A. M., Williams, D. A., & Kemm, R. E. (2009). Promoting student-centered active learning in lectures with a personal response system. *Advances in Physiology Education, 33,* 60-71. doi:10.1152/advan.00109.2007

Gender differences in science achievement. (2009). *SWE-AWE CASEE Overviews*. Retrieved from www.engr.psu.edu/awe/misc/ARPs/ARP_InfoSheet_Science.pdf

Glynn, S. M., & Koballa, T. R. (2006). Motivation to learn college science. In Joel J. Mintzes and William H. Leonard (Eds.), *Handbook of College Science Teaching* (pp. 25-32). Arlington, VA: National Science Teachers Association Press.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching, 44*, 1088-1107. Doi: 10.1002/tea.20181.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46,* 127-146. doi: 10.1002/tea.20267

Harackiewicz, J. M., Barron, K. E., & Elliot, A. J. (1998). Rethinking achievement goals: When are they adaptive for college students and why? *Educational Psychologist, 33,* 1-21.

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of Educational Research, 58(1)*, 47-77.

Ironsmith, M., Marva, J., Harju, B., & Eppler, M. (2003). Motivation and performance in college students enrolled in self-paced versus lecture-format remedial mathematics courses. *Journal of Instructional Psychology, 30*, 276-284.

Kaufmann, J.C., Agars, M.D., & Lopez-Wagner, M.C. (2008). The role of personality and motivation in predicting early college success in nontraditional students at a Hispanic-serving institution. *Learning and Individual Differences, 19,* 492-496.

Lavigne, G. L., Vallerand, R. J., & Miquelon, P. (2007). A motivational model of persistence in education: A self-determination theory approach. *European Journal of Psychology of Education, XXII,* 351-369.

Lent, R.W., Brown, S. D., & Larkin, K. C. (1984). Relation of self-efficacy expectations to academic achievement and persistence. *Journal of Counseling Psychology, 31*, 356-362.

Lewis, B. F., & Connell, S. (2005). African American students' career considerations for enrolling in advanced science courses. *The Negro Educational Review, 56,* 221-31.

Lin, Y. G., McKeachie, W. J., & Kim, Y. C. (2002). College student intrinsic and/or extrinsic motivation and learning. *Learning and Individual Differences, 13,* 251-258.

Linder, R. W., & Harris, B. (1992, April). *Self-regulated learning and academic achievement in college students*. Paper presented at the American Educational Research Association Annual Meeting, San Francisco.

McGregor, H. A., & Elliot, A. J. (2002). Achievement goals as predictors of achievement-relevant processes prior to engagement. *Journal of Educational Psychology, 94,* 381-395. doi: 10.1037//0022-0663.94.2.381

Meece, J. L., Glienke, B., & Burg, S. (2006). Gender and motivation. *Journal of Social Psychology*, *44*, 351-73.

Meece, J. L., & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching, 33*, 393-406.

Miyake, A., Kost-Smith, L. E., Finkelstein, N. D., Pollock, S. J., Cohen, G. L., & Ito, T. A. (2010, November). Reducing the gender achievement gap in college science: A classroom study of values affirmation. *Science, 330,* 1234-1237.

Modell, H. (1996). Preparing students to participate in an active learning environment. *Advances in Physiology Education, 15,* S69-S77.

Murphy, P. K., & Alexander, P. A. (2000). A motivated explorations of motivation terminology. *Contemporary Educational Psychology 25*(3), 3-53. doi: 10.1006/ceps.1999.1019

National Center for Education Statistics. (2009). *Digest of Education Statistics: 2009*. Retrieved from http://nces.ed.gov/programs/digest/d09/

National Center for Education Statistics. (2010). *Digest of Education Statistics: 2010.* Retrieved from http://nces.ed.gov/programs/digest/d10/

National Science Board. (2010). *Science and Engineering Indicators 2010.* Arlington, VA: National Science Foundation (NSB 10-01).

Nelson, C. E. (1996). Student diversity requires different approaches to college teaching, even in math and science." *American Behavioral Scientist 40,* 165-75.

Nosek B. A., Smyth, F.L., Sriram, N., Lindner, N.M. Devos, T., Ayala, A… Greenwald, A. G. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *PNAS, 106*, 10593-10597.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543-578.

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory Into Practice, 41*, 116-125.

Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review, 16*, 385-407.

Pintrich, P. R., & De Groot, E.V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82,* 33-40.

Pittman, T. S., & Boggiano, A. K. (1992). Psychological perspectives on motivation and achievement. In A.K. Boggiano & T.S. Pittman (Eds.), *Achievement and motivation: A social-developmental perspective* (pp. 1-5). Location: Cambridge University Press.

Pokay, P., & Blumenfeld, P. C. (1990). Predicting achievement early and late in the semester: The role of motivation and learning strategy use. *Journal of Educational Psychology, 82*, 41-50.

Prus, J., Hatcher, L., Hope, M., & Grabiel, C. (1995). The Learning and Study Strategies Inventory (LASSI) as a predictor of first-year college academic success. *Journal of The Freshman Year Experience, 7,* 7-26.

Rickey, D., & Stacy, A. M. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education, 77,* 916-920.

Robbins, S. B., Allen, J., Casillas, A., Peterson, C. H., & Le, H. (2006). Unraveling the differential effects of motivational and skills, social, and self-management measures from traditional predictors of college outcomes. *Journal of Educational Psychology, 98,* 598-616. doi: 10.1037/0022-0663.98.3.598

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin, 130*, 261-288. doi: 10.1037/0033-2909.130.2.261

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology, 25,* 54-67. doi:10.1006/ceps.1999.1020

Schraw, G., Horn, C., Thorndike-Christ, T., & Bruning, R. (1995) Academic goal orientations and student classroom achievement. *Contemporary Educational Psychology, 20,* 359-368.

Schunk, D. H. (2005). Self-regulated learning: The educational legacy of Paul R. Pintrich. *Educational Psychologist, 40(2)*, 85-94.

Schuss, D. G. (1999, May 30). Many top college students use tutors to keep an edge study sessions aren't just for catching up. *Boston Globe*, p. D5.

Schwartz, M. C., Sadler, P. M., Sonnert, G., & Tai, R. H. (2008). Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93,* 798-826. doi: 10.1002/sce.20328

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*, 323-332.

Smith, W.,S., Gould, S. M., & Jones, J. A. (2004). Starting the semester at odds: Educators’ versus students’ reasons for studying science. *Journal of College Science Teaching, 34*, 44-49.

Spencer, H. E. (1996). Mathematical SAT test scores and college chemistry grades. *Journal of Chemical Education, 73*, 1150-1153.

Stedman, L. C. (2009, March). The NAEP long-term trend assessment: A review of its transformation, use, and findings. Paper commissioned for the 20th anniversary of the National Assessment Governing Board, 1988-2008.

Tai, R. T., Sadler, P. M., & Loehr, J. F. (2005). Factors influencing success in introductory college chemistry. *Journal of Research in Science Teaching, 42*, 987-1012.

Taasoobshirazi, G., & Glynn, S. M. (2009). College students solving chemistry problems: A theoretical model of expertise. *Journal of Research in Science Teaching, 46*, 1070-1089.

Vollmeyer, R., & Rheinberg, F. (2006). Motivational effects on self-regulated learning with different tasks. *Educ Psychol Rev, 18*, 239-253.

Walker, C. O., Greene, B. A., & Mansell, R. A. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. *Learning and Individual Differences, 16,* 1-12.

Watson, M., McSorley, M., Foxcroft, C., & Watson, A. (2004). Exploring the motivation and learning strategies of first year university learners. *Tertiary Education and Management, 10*, 193-207.

Weinburgh, M. H. (2000). Gender, ethnicity, and grade level as predictors of middle school students' attitudes toward science. (Unpublished). Georgia State University, Atlanta.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology, 70*, 767-779.

Wolters, C. A. (1998). Self-regulated learning and college students' regulation of motivation. *Journal of Educational Psychology, 90(2)*, 224-234.

Wood, W. B. (2009). Innovations in teaching undergraduate biology and why we need them. *Annual Review of Cell and Development Biology, 25,* 93-112. doi: 10.1146/annurev.cellbio.24.110707.175306

Yerkes, R. M., & Dodson, J. D. (1908) The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18,* 459-482.

Young, D., & Ley, K. (2005). Developmental college student self-regulation: results from two measures. *Journal of College Reading and Learning, 36*, 60-80.

Yu, S. L. (1999). Women's motivation and strategy use in college science classes. *Journal of Staff, Program, & Organization Development, 16*, 93-101.

Zeegers, P. (2001). Approaches to learning in science: A longitudinal study. *British Journal of Educational Psychology, 71*, 115-132.

Zeyer, A. (2010). Motivation to learn science and cognitive style. *Eurasia Journal of Mathematics, Science & Teaching Education, 6*, 123-130.

Zimmerman, B. J. (2008) Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45(1)*, 166-83.

Zusho, A., Pintrich, P. A, & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education, 25*, 1081-1094.

CHAPTER 2

HOW MOTIVATION AND LEARNING STRATEGIES PREDICT INTRODUCTORY COLLEGE CHEMISTRY SUCCESS

All college students need to become scientifically literate citizens to be able to understand global issues and solve basic real world problems using scientific principles (Glynn, Taasoobshirazi, & Brickman, 2009; Smith, Gould, & Jones, 2004). As the number of students pursuing post-secondary degrees in science is higher than ever before (National Center for Education Statistics, 2010), their success is important for a number of reasons. First, completing science degrees will prepare students to confront challenges they face in the rapidly changing world of the 21st century. Second, they will help students advance to graduate programs and reach professional goals in a science research, technology, or medicine. In order to facilitate student achievement in science, it is crucial to understand the variables that predict success in the sciences.

Traditional predictors of college science success include previous academic achievement as measured by math SAT scores and/or high school GPAs (Spencer, 1996; Tai, Sadler, & Loehr, 2005; Zusho, Pintrich, & Coppola, 2003), and students' exposure to in-depth science topics in high school which prepare them for learning in advanced college courses (Schwartz, Sadler, Sonnert, & Tai, 2008). Since these measures of previous achievement are fixed variables not amenable to change, additional factors need to be considered once students matriculate in college science courses (Singh, Granville, & Dika, 2002). Challenges for identifying additional predictors of college science success include the following: many students may not be prepared to learn at the college level, students have varied interest levels in science, or some students lack conceptual understanding of scientific ideas and essential learning strategies, such as critical thinking (Bao et al., 2009; Bleicher, Romance, & Haky, 2002; National Center for Education Statistics, 2009; Schuss, 1999).

Students' level of motivation and learning strategy use in college science courses may help fill the gaps left by Math SAT, high school GPA and/or in-depth exposure to science material (Garcia, 1993; Yu, 1999; Zusho et al., 2003). Motivation is the process that drives, initiates and sustains behavior. To be motivated to learn, students must participate in activities that are personally meaningful and worthwhile (Glynn & Koballa, 2006). Motivation constructs do not always illustrate the specific actions students take or perform to reach learning objectives, such as implementation of learning strategies. In college science courses, students must retain basic information in order to learn new and advanced material and apply concepts to problem-solving and scientific inquiry (Bleicher et al. 2002; Taasoobshirazi & Glynn, 2009). To do this, students must employ a variety of self-regulated learning strategies. Considering a broad range of motivation constructs and learning strategies in a single study could help better predict success.

Intrinsic and extrinsic motivation, task value, self-determination, self-efficacy and assessment anxiety are important constructs for science learning (Glynn & Koballa, 2006; Glynn et al., 2009). Intrinsic and extrinsic motivations explain the rewards students expect by engaging in particular learning activities (Eccles & Wigfield, 2002). Intrinsic motivation refers to performance of a task rewarded by completing the task itself, whereas extrinsic motivation refers to performance of a task in order to receive an external reward (Murphy & Alexander, 2000; Ryan & Deci, 2000). Biology students with high levels of intrinsic motivation and medium levels of extrinsic motivation outperformed their peers (Lin, McKeachie, & Kim, 2002, and both intrinsic and extrinsic motivation positively predicted organic chemistry final grades (Garcia, 1993). Contrary to these findings, Yu (1999) found that intrinsic motivation negatively predicted performance in introductory chemistry (Yu, 1999).

Task value explains whether course material and learning activities are personally relevant to the student (Duncan & McKeachie, 2005; Eccles & Wigfield, 2002). Students must identify why performing well on a task is important and decide whether tasks are useful, practical or relevant (Eccles & Wigfield, 2002).When students' task value is high, performance in college science courses is higher (Glynn, Taasoobshirazi, & Brickman, 2007; Zusho et al., 2003). While task value often declines during a semester of college science (Garcia 1993; Yu, 1999; Zusho et al., 2003) it significantly predicted introductory chemistry performance even more than previous achievement (Zusho et al, 2003).

Academic self-determination is defined by the control a student perceives he or she has over learning. This sense of control includes both a perception of autonomy in the learning environment and competence in the ability to perform a task (Glynn & Koballa, 2006; Lavigne, Vallerand, & Miquelon, 2007). While self-determination is not always a direct predictor of science success, it is strongly related to motivation orientation (Garcia & Pintrich, 1996) and lower assessment anxiety (Black & Deci, 2000).

Self-efficacy describes whether a student believes he or she can successfully perform a specific task. Students with high self-efficacy believe tasks can be accomplished and are more likely to proceed with the task, while students with low self-efficacy avoid tasks (Bandura, 1997). Self-efficacy regulates the perception of difficulty and the amount of effort and persistence for completing a task (Pajares, 1996). For college science students, higher self-efficacy consistently relates to higher performance (Andrew, 1998; Lent, Brown, & Larkin, 1984; Yu, 1999) and by the end of a semester has even been found to be a stronger predictor of course performance than previous achievement in introductory chemistry (Yu, 1999; Zusho et al., 2003).

Assessment anxiety occurs when the test taker is unsure about the testing situation, fears the unknown and/or failure, or believes that tests are unfair (Berkley & Sproule, 1973). Anxiety can motivate students to reach academic goals, but too much or too little can hurt learning and negatively affect performance (Glynn & Koballa, 2006). Students who report lower assessment anxiety have higher course grades and GPAs report lower anxiety (Chapell et al., 2005; Lin et al., 2002). By the end of a semester, test anxiety also has negatively predicted organic chemistry performance (Garcia, 1993).

Learning strategies that relate to college science performance can be categorized as cognitive, metacognitive self-regulation, and resource management skills. Cognitive skills include both surface and deep strategies. Rehearsal, a surface strategy, is the process of repeating information in order to memorize and recall facts. Deep strategies include elaboration (making connections between new and previously learned information), organization (summarizing how ideas and concepts relate to each other by creating outlines, lists or concept maps) and critical thinking (applying concepts to problem solving and other evaluations) (Pintrich, Smith, Garcia, & McKeachie, 1991). Some researchers have reported a significant negative correlation between the use of surface learning strategies and final organic chemistry grade or science GPA (Garcia, 1993; Zeegers, 2001). Others reported high course performers use rehearsal and that it positively predicted introductory chemistry performance (Zusho et al., 2003). While high course performers often reported using more deep strategies than low performers (BouJaoude & Giuliano, 1994; Zeegers, 2001; Zusho et al., 2003), use of these strategies did not always predict college science course success (Yu, 1999).

Metacognitive self-regulation skills include a variety of self-awareness tasks in which students plan, monitor and evaluate what they learn (Corno & Randi, 1999; Zimmerman, 2008). Science education researchers suggest that students employ metacognitive self-regulation skills to facilitate science course success in college (Rickey & Stacy, 2000). While students who employ metacognitive self-regulation skills generally perform better academically (Ablard & Lipschultz, 1998; Linder & Harris, 1992; Pintrich & De Groot, 1990), metacognitive self-regulation skills were not significant predictors of science success in courses such as organic or introductory chemistry (Garcia, 1993; Zusho et al., 2003).

Resource management skills include time and study space management, effort regulation (persisting with learning even if bored or distracted), and use of resources such as working with peers or seeking additional help from instructors and/or support programs (Pintrich et al., 1991). Effort regulation has most consistently associated with higher performance in college science courses (Chen, 2002; Garcia, 1993; Yu, 1999). However, time and study environment management has also been linked to higher science performance (Chen, 2002). Peer-learning supports higher science performance in multiple areas, independent of student achievement levels (Arendale, 2003-2005). Students who implemented more learning strategies did not seek help unless there was a perceived need for help (Karabenick & Knapp, 1991). Research often does not consider whether help-seeking relates to science course performance.

It is well documented that motivation and learning strategies change over the course of a semester (Garcia, 1993; Yu, 1999; Zusho et al., 2003). However, investigations of the impact of these changes on science course success have inconsistent findings. Differences in science performance by gender (Britner, 2008; Freeman, 2004) and ethnicity (Stedman, 2009) continue to be reported. Levels of motivation and learning strategy use also vary between these groups (Cavallo, Potter, & Rozman, 2004; Garcia, 1993; Yu, 1999). Mixed results on the relationship between science performance, motivation and learning strategy use by gender and ethnicity make interpretation of the data difficult.

The primary purpose of this study is to investigate the predictive ability of motivation and learning strategy use on success in introductory college chemistry. Introductory college chemistry is a foundational course often required for students to continue as natural science majors or apply to graduate programs in the science or health fields (Association of American Medical Colleges, 2010; Schwartz et al., 2008). Performance in introductory college chemistry also influences whether a student pursues higher level science courses. A second purpose of this study is to examine when during a semester motivation levels and learning strategy use increase or decrease and how these changes impact performance in introductory college chemistry. This study also considers whether these changes are different for High, Average and Low course performers throughout the semester. The third purpose of this study is to investigate differences in motivation and learning strategy use by gender and ethnicity and evaluate the predictive ability of these variables on introductory college chemistry success for each group.

Thus, the current study expands on previous research and considers a comprehensive set of motivation, learning strategies and demographic variables to answer the following questions.

1. Which motivation constructs and learning strategies have the strongest predictive ability for success in introductory college chemistry? Previous research revealed that self-efficacy and effort regulation are two specific variables that often emerge as strong predictors of success (Garcia, 1999; Yu, 1999; Zusho et al., 2003). By investigating a comprehensive set of motivation constructs and learning strategies within the same study, similar findings are expected for this study, and it is likely that additional variables will emerge as significant predictors.

2. How do levels of motivation and learning strategy use change throughout a semester, and are these changes different for High, Average and Low course performers? Previous studies found decreases in overall levels of motivation and varied results in changes in learning strategy use (Garcia, 1999; Yu, 1999; Zusho et al., 2003). It is probable that High course performers will report higher levels of motivation and more learning strategy use than Average and Low course performers as reported by previous research (Zusho et al., 2003). The consideration of multiple motivation constructs and learning strategies will reveal how and when these variables change for these groups.

3. How do levels of motivation and learning strategy use vary by gender and ethnicity, and which motivation constructs and learning strategies have the strongest predictive ability for success by each group? Previous studies have reported varied levels of motivation and learning strategy use by gender and ethnicity (Cavallo et al., 2004;

Garcia, 1993; Yu, 1999). This study will provide important information on which motivational constructs and learning strategies have the strongest predictive ability for each group.

Method

Participants

Participants were 413 college students (145 male, 268 female) enrolled in five sections of Introductory General Chemistry with Lab at a highly selective private university in the southeastern United States. Data was collected during fall semester, 2010. Participants represented 76.2% of all students enrolled in the course. The majority of participants were freshmen (70.0%); however sophomores (23.5%), juniors (3.9%) and seniors (2.2%) also participated. Ethnicity breakdown was based on self-report, ‘White/European descent’, 44.8%, ‘Asian/Pacific Islander’, 38.5%, ‘Black/African descent’, 10.2%, ‘Hispanic/Latino’ 4.1% and ‘Other’, 3.1%. Participants’ average Math SAT score was 705.52 and 35.1% took advanced placement (AP) Chemistry in high school. Participants also reported their primary reason for enrolling in the course. The majority (70.9%) selected ‘Pre-Health Requirement’, followed by ‘Other Science Major Requirement’ (10.2%), ‘Chemistry Major Requirement’ (4.8%), ‘General Education Requirement’ (2.7%) and ‘Other’ (2.4%).

Procedure

Participation was voluntary and the researcher recruited students through in-class announcements and e-mail. Participants completed self-reports about demographic information, their motivation and learning strategy use for their introductory college chemistry course through survey questions posted on Blackboard, a secure web-based platform, three times during semester. During the first administration at week 5 of the semester (Time 1), students completed demographic questions pertaining to gender, ethnicity, Math SAT score, AP Chemistry experience, the 30-item Chemistry Motivation Questionnaire (CMQ) and 50 items from the Learning Strategies section of the Motivated Strategies for Learning Questionnaire (MSLQ). On second and third administrations at weeks 10 and 15 of the semester (Times 2 and 3 respectively), students completed the same 30-item CMQ and 50 items from the MSLQ. Both the CMQ and MSLQ ask students to report answers on a Likert Scale. Professors awarded 1% extra credit to those students who completed surveys at all three time points.

Materials

The Chemistry Motivation Questionnaire (CMQ) (Glynn & Koballa, 2005a) is the chemistry specific version of the Science Motivation Questionnaire (SMQ) (Glynn & Koballa, 2005b; Glynn & Koballa, 2006; Glynn et al., 2009). This 30 question instrument measures motivation to learn chemistry in six areas: intrinsic motivation to learn chemistry (IM), extrinsic motivation to learn chemistry (EM), relevance of learning chemistry to personal goals (PR) (typically referred to in the literature as task value), self-determination to learn chemistry (SD), self-efficacy for learning chemistry (SE), and anxiety about chemistry assessment (AX) (Appendix A). Each category contains five questions and asks students to rate themselves by answering the following question "When I am in a college chemistry course…." using a five point Likert scale ranging from never to always (Glynn & Koballa, 2005a). Developed specifically to measure motivation to learn college chemistry, this instrument can be used as an advising tool before a course or as a pre/post test to see changes in chemistry motivation.

Total CMQ scores range between 30 and 150 with higher scores indicating higher motivation (30-59 low, 60-89 moderate, 90-119 high, 120-150 very high) (Glynn et al., 2007). In addition, each of the six subscales scores range between five and 25. Intrinsic and extrinsic motivation, personal relevance, self-determination and self-efficacy scores may be interpreted by the following range of scores: 5-9 'never to rarely', 10-15 'rarely to sometimes', 15-19 'sometimes to often' 20-25 'often to always'; while anxiety about chemistry assessment scores were reversed resulting in the following range of scores: 5-9 'often to always', 10-14 'sometimes to often', 15-19 rarely to sometimes, 20-25 'never to rarely'. Higher anxiety scores indicate lower levels of assessment anxiety, so that when included in the CMQ total score, higher scores indicate higher motivation (Glynn & Koballa, 2005b). Internal consistency reliability of this measurement as measured by coefficient alpha was reported as .93. Criterion-related validity testing found that SMQ scores significantly correlated with high school preparation for science (r = .58), college science GPA (r = .61) and relevance of science to personal careers (r = .50) (Glynn et al., 2009).

The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991) assesses both motivation orientation and learning strategies for college students in a particular course. For this study, questions from the Learning Strategies section were used (Appendix B). The MSLQ was selected for this study because it is a commonly used learning strategies inventory in the literature (Duncan & McKeachie, 2005), making comparisons to previous research more salient.

The MSLQ Learning Strategies section consists of 50 questions on nine subscales that assess cognitive skills, rehearsal (RE), elaboration (EL), organization (ORG) and critical thinking (CT), metacognitive self-regulation skills (MET) (monitoring, planning and evaluating), and resource management skills (time and study environment management (TSE), effort regulation (ER), peer learning (PL) and help-seeking (HS)) (Pintrich et al., 1991). All questions are asked on a seven point Likert scale ranging from 'not very true of me', to 'very true of me' (Duncan & McKeachie, 2005). There is no composite score, and subscales are scored and may be used individually. Cronbach alpha reliabilities ranged from .52 to .80. Validity scores measured nine latent but interrelated factors for the learning strategies scales (lambda skis ranges from .17-.90, mean .58). All subscales correlated with final course grade and significantly related to GPA (r = .30-.60) with the exception of rehearsal, peer-learning and help-seeking (Pintrich, Smith, Garcia & McKeachie,, 1993).

Students' Math SAT scores and whether they took AP Chemistry in high school were used as measures of prior achievement. Academic success was determined by final course grade in the chemistry course, calculated using scores on three in-class exams, homework assignments, lab assignments, quizzes and a cumulative final exam.

Results

Question 1: Which Motivation Constructs and Learning Strategies Have the Strongest Predictive Ability for Success in Introductory College Chemistry?

To answer this question, zero-order correlations were calculated between final course grades and each of the motivational and learning strategy scores at Times 1, 2 and 3, reported in Tables 1, 2 and 3 respectively. Because of the large sample, almost all of the motivation and learning strategies were significantly related to final course grades at the α = .01 level. Of the motivation scales, strong correlations with final course grades were only found with self-efficacy (SE) at Times 2 (r = .54) and 3 (r = .56). Medium correlations were found with self-efficacy at Time 1 (r = .40), intrinsic motivation (IM) at Times 2 (r = .33) and 3 (r = .35), and assessment anxiety (AX) at Times 1 (r = .30), 2 (r = .41) and 3 (r = .46). Of the learning strategies subscales, effort regulation (ER) at Times 1 (r = .31), 2 (r = .30) and 3 (r = .34) correlated most strongly with final course grades. However these correlations were in the medium range.

Hierarchical multiple regression assessed the ability of the motivation and learning strategies to predict final course grades, after controlling for the influence of previous achievement (Math SAT scores and taking AP chemistry) at Times 1, 2 and 3. Only the motivation and learning strategies subscales with medium or strong correlations with final course grades at each Time (1, 2 or 3) were included in the regression models. To compare to previous studies, the motivation subscales were entered into the regression model at step 2, and learning strategies at step 3 (Garcia, 1993; Zusho et al., 2003).

Preliminary analyses were conducted to ensure no violation for the assumptions of multicollinearity, normality, linearity and homoscedasticity. For all three models, Math SAT and AP Chemistry variables were entered at Step 1, and explained 30.4% of the variance in final course grade.

Table 1

Time 1 Zero-order Correlations of Final Course Grades, Motivation, and Learning Strategies

	Grade	IM	EM	PR	SD	SE	AX	RE	EL	ORG	CT	MET	TSE	ER	PL
IM	.24*														
EM	.03	.30*													
PR	.13*	**.69***	**.54***												
SD	.26*	.46*	.32*	.39*											
SE	.40*	**.58***	.24*	.47*	.41*										
AX	.30*	.36*	−.13*	.22*	.14*	**.59***									
RE	.06	.21*	.32*	.26*	.38*	.14*	−.14*								
EL	.11	.38*	.28*	.39*	.46*	.26*	.01	**.57***							
ORG	.04	.20*	.25*	.25*	.39*	.10	−.14*	**.62***	**.61***						
CT	.16*	.40*	.20*	.42*	.31*	.34*	.09	.32*	**.55***	.28*					
MET	.17*	.49*	.29*	.45*	**.56***	.41*	.17*	**.56***	**.71***	**.60***	**.50***				
TSE	.24*	.38*	.26*	.31*	**.64***	.41*	.18*	.45*	.47*	**.51***	.21*	**.65***			
ER	.30*	.44*	.24*	.30*	**.60***	.42*	.22*	.35*	.38*	.37*	.13*	**.58***	**.75***		
PL	.12	.24*	.17*	.25*	.26*	.15*	−.10	.33*	.32*	.38*	.36*	.37*	.21*	.14*	
HS	.16*	.16*	.13*	.15*	.25*	.11	−.07	.23*	.21*	.34*	.15*	.28*	.24*	.22*	**.50***

Note. Correlations ≥ .50 are in boldface. Grade = final course grade; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking.
* $p < .01$ (2 tailed).

Table 2

Time 2 Zero-order Correlations of Final Course Grades, Motivation, and Learning Strategies

	Grade	IM	EM	PR	SD	SE	AX	RE	EL	ORG	CT	MET	TSE	ER	PL
IM	.31*														
EM	.16*	.42*													
PR	.21*	**.70***	**.61***												
SD	.24*	.48*	**.52***	.45*											
SE	**.53***	**.64***	.38*	**.52***	.43*										
AX	.38*	.27*	−.16*	.10*	−.03	**.53***									
RE	.06	.30*	.42*	.35*	.41*	.14*	−.19								
EL	.15*	**.51***	.37*	.46*	.45*	.34*	.02	**.58***							
ORG	.05	.26*	.40*	.33*	.42*	.14*	−.17*	**.65***	**.58***						
CT	.17*	.47*	.22*	.47*	.23*	.36*	.13*	.30*	**.55***	.31*					
MET	.19*	**.57***	.40*	**.50***	**.58***	.39*	.10	**.57***	**.70***	**.57***	**.55***				
TSE	.23*	.35*	.35*	.32*	**.62***	.34*	.10	.43*	.36*	.43*	.13*	**.58***			
ER	.30*	.39*	.35*	.31*	**.60***	.36*	.14*	.36*	.35*	.35*	.07	**.56***	**.71***		
PL	.08	.32*	.27*	.29*	.30*	.20	−.06	.33*	.35*	.40*	.41*	.41*	.20*	.16*	
HS	.15*	.28*	.21*	.22*	.36*	.15*	−.07	.36*	.32*	.38*	.26*	.41*	.32*	.24*	**.68***

Note. Correlations ≥ .50 are in boldface. Grade = final course grade; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking.
* $p < .01$ (2 tailed).

Table 3

Time 3 Zero-order Correlations of Final Course Grades, Motivation, and Learning Strategies

	Grade	IM	EM	PR	SD	SE	AX	RE	EL	ORG	CT	MET	TSE	ER	PL
IM	.34*														
EM	.11*	.44*													
PR	.20*	**.72***	**.63***												
SD	.25*	**.54***	**.51***	.48*											
SE	**.56***	**.63***	.39*	**.52***	.49*										
AX	.41*	.16*	−.22*	.02	−.09	.43*									
RE	.00	.26*	.38*	.31*	.46*	.14*	−.24*								
EL	.08	.49*	.40*	.49*	.51*	.31*	−.11*	**.55***							
ORG	.04	.31*	.34*	.35*	.48*	.17*	−.19*	**.68***	**.60***						
CT	.15*	**.50***	.25*	**.53***	.30*	.41*	.03	.25*	**.51***	.25*					
MET	.21*	**.54***	.42*	**.54***	**.67***	.40*	.03	**.57***	**.72***	**.60***	.46*				
TSE	.25*	.33*	.34*	.31*	**.65***	.32*	.10	.42*	.45*	.47*	.10	**.67***			
ER	.33*	.35*	.33*	.27*	**.54***	.35*	.20*	.27*	.34*	.33*	.03	**.58***	**.75***		
PL	.10	.33*	.26*	.31*	.35*	.21*	−.13*	.32*	.39*	.31*	.36*	.41*	.25*	.19*	
HS	.16*	.28*	.25*	.25*	.36*	.20*	−.08	.29*	.35*	.30*	.22*	.41*	.31*	.30*	**.68***

Note. Correlations ≥.50 are in boldface. Grade = final course grade; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking.

* $p < .01$ (2 tailed).

At Time 1, SE T1 and AX T1 were entered at Step 2, explaining 39.3% of the variance in final course grade, $F(4, 347) = 56.21$, $p < .001$. The Time 1 motivation subscales explained an additional 9.0% of the variance in final course grades after controlling for previous achievement, R square change = .090, F change (2, 347) = 25.63, $p < .001$. ER T1 was entered at Step 3 resulting in a model explaining 43.3% of the variance in final course grade, F (5, 346) = 52.76, $p < .001$, explaining an additional 3.9% of the variance, R square change = .039, F change (1, 346) = 24.04, $p < .001$. In the final model, SE T1 and ER T1 were significant predictors of final course grade in addition to Math SAT and AP chemistry (Beta values in order of highest value: Math SAT ($\beta = .44$ $p < .001$), ER T1 ($\beta = .21$, $p < .001$), SE T1 ($\beta = .19$, $p = .001$) and AP Chemistry ($\beta = .18$, $p < .001$)). At Time 1, Math SAT was the strongest predictor of final course grade, followed by effort regulation, self-efficacy and AP chemistry. Assessment anxiety at Time 1 was not a significant predictor of final course grade.

At Time 2, IM T2, SE T2 and AX T2 were entered at Step 2, explaining 47.8% of the variance in final course grades, $F(5, 346) = 63.41$, $p < .001$. The Time 2 motivation subscales explained an additional 17.5% of the variance in final course grades after controlling for previous achievement, R square change = .175, F change (3, 346) = 38.60, $p < .001$. ER T2 was entered at Step 3 resulting in a model that explained 50.2% of the variance in final course grade, F (6, 345) = 57.97, $p < .001$, an additional 2.4% of the variance, R square change = .024, F change (1, 345) =16.54, $p < .001$. In the final model, SE T2 and ER T2 were significant predictors of final course grade in addition to Math SAT and AP chemistry (Beta values in order of highest value: Math SAT ($\beta = .40$ $p < .001$), SE T2 ($\beta = .37$, $p < .001$), ER T2 ($\beta = .17$, $p < .001$) and AP Chemistry ($\beta = .14$, p

< .001)). At Time 2, Math SAT continued to be the strongest predictor of final course grade. Self-efficacy became a stronger predictor than effort regulation; however both were stronger than AP chemistry. Intrinsic motivation and assessment anxiety were not significant predictors of final course grade at Time 2.

At Time 3, IM T3, SE T3 and AX T3 were entered at Step 2, explaining 50.4% of the variance in final course grades, $F(5, 346) = 70.19$, $p < .001$. The Time 3 motivation subscales explained an additional 20.0% of the variance in final course grades after controlling for previous achievement, R square change = .200, F change (3, 346) = 46.67, $p < .001$. ER 3 was entered at Step 3 resulting in a model that explained 52.2% of the variance in final course grade, F (6, 345) = 62.84, $p < .001$, an additional 1.9% of the variance, R square change = .019, F change (1, 345) =13.47, $p < .001$. In the final model, SE T3, AX T3 and ER T3 were significant predictors of final course grade in addition to Math SAT and AP chemistry (Beta values in order of highest value: Math SAT ($\beta = .36$ $p < .001$), SE 3 ($\beta = .34$, $p < .001$), ER 3 ($\beta = .15$, $p < .001$), AP Chemistry ($\beta = .13$, $p = .001$) and AX 3 ($\beta = .13$, $p = .006$)). At Time 3, predictors follow the same pattern as Time 2, with the addition of assessment anxiety as the fifth significant predictor of final course grade. Intrinsic motivation was not a significant predictor of final course grade at Time 3.

Question 2: How Do Levels of Motivation and Learning Strategy Use Change Throughout a Semester, and are These Changes Different for High, Average and Low Course Performers?

The overall interpretation of the CMQ Total scores shows that participants were motivated in the “high” range at all three times of the semester. Table 4 presents the means, standard deviations and significant changes in motivation scores. In general, overall motivation declined over the course of the semester. A one-way repeated measures ANOVA compared CMQ Total scores at three times during the semester and a significant effect was found, $F(2, 824) = 6.53$, $p = .002$. Follow-up protected *t* tests, revealed scores at Time 3 were significantly lower than both Times 1 and 2 using the Bonferrroni-adjusted alpha level of .0167.

Table 4

Mean Motivation Scores

	Time 1		Time 2		Time 3	
Scale	M	SD	M	SD	M	SD
CMQ Total	103.68_a	13.09	103.14_a	14.03	102.15_b	14.21
IM	17.48	3.19	17.41	3.29	17.22	3.17
EM	20.37	2.58	20.37	2.75	20.23	2.80
PR	16.28_a	3.47	16.52	3.62	16.77_b	3.76
SD	19.36	2.47	19.30	2.57	19.12	2.78
SE	18.03_a	3.35	17.54_b	3.66	17.08_c	3.79
AX	12.15_a	4.13	11.99	4.13	11.73_b	4.26

Note. CMQ Total = Chemistry Motivation Questionnaire Total Score; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety. Means within a row with different subscripts are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

Further analyses by one-way repeated measures ANOVAs were conducted with each of the CMQ subscales. Significant changes were found for relevance of learning chemistry to personal goals (PR), $F(2, 824) = 6.62$, $p = .001$, which increased from Time 1 to Time 3, self-efficacy (SE) ($F(2, 824) = 26.10$, $p < .001$, which decreased Time 1 to Time 2 and again to Time 3, and assessment anxiety (AX) ($F(2, 824) = 18.83$, $p = .011$), which also increased (indicated by decreasing scores) from Time 1 to Time 3. There were no significant changes found for intrinsic motivation (IM), extrinsic motivation (EM) or self determination (SD) to learn chemistry over the course of the semester.

Students' learning strategy use changed during the course of the semester. Table 5 presents the means, standard deviations and significant changes in learning strategies scores. One-way repeated measures ANOVAs compared each learning strategies subscale from the MSLQ at Times 1, 2 and 3, and follow-up protected *t* tests revealed when significant changes occurred at the Bonferroni-adjusted alpha level of .0167.

Table 5

Mean Learning Strategies Scores

	Time 1		Time 2		Time 3	
Scale	M	SD	M	SD	M	SD
RE	4.76	1.20	4.78	1.19	4.84	1.20
EL	4.81_a	1.03	4.85	1.04	4.92_b	0.99
ORG	4.84	1.33	4.81	1.31	4.89	1.30
CT	3.56_a	1.31	3.72	1.40	3.83_b	1.38
MET	4.70_a	0.83	4.76	0.80	4.80_b	0.81
TSE	5.14_a	0.99	5.01_b	0.97	5.01_b	1.03
ER	5.46_a	1.08	5.25_b	1.12	5.20_b	1.13
PL	4.11_a	1.40	4.26_b	1.43	4.38_c	1.49
HS	4.39	1.14	4.35	1.14	4.34	1.20

Note. RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. Means within a row with different subscripts are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

Significant changes were found for six of the learning strategies. Increasing from Time 1 to Time 3 were elaboration (EL) $F(2, 824) = 3.49$, $p = .03$, critical thinking (CT) $F(2, 824) = 15.637$, $p < .001$), and metacognitive self-regulation skills (MET) ($F(2, 824) = 5.574$, $p = .004$. Peer learning (PL) $F(2, 824) = 12.054$, $p < .001$), increased from Time

1 to Time 2, and again to Time 3. Decreasing was time and study environment management (TSE) $F(2, 824) = 8.67, p < .001$), and effort regulation (ER) $F(2, 824) = 21.65, p < .001$), both highest at Time 1. There were no significant differences in students' reports in use of rehearsal (RE), organization (ORG), or help-seeking (HS).

To determine whether students' motivation and learning strategies differed by final course grade, the sample was divided into three performance groups according to cut scores produced in SPSS Statistics Version 19. Low performers earned final course grades 2.3/C+ and below, Average performers earned final course grade between 2.7/B- and 3.0/B, and High performers earned final course grades 3.3/B+ to 4.0/A. Three x three mixed-design ANOVAs were calculated to examine whether there were differences between the performance groups at Times 1, 2 and 3. Tukey's post-hoc tests indicated whether there were significant differences between the performance groups, and dependent measure *t* tests identified if significant differences occurred within the performance groups at the Bonferroni-adjusted alpha level of .0167.

Table 6 summarizes means and standard deviations of motivation scores at Times 1, 2 and 3, as well as significant differences in motivation scores between performance groups. The Total CMQ and subscale scores were analyzed separately. There were significant main effects for performance group for CMQ Total ($F(2, 812) = 9.77, p < .001$), IM ($F(2, 406) = 17.45, p < .001$), PR ($F(2, 406) = 5.10, p < .001$), SD ($F(2, 406) = 13.38, p < .001$), SE ($F(2, 406) = 73.23, p < .001$), and AX $F(2, 406) = 39.07, p < .001$).

Table 6

Mean Motivation Scores by Performance Level

Scale	Low (n =119) M	Low (n =119) SD	Average (n = 114) M	Average (n = 114) SD	High (n = 176) M	High (n = 176) SD
CMQ T1	$99.08_{a,x}$	12.82	102.53_{a}	11.80	$107.73_{b,x}$	13.12
CMQ T2	$94.69_{a,y}$	13.98	102.70_{b}	11.86	$109.47_{c,y}$	12.11
CMQ T3	$94.05_{a,y}$	14.00	101.06_{b}	11.67	108.62_{c}	12.71
IM T1	$16.74_{a,x}$	3.48	17.30	2.90	18.11_{b}	3.07
IM T2	$16.01_{a,y}$	3.42	17.43_{b}	3.14	18.39_{c}	2.97
IM T3	$15.90_{a,y}$	3.28	17.34_{b}	2.81	18.09_{b}	3.00
EM T1	20.51_{x}	2.72	20.23	2.21	20.38	2.60
EM T2	$19.74_{a,y}$	2.91	20.40	2.71	20.79_{b}	2.62
EM T3	19.95	3.03	19.92	2.84	20.61	2.59
PR T1	15.82	3.68	16.22	3.42	16.65_{x}	3.37
PR T2	15.59_{a}	4.00	16.65	3.39	17.13_{b}	3.43
PR T3	16.11_{a}	4.12	16.54	3.47	$17.41_{b,y}$	3.60
SD T1	18.82_{a}	2.63	18.97_{a}	2.22	20.00_{b}	2.31
SD T2	18.60_{a}	2.55	19.08_{a}	2.59	19.94_{b}	2.43
SD T3	18.42_{a}	2.93	18.94_{a}	2.67	19.75_{b}	2.61
SE T1	$16.55_{a,x}$	3.61	$17.75_{b,x}$	3.06	19.26_{c}	2.90
SE T2	$15.00_{a,y}$	3.71	17.25_{b}	2.99	19.51_{c}	2.83
SE T3	$14.41_{a,z}$	3.80	$16.72_{b,y}$	2.97	19.18_{c}	2.95
AX T1	$10.62_{a,x}$	3.76	12.08_{b}	4.08	13.34_{c}	4.02
AX T2	$9.76_{a,y}$	3.47	11.89_{b}	3.83	12.05_{c}	4.11
AX T3	$9.26_{a,y}$	3.51	11.59_{b}	4.01	13.58_{c}	3.99

Note: CMQ = Chemistry Motivation Questionnaire Total Score; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety: T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b,c}$ are significant from one another and means within a column with different subscripts $_{x,y,z}$ are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

Low performers had significantly lower total motivation scores, specifically impacted by lower intrinsic motivation, self-efficacy, and higher anxiety than Average performers. They scored significantly lower on all of the motivation scales than High performers. Average performers also reported lower total motivation scores, impacted by lower intrinsic motivation, self-determination, self-efficacy, and higher assessment anxiety than High performers. No main effect for performance group was found for extrinsic motivation.

Significant main effects for time were found for CMQ Total ($F(2, 406) = 42.06$, $p < .001$), PR ($F(2, 812) = 5.49$, $p = .004$), SE ($F(2,812) = 34.99$, $p < .001$) and AX ($F(2, 812) = 7.01$, $p = .001$). Low performers' total motivation decreased as indicated by decreases in intrinsic motivation, extrinsic motivation and self-efficacy, as well as an increase in assessment anxiety. Average performers' total motivation scores also decreased as indicated by a decrease in self-efficacy, while High performers' total motivation and specifically, relevance of learning chemistry to personal goals increased.

There were significant time × performance interactions for CMQ total ($F(4, 812) = 12.37$, $p < .001$; see Figure 1), IM ($F(4, 812) = 12.02$, $p = .001$; see Figure 2), EM ($F(4, 812) = 5.44$, $p < .001$; see Figure 3), SE ($F(4.812) = 13.25$, $p < .001$; see Figure 4), and AX ($F(4, 812) = 6.12$, $p < .001$; see Figure 5). While total motivation scores dropped from Times 1 to 3 for Low and Average performers, they rose for High performers. Analyses of the subcales found Low performers' intrinsic motivation and extrinsic motivation decreased while their assessment anxiety increased. Self-efficacy scores decreased over time for Low and Average performers.

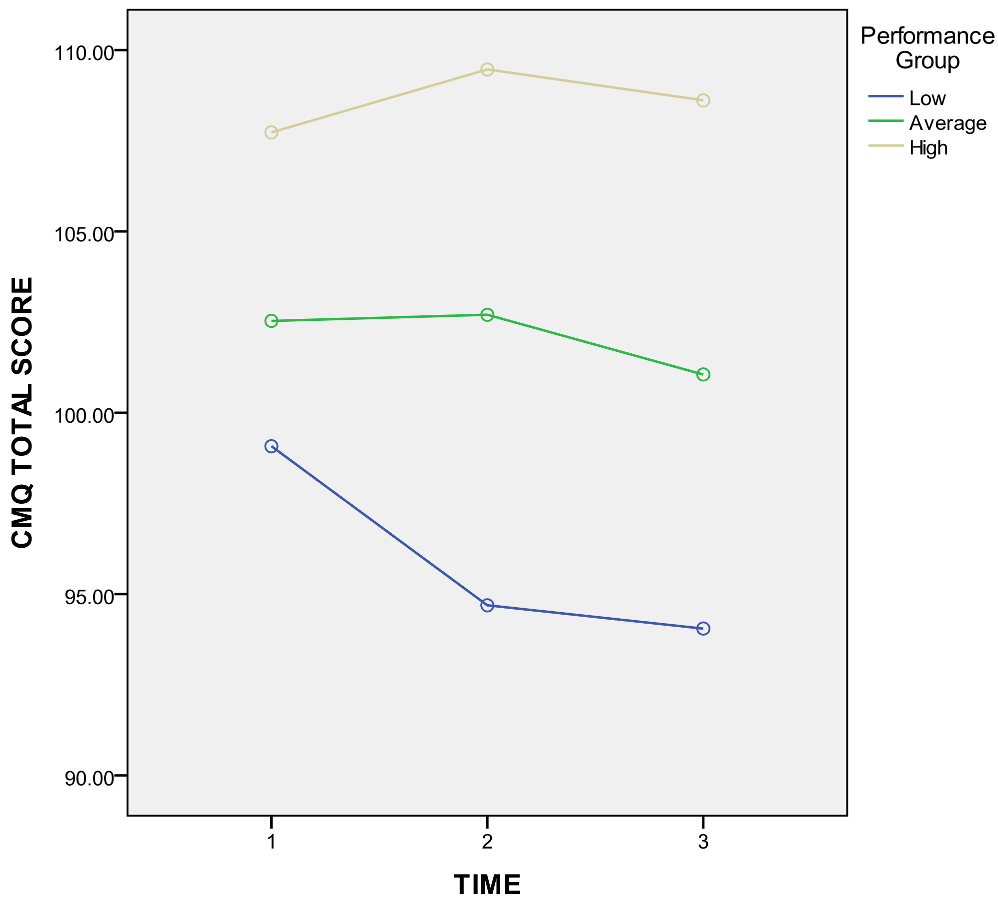

Figure 1. Time × Performance Group Interaction of CMQ Total Scores.

Table 7 summarizes means and standard deviations of learning strategies scores at Times 1, 2 and 3, as well as significant differences between performance groups. There were significant main effects for performance group for EL ($F(2, 406) = 3.19$, $p < .05$), CT ($F(2, 406) = 3.45$, $p = .042$), MET ($F(2, 406) = 5.23$, $p = .006$), TSE ($F(2, 406) = 11.19$, $p < .001$), ER ($F(2, 406) = 20.06$, $p < .001$) and HS ($F(2, 406) = 4.93$, $p = .008$). Low performers reported lower effort regulation scores than Average performers, and lower elaboration, critical thinking, metacognitive self-regulation skills, time and study environment management, effort regulation and help-seeking scores than High

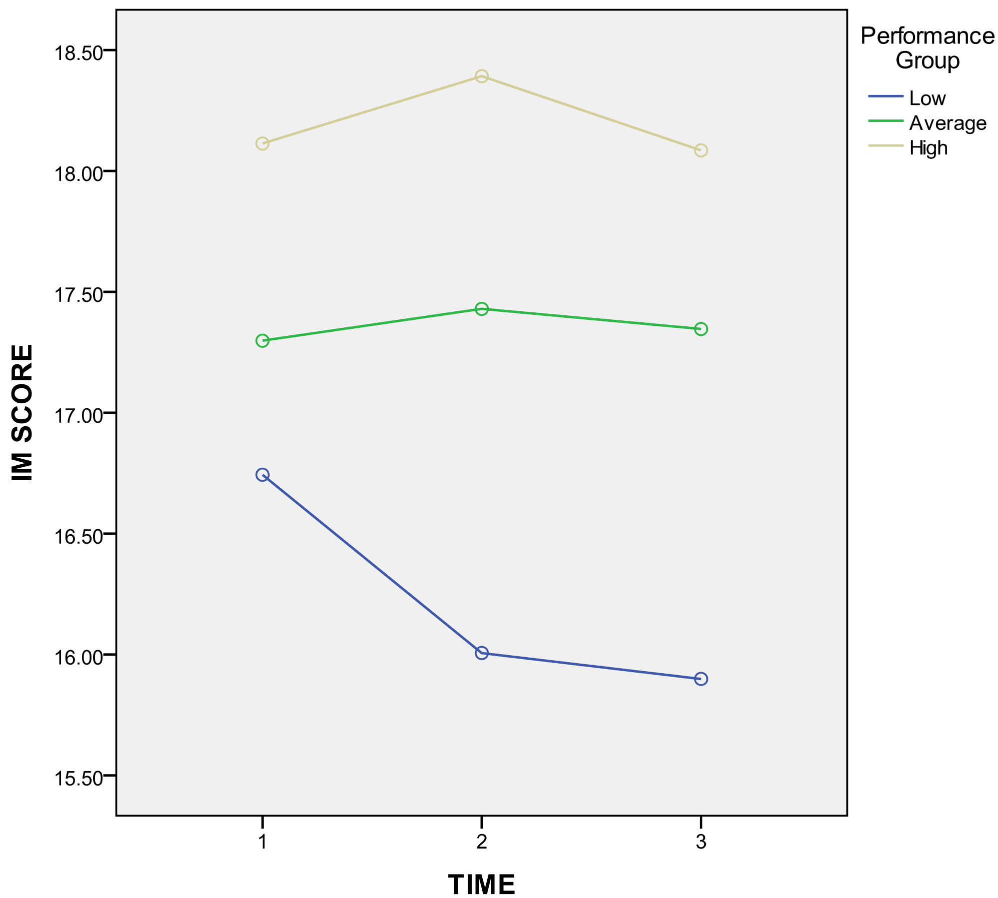

Figure 2. Time × Performance Group Interaction of Intrinsic Motivation Scores.

performers. Average performers also reported lower elaboration, time and study environment management and effort regulation scores than High performers. No significant main effects for achievement were found for rehearsal, organization or peer learning. Significant main effects for time were found for EL ($F(2, 812) = 4.41$, $p = .013$), CT ($F(2, 812) = 14.80$, $p < .001$), MET($F(2, 812) = 4.81$, $p = .003$), TSE ($F(2, 812) = 8.40$, $p < .001$), ER ($F(2, 812) = 20.71$, $p < .001$) and PL ($F(2, 812) = 12.23$, $p < .001$).

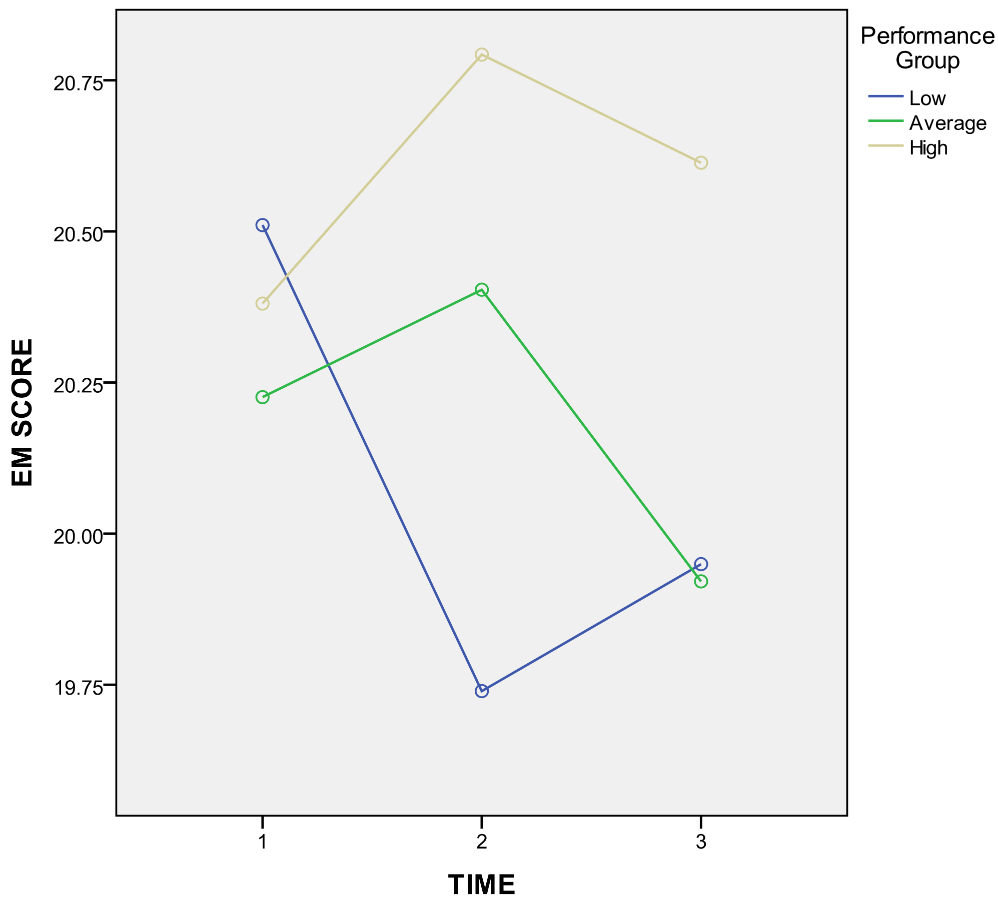

Figure 3. Time × Performance Group Interaction of Extrinsic Motivation Scores.

Low performers' elaboration and peer learning scores rose, Average performers' elaboration, critical thinking, and metacognitive self-regulation skills scores rose, while their time and study environment management scores fell, and High performers' critical thinking scores rose. All groups' effort regulation scores decreased during the semester. No main effects for time were found for rehearsal or organization scores. There were no significant interactions for any of the learning strategies.

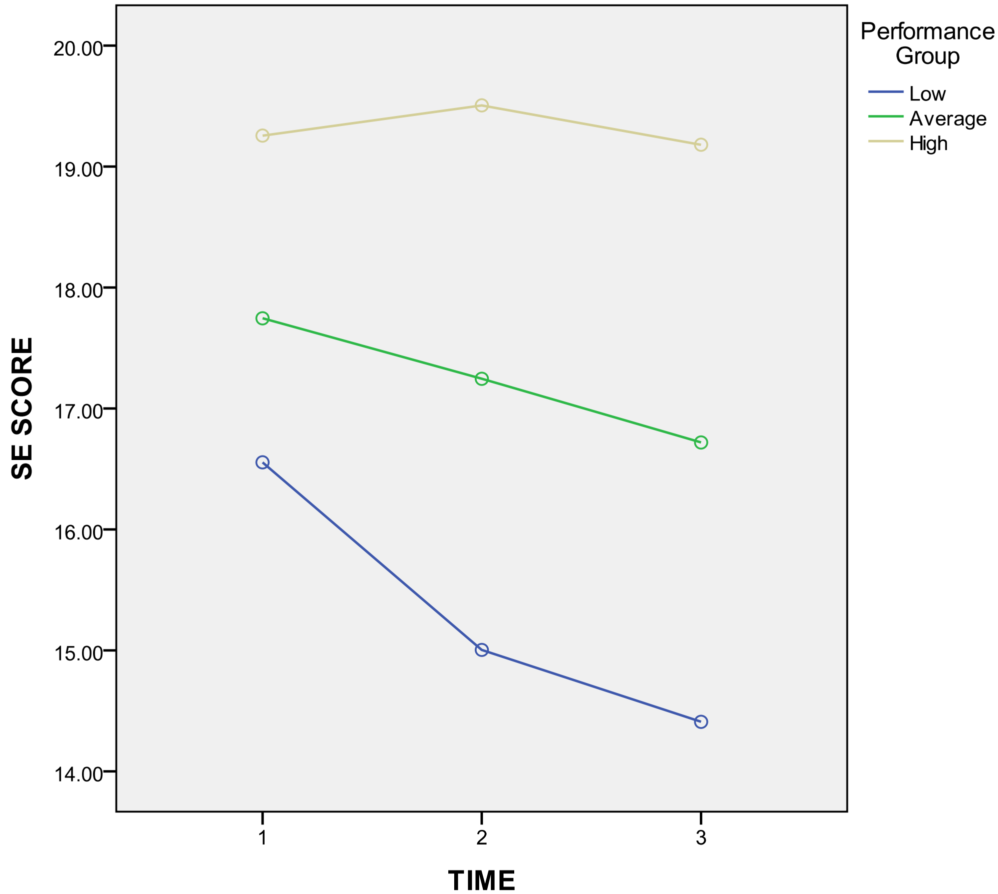

Figure 4. Time × Performance Group Interaction of Self-Efficacy Scores.

Question 3: How Do Levels of Motivation and Learning Strategy Use Vary by Gender and Ethnicity, and Which Motivation Constructs and Learning Strategies Have the Strongest Predictive Ability for Success by Each Group?

An independent samples t test found a significant difference in final course grades between males and females $t(407) = 2.52$, $p < =.05$, with males earning higher final grades ($m = 3.03$, $sd = 0.88$) than females ($m = 2.80$, $sd = 0.94$). Two by three mixed-design ANOVAs were calculated to determine whether there were gender differences in motivation and learning strategies at Times 1, 2 and 3.

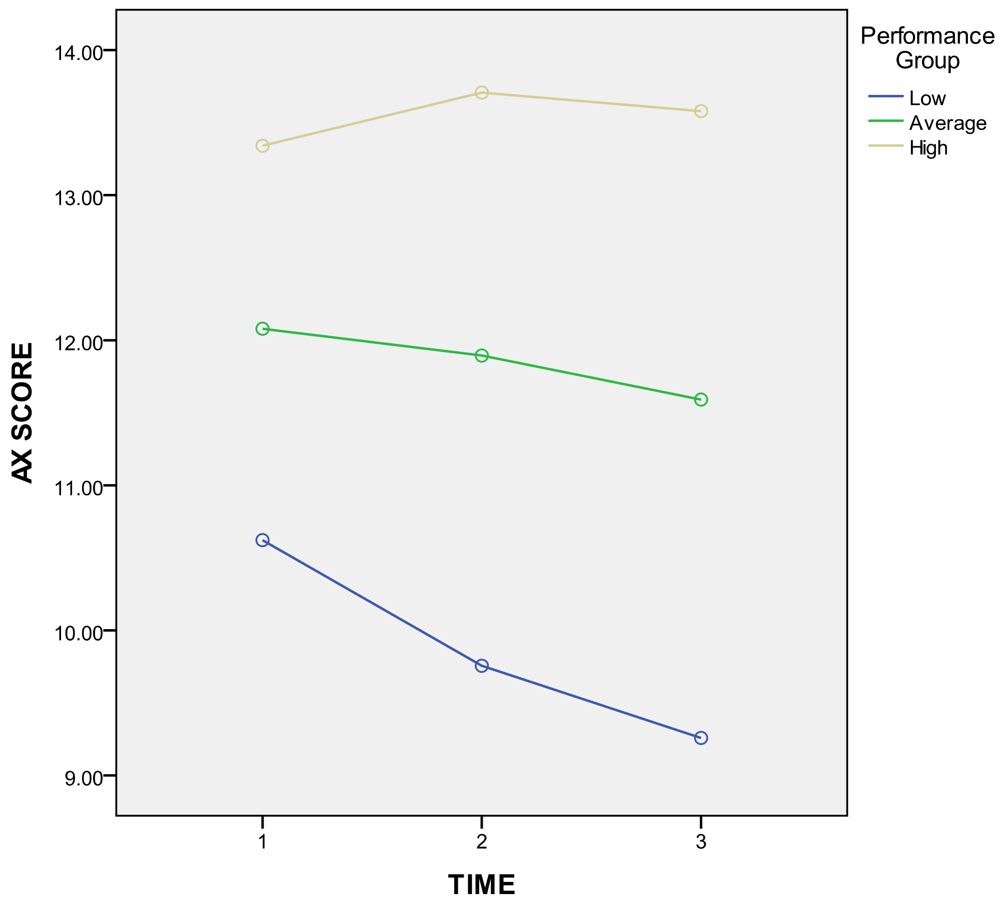

Figure 5. Time × Performance Group Interaction of Assessment Anxiety Scores.

Post-hoc tests were conducted if significant differences were found (independent *t* tests for differences between groups, and dependent *t* tests for differences within groups over time).

Table 8 summarizes the means, standard deviation and differences in motivation scores by gender. There were significant main effects for gender for CMQ Total ($F(1, 411) = 18.44$, $p < .001$), IM ($F(1, 411) = 6.91$, $p = .009$), PR ($F(1,411) = 5.44$, $p = .02$), SE ($F(1, 411) = 32.24$, $p < .001$), and AX ($F(1, 411) = 28.56$, $p < .001$). In sum, males

Table 7

Mean Learning Strategies Scores by Performance Level

	Low (n =119)		Average (n = 114)		High (n = 176)	
Scale	M	SD	M	SD	M	SD
RE T1	4.72	1.21	4.78	1.13	4.75	1.24
RE T2	4.74	1.21	4.79	1.18	4.77	1.19
RE T3	4.85	1.18	4.95	1.27	4.75	1.17
EL T1	4.79	1.01	$4.63_{a,x}$	1.03	4.95_{b}	1.03
EL T2	$4.67_{a,x}$	1.07	4.76	1.07	5.02_{b}	0.99
EL T3	4.88_{y}	0.97	4.86_{y}	1.09	5.00	0.93
ORG T1	4.81	1.31	4.85	1.20	4.84	1.33
ORG T2	4.72	1.33	4.80	1.16	4.85	1.38
ORG T3	4.87	1.27	4.94	1.24	4.86	1.30
CT T1	3.36	1.34	3.51_{x}	1.30	3.71_{x}	1.29
CT T2	3.48_{a}	1.50	3.71	1.30	$3.89_{b,y}$	1.38
CT T3	3.59	1.40	3.85_{y}	1.38	3.98_{y}	1.32
MET T1	4.55_{a}	0.83	4.64_{x}	0.78	4.83_{b}	0.83
MET T2	4.57_{a}	0.76	4.80_{y}	0.74	4.85_{b}	0.83
MET T3	4.64_{a}	0.87	4.80_{y}	0.74	4.91_{b}	0.80
TSE T1	4.88_{a}	0.98	5.08_{x}	1.00	5.35_{b}	0.94
TSE T2	4.78_{a}	0.96	$4.90_{a,y}$	0.94	5.23_{b}	0.96
TSE T3	4.72_{a}	1.00	4.96	1.00	5.24_{b}	1.01
ER T1	$5.06_{a,x}$	1.11	$5.44_{b,x}$	1.02	$5.75_{c,x}$	1.01
ER T2	4.87_{a}	1.13	$5.15_{a,y}$	1.11	$5.60_{b,y}$	1.02
ER T3	$4.80_{a,y}$	1.16	$5.16_{b,y}$	1.10	$5.53_{c,y}$	1.03
PL T1	3.90_{x}	1.40	4.14	1.49	4.25	1.36
PL T2	4.09	1.47	4.38	1.40	4.30	1.44
PL T3	4.29_{y}	1.52	4.38	1.53	4.46	1.47
HS T1	4.09_{a}	1.20	4.40	1.10	4.57_{b}	1.15
HS T2	4.13_{a}	1.12	4.36	1.14	4.49_{b}	1.15
HS T3	4.13	1.21	4.41	1.22	4.44	1.17

Note. RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b,c}$ are significant from one another and means within a column with different subscripts $_{x,y}$ are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

Table 8

Mean Motivation Scores by Gender

Scale	Male (n = 145)		Female (n = 248)	
	M	SD	M	SD
CMQ T1	107.15_{a}	13.58	$101.80_{b,x}$	12.45
CMQ T2	106.95_{a}	13.84	101.07_{b}	13.72
CMQ T3	105.71_{a}	14.07	$100.23_{b,y}$	13.94
IM T1	17.88	3.10	17.26	3.21
IM T2	18.01_{a}	3.16	17.08_{b}	3.33
IM T3	17.76_{a}	2.91	16.94_{b}	3.27
EM T1	20.23	2.77	20.45	2.48
EM T2	20.28	2.75	20.42	2.76
EM T3	20.25	2.86	20.22	2.77
PR T1	16.66_{x}	3.58	16.07	3.41
PR T2	16.92_{x}	3.57	16.31	3.66
PR T3	$17.51_{a,y}$	3.71	16.37_{b}	3.73
SD T1	19.58	2.51	19.24	2.39
SD T2	19.46	2.58	19.21	2.57
SD T3	19.18	2.91	19.09	2.69
SE T1	$19.18_{a,x}$	3.24	$17.41_{b,x}$	3.24
SE T2	$18.86_{a,x}$	3.37	$16.82_{b,y}$	3.61
SE T3	$18.18_{a,y}$	3.78	$16.48_{b,z}$	3.66
AX T1	$13.61_{a,x}$	4.31	11.36_{b}	3.81
AX T2	13.41_{a}	4.09	11.23_{b}	3.95
AX T3	$12.83_{a,y}$	4.30	11.13_{b}	4.13

Note. CMQ = Chemistry Motivation Questionnaire total score; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety. T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b}$ are significant from one another at $\alpha = .05$. Means within a column with different subscripts $_{x,y,z}$ are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

reported significantly higher total motivation scores with higher subscales scores on intrinsic motivation, relevance of learning chemistry to personal goals, and self-efficacy, as well as lower assessment anxiety than females. No significant main effects for gender were found for extrinsic motivation or self determination.

There were significant main effects for time for CMQ Total ($F(2, 822) = 5.92$, $p = .003$), PR ($F(2, 822) = 8.27$, $p < .001$), SD ($F(2, 822) = 3.06$, $p = .05$), SE ($F(2, 822) = 24.28$, $p < .001$) and AX ($F(2, 822) = 6.00$, $p < .001$). Males' relevance of learning chemistry to personal goals scores rose during the semester, while their scores for self-efficacy decreased and assessment anxiety increased. Females' total motivation scores decreased, most notably from a decrease in self-efficacy scores. Although a main effect for time was found for self-determination, post hoc tests with the most conservative approach were not significant. No significant main effects for time were found for intrinsic or extrinsic motivation. There were no significant interactions found on any of the motivation scales.

Table 9 summarizes the means, standard deviations and differences in learning strategies scores by gender. Significant main effects for gender were found for RE ($F(1,411) = 15.45$, $p < .001$), ORG ($F(1,411) = 22.63$, $p < .001$), and CT ($F(1, 411) = 32.18$, $p < .001$). Males' rehearsal and organization scores were lower than females', however their critical thinking scores were significantly higher. No significant main effects for gender were found for elaboration, metacognitive self-regulation skills, time and study environment management, effort regulation, peer learning or help-seeking.

Significant main effects by time for CT ($F(2, 822) = 16.12$, $p < .001$), MET ($F(2, 822) = 5.18$, $p = .006$), TSE ($F(2, 822) = 7.86$, $p < .001$), ER ($F(2, 822) =$

Table 9

Mean Learning Strategy Scores by Gender

	Male (n = 145)		Female (n = 248)	
Scale	M	SD	M	SD
RE T1	4.49_{a}	1.27	4.90_{b}	1.13
RE T2	4.51_{a}	1.28	4.92_{b}	1.12
RE T3	4.56_{a}	1.33	5.00_{b}	1.10
EL T1	4.79	1.02	4.83_{x}	1.04
EL T2	4.88	1.01	4.83_{x}	1.07
EL T3	4.85	1.03	4.97_{y}	0.97
ORG T1	4.42_{a}	1.34	5.07_{b}	1.27
ORG T2	4.51_{a}	1.30	4.97_{b}	1.28
ORG T3	4.51_{a}	1.34	5.09_{b}	1.22
CT T1	$3.97_{a,x}$	1.29	$3.33_{b,x}$	1.27
CT T2	$4.17_{a,y}$	1.30	3.48_{b}	1.39
CT T3	$4.32_{a,y}$	1.27	$3.56_{b,y}$	1.36
MET T1	4.69	0.86	4.70_{x}	0.81
MET T2	4.77	0.80	4.75	0.79
MET T3	4.80	0.81	4.81_{y}	0.81
TSE T1	5.07	0.96	5.18_{x}	1.00
TSE T2	4.96	0.94	5.03_{y}	0.98
TSE T3	4.92	1.00	5.06_{y}	1.04
ER T1	5.47_{x}	1.05	5.46_{x}	1.10
ER T2	5.22_{y}	0.99	5.27_{y}	1.18
ER T3	5.21_{y}	1.03	5.20_{y}	1.18
PL T1	4.10_{x}	1.33	4.12_{x}	1.44
PL T2	4.36_{y}	1.44	4.20_{x}	1.43
PL T3	4.42_{y}	1.50	4.36_{y}	1.49
HS T1	4.28	1.08	4.44	1.18
HS T2	4.25	1.14	4.40	1.14
HS T3	4.19	1.12	4.42	1.23

Note: RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b}$ are significant from one another at α = .05. Means within a column with different subscripts $_{x,y}$ are significant from one another at α = .0167 according to the Bonferroni adjustment.

19.72, $p < .001$), and PL ($F(2, 822) = 12.05$, $p < .001$) were found. Both males' and females' critical thinking and peer learning scores increased during the semester. Females' metacognitive self-regulation skills scores increased, and although no main effect for elaboration was found, their elaboration scores also increased while their time and study environment management scores decreased. Effort regulation scores decreased for all students. There were no significant main effects for time for rehearsal, elaboration, organization, time and study management or help-seeking. No significant gender x time interactions were found for any of the learning strategies scales.

Finally, hierarchical regressions were run separately for male and female students to determine if different variables predicted final course grades. Preliminary analyses were conducted to ensure no violation for the assumptions of multicollinearity, normality, linearity and homoscedasticity. Tables 10, 11, and 12 report standardized coefficients of variables and the change in R^2 for the models predicting final course grades for males and females separately at Times 1, 2 and 3 respectively. Math SAT and AP Chemistry were entered at Step 1, followed by all motivation subscales at Step 2 and all learning strategies subscales at Step 3.

At Time 1, the final model was significant for males, $F(17, 108) = 5.75$, $p < .001$, explaining 47.5% of the variance in final course grades. As presented in Table 10, Math SAT, self-efficacy, effort regulation, and AP Chemistry were significant predictors of final course grade. For females, the final model also was significant, $F(17, 209) = 11.40$, $p < .001$, explaining 48.1% of the variance in final course grades. Math SAT, AP Chemistry, self-efficacy, help-seeking and self-determination were significant predictors of final course grade. Although both final models explain about the same amount of

Table 10

Time 1 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation and Learning Strategies by Gender

	Male			Female		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1						
Math SAT	.46***	.44***	.45***	.48***	.47***	.44***
AP Chem	.18*	.18*	.19*	.18**	.17**	.20***
Step 2						
IM T1		.12	.06		-.02	-.06
EM T1		-.04	-.04		-.07	-.08
PR T1		-.21	-.17		-.03	.02
SD T1		.04	-.05		.24***	.17*
SE T1		.32**	.33**		.25**	.18*
AX T1			.06		.01	.02
Step 3						
RE T1			.01			-.01
EL T1			-.01			.03
ORG T1			-.07			-.14
CT T1			-.02			.05
MET T1			-.10			-.06
TSE T1			.48			.04
ER T1			.24*			.14
PL T1			.14			-.01
HS T1			.02			.18**
R^2	.26***	.42***	.48***	.30***	.44***	.48***
ΔR^2		.16***	.05		.15***	.04

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T1 = Time 1.
*** $p < .001$, ** $p < .01$, *$p < .05$.

Table 11

Time 2 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation and Learning Strategies by Gender

	Male			Female		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1						
Math SAT	.46***	.42***	.45***	.48***	.39***	.38***
AP Chem	.18*	.15*	.16*	.18**	.13*	.15**
Step 2						
IM T2		-.03	-.06		.05	.02
EM T2		.01	.01		.02	.01
PR T2		-.13	-.14		-.05	-.01
SD T2		.15	.05		.10	-.00
SE T2		.43***	.43**		.36***	.36***
AX T2		.07	.09		.07	.03
Step 3						
RE T2			.05			-.09
EL T2			.07			.05
ORG T2			-.10			-.03
CT T2			.03			-.11
MET T2			-.08			.02
TSE T2			.17			.06
ER T2			.00			.11
PL T2			.07			.02
HS T2			.03			.11
R^2	.26***	.49***	.51***	.30***	.50***	.53***
ΔR^2		.23***	.54		.20***	.03

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T2 = Time 2.
*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 12

Time 3 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation and Learning Strategies by Gender

	Male			Female		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1						
Math SAT	.46***	.43***	.43***	.48***	.35***	.36***
AP Chem	.18*	.14*	.17*	.18**	.11*	.11*
Step 2						
IM T3		.14	.14		.04	.06
EM T3		.12	.07		.04	.06
PR T3		-.29*	-.24		-.08	-.06
SD T3		.01	-.05		.13*	.02
SE T3		.37***	.38***		.38***	.36***
AX T3		.20*	.16		.10	.07
Step 3						
RE T3			.05			-.06
EL T3			.03			-.09
ORG T3			-.12			-.06
CT T3			-.03			-.08
MET T3			-.05			.08
TSE T3			.10			.20*
ER T3			.05			-.05
PL T3			.01			.03
HS T3			.05			.08
R^2	.26***	.52***	.54***	.30***	.54***	.58***
ΔR^2		.26***	.02		.24***	.03

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T3 = Time 3.
*** $p < .001$, ** $p < .01$, * $p < .05$.

variance in final grades, the significant predictors and Beta values differed for males and females.

Prediction models were similar for males and females at Time 2. Final models were significant for males $F(17, 108) = 6.73$, $p < .001$, explaining 51.4% of the variance in final course grades, and females $F(17, 209) = 14.00$, $p < .001$, explaining 53.2%. For all students, the strongest Beta values were associated with Math SAT, followed by self-efficacy and AP Chemistry (Table 11). At Time 2, although Beta values differed, the same variables explain the variance in final course grade in the same order for males and females.

Prediction models at Time 3 were slightly different for males and females (Table 12). Again, final models were significant for both males $F(17, 108) = 7.46$, $p < .001$, explaining 54% of the variance in final grades, and females $F(17, 209) = 16.72$, $p < .001$, explaining 57.6%. For males, the strongest Beta values were found for Math SAT followed by self-efficacy and AP Chemistry, while for females, the order was Math SAT, followed by self-efficacy, time and study environment management and AP Chemistry. At Time 3, a difference in the models is that time and study environment management becomes a significant predictor for females.

Participants self-reported their ethnicity on the first questionnaire. Because of the lower number of “Black/African descent,” “Hispanic/Latino,” and “Other” participants, the three groups were collapsed into an “Other Collapsed group”. Analyses were conducted between the “Asian/Pacific Islander” (Asian), “White/European descent” (White), and “Other Collapsed” (Other) groups. A one-way ANOVA found a significant difference in final course grades by ethnicity, $F\ (2, 405) = 13.84$, $p < .001$. Tukey’s post-hoc test indicated that mean final course grade of the Other group was significantly lower (m = 2.38, sd = .95) than the Asian (m = 3.05, sd = .88) and White (m = 2.94, sd = .87) groups, whose grades were not significantly different from each other.

Repeated-measures ANOVAs investigated whether differences in motivation or learning strategies occurred by ethnicity. If significant differences were found, post hoc tests determined where differences occurred (one-way ANOVAs for between group differences and dependent t tests using the Bonferroni-adjusted alpha level of .0167 for within group differences over time).

Table 13 summarizes means, standard deviations and differences in motivation scores by ethnicity. A significant main effect for ethnicity was found only for PR ($F(2,409) = 3.84$, $p = .022$). The Asian groups' relevance of learning chemistry to personal goals scores were significantly higher than the Other groups'. Main effects for ethnicity were not found for total motivation, intrinsic motivation, extrinsic motivation, self-efficacy, self-determination or anxiety.

Significant main effects for time were found for the CMQ Total ($F(2,818) = 6.32$, $p = .002$), PR ($F(2,818) = 8.70$, $p < .001$), SD ($F(2,818) = 3.54$, $p = .03$), SE ($F(2,818) = 30.7$, $p < .001$) and AX ($F(2,818) = 4.90$, $p = .008$) . The Other groups' relevance of learning chemistry to personal goals scores significantly increased over time; however their assessment anxiety also increased. Both the White and Other groups' self-efficacy scores significantly decreased during the semester. Post hoc tests with the most conservative approach were not significant for total motivation or self-determination. No significant main effect for time was found for either intrinsic or extrinsic motivation. Only one significant ethnicity x time interaction was found for the SE scores $F(4,818)$ =

Table 13

Mean Motivation Scores by Ethnicity

	Asian (n = 158)		White (n=181)		Other (n=69)	
Scales	M	SD	M	SD	M	SD
CMQ T1	103.98	11.83	103.81	14.00	102.49	13.49
CMQ T2	104.24	13.14	103.11	14.79	100.61	13.89
CMQ T3	102.90	13.46	102.24	14.57	100.18	14.98
IM T1	17.70	2.79	17.43	3.46	17.04	3.27
IM T2	17.87_a	3.15	17.26	3.50	16.75_b	2.98
IM T3	17.60	3.13	17.00	3.22	16.89	3.06
EM T1	20.54	2.11	20.10	2.91	20.65	2.62
EM T2	20.52	2.50	20.16	3.00	20.54	2.62
EM T3	20.10	2.62	20.15	2.92	20.65	2.87
PR T1	16.88_a	3.13	16.00	3.57	$15.58_{b,x}$	3.76
PR T2	17.09	3.44	16.12	3.81	16.24	3.46
PR T3	17.24	3.56	16.36	3.89	16.70_y	3.78
SD T1	19.23	2.48	19.51	2.49	19.26	2.23
SD T2	19.22	2.60	19.44	2.48	19.10	2.75
SD T3	18.97	2.78	19.43	2.70	18.68	2.88
SE T1	17.87	3.15	18.15_x	3.43	18.04_x	3.59
SE T2	17.67	3.36	17.70_y	3.82	16.82_y	3.86
SE T3	17.33	3.53	17.21_z	3.76	16.18_y	4.32
AX T1	11.75	3.65	12.60	4.33	11.89_x	4.57
AX T2	11.88	3.68	12.43	4.34	11.17	4.46
AX T3	11.64	3.57	12.07	4.59	11.07_y	4.74

Note. CMQ Tot = Chemistry Motivation Questionnaire Total Score; IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety. T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b}$ are significant from one another and means within a column with different subscripts $_{x,y,z}$ are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

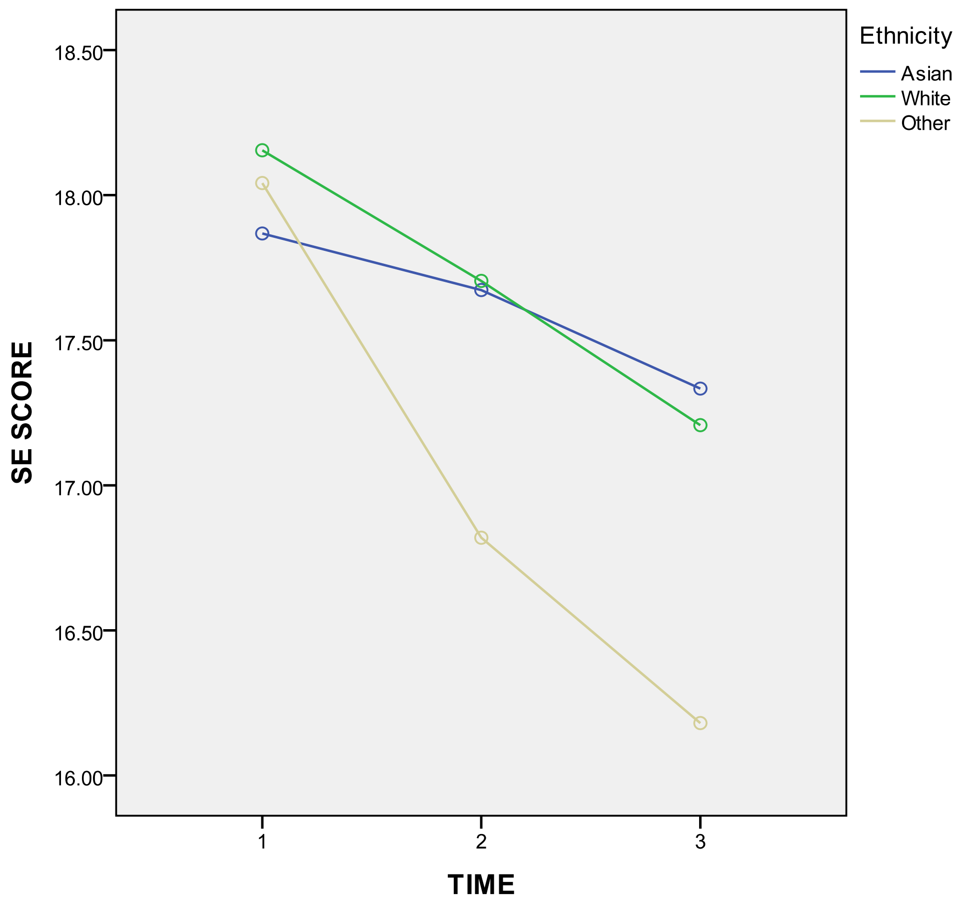

Figure 6. Time × Ethnicity Interaction of Self-Efficacy Scores.

3.39, $p = .009$ (see Figure 6). While self-efficacy scores fell for all three groups, at Time 1, the Other group's self-efficacy scores were in between the scores of the Asian and White groups. However, by Time 3, their scores were lower than the other two groups.

Table 14 presents means, standard deviations and differences in learning strategies scores by ethnicity. There were significant main effects by ethnicity for CT ($F(2,409) = 6.27$, $p = .002$), TSE ($F(2,409) = 7.767$, $p < .001$), and ER ($F(2,409) = 3.90$, $p = .02$). Significant differences were found between groups for critical thinking scores as the Asian group reported higher scores than the other two groups. Time and study

Table 14

Mean Learning Strategies Scores by Ethnicity

Scales	Asian (n = 158) M	SD	White (n=181) M	SD	Other (n=69) M	SD
RE T1	4.67	1.19	4.80	1.26	4.84	1.07
RE T2	4.73	1.17	4.81	1.21	4.83	1.21
RE T3	4.74	1.14	4.87	1.25	5.01	1.21
EL T1	4.74	1.02	4.87	1.04	4.85	1.04
EL T2	4.84	0.94	4.87	1.13	4.84	1.07
EL T3	4.83	0.92	5.00	1.03	4.94	1.02
ORG T1	4.68	1.28	5.00	1.41	4.76	1.19
ORG T2	4.69	1.18	4.95	1.41	4.72	1.29
ORG T3	4.77	1.23	5.01	1.34	4.84	1.33
CT T1	$3.84_{a,x}$	1.26	$3.38_{b, x}$	1.30	$3.36_{b,x}$	1.34
CT T2	3.96_{a}	1.22	3.64_{y}	1.48	3.41_{b}	1.49
CT T3	$4.11_{a,y}$	1.22	$3.64_{b, y}$	1.42	$3.68_{b,y}$	1.52
MET T1	4.64	0.82	4.74_{x}	0.82	4.72	0.88
MET T2	4.68	0.73	4.83	0.83	4.75	0.85
MET T3	4.70	0.78	4.89_{y}	0.77	4.80	0.93
TSE T1	4.95_{a}	1.00	$5.33_{b, x}$	0.95	5.09	1.01
TSE T2	4.83_{a}	0.92	$5.16_{b, y}$	0.94	5.01	1.08
TSE T3	4.82_{a}	1.01	5.23_{b}	0.96	4.89_{a}	1.14
ER T1	5.37_{x}	1.06	5.57_{x}	1.07	5.38_{x}	1.17
ER T2	5.15_{y}	1.07	5.41_{y}	1.09	5.10_{y}	1.25
ER T3	$5.03_{a,y}$	1.08	$5.40_{b,y}$	1.09	5.10	1.27
PL T1	4.14_{x}	1.36	4.18_{x}	1.48	3.89	1.33
PL T2	4.23	1.31	4.38_{y}	1.49	4.01	1.53
PL T3	4.36_{y}	1.38	4.46_{y}	1.59	4.24	1.52
HS T1	4.37	1.09	4.48	1.17	4.19	1.18
HS T2	4.32	1.06	4.44	1.19	4.20	1.19
HS T3	4.26	1.04	4.43	1.29	4.27	1.27

Note. RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T1 = Time 1; T2 = Time 2; T3 = Time 3. Means within a row with different subscripts $_{a,b}$ are significant from one another and means within a column with different subscripts $_{x,y}$ are significant from one another at $\alpha = .0167$ according to the Bonferroni adjustment.

environment management scores also were significantly different as students in the White group reported higher scores than the other two groups. Students in the White group also reported higher effort regulation scores than the Asian group. There were no significant main effects by ethnicity for rehearsal, elaboration, organization, metacognitive self-regulation skills, peer learning or help-seeking.

Significant main effects by time were found for CT ($F(2,818) = 13.95$, $p < .001$), MET ($F(2,818) = 4.24$, $p = .015$), TSE ($F(2,818) = 7.57$, $p = .001$), ER ($F(2,818) = 19.76$, $p < .001$) and PL ($F(2,818) = 11.34$, $p < .001$). Critical thinking scores significantly increased for all groups, while effort regulation scores significantly decreased for all groups. Peer learning scores increased for the Asian and White groups. In addition, the White groups' metacognitive self-regulation skills increased, but their time and study environment management scores decreased. There were no significant main effects by time for rehearsal, elaboration, organization, or help-seeking. No significant ethnicity x time interactions were found for any of the learning strategies.

Similar to the analyses run by gender, hierarchical multiple regression assessed the ability of motivation and learning strategies to predict final course grades for each ethnic group. Preliminary analyses were conducted to ensure no violation for the assumptions of multicollinearity, normality, linearity and homoscedasticity. Math SAT and AP Chemistry were entered at Step 1, motivation subscales were entered at step 2 and learning strategies were entered at Step 3. Tables 15, 16 and 17 report standardized coefficients of variables and the change in R^2 for the models predicting final course grades for Asian, White, and Other students at Times 1, 2 and 3 respectively.

Table 15

Time 1 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation, and Learning Strategies by Ethnicity

	Asian			White			Other		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1									
Math SAT	.40***	.31***	.34***	.52***	.48***	.43***	.55***	.51***	.57**
AP Chem	.13	.13	.13	.22**	.21**	.22***	.21	.20	.14
Step 2									
IM T1		.13	.06		−.09	−.12		.04	.16
EM T1		−.12	−.13		−.03	−.04		−.07	−.09
PR T1		−.12	−.12		.03	.06		−.14	−.06
SD T1		.20*	.18		.19**	.14		.06	.00
SE T1		.30**	.34**		.33**	.24*		.03	−.22
AX T1		−.06	−.08		.03	.04		.16	.24
Step 3									
RE T1			.04			.02			−.06
EL T1			−.01			−.07			.02
ORG T1			−.12			−.11			.13
CT T1			−.04			.04			.21
MET T1			.00			−.02			−.55*
TSE T1			−.13			.02			.27
ER T1			.20*			.23*			.12
PL T1			.08			.08			−.10
HS T1			.13			.09			.33*
R^2	.19***	.38***	.42***	.34***	.50***	.55***	.35***	.41**	.58**
ΔR^2		.18***	.05		.16***	.05		.06	.17

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T1 = Time 1.
*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 16

Time 2 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation, and Learning Strategies by Ethnicity

	Asian			White			Other		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1									
Math SAT	.40***	.28***	.30***	.52***	.45***	.43***	.55***	.37**	.39**
AP Chem	.13	.12	.13*	.22**	.15*	.16**	.21	.20	.19
Step 2									
IM T2		.19	.13		−.07	−.10		−.16	−.10
EM T2		−.01	−.04		.03	.00		−.04	.06
PR T2		−.22	−.23*		.05	.11		.04	−.07
SD T2		.09	.03		.14	−.04		.11	.25
SE T2		.42***	.49***		.34***	.30**		.39*	.38
AX T2		.08	.16		.09	.04		.07	−.04
Step 3									
RE T2			.04			−.07			−.11
EL T2			.01			.11			.09
ORG T2			.04			−.11			−.23
CT T2			−.13			−.07			.05
MET T2			−.02			.00			.08
TSE T2			.01			.08			.28
ER T2			.02			.27**			−.36
PL T2			.06			−.02			−.10
HS T2			.17			.06			.07
R^2	.19***	.45***	.50***	.34***	.55***	.62***	.35***	.48***	.55**
ΔR^2		.26***	.05		.21***	.07**		.14	.07

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T2 = Time 2.
*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 17

Time 3 Hierarchical Multiple Regression Analyses Predicting Final Course Grade from Previous Achievement, Motivation, and Learning Strategies by Ethnicity

	Asian			White			Other		
Predictor	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β	Model 1 β	Model 2 β	Model 3 β
Step 1									
Math SAT	.40***	.28***	.27***	.52***	.37***	.37***	.55***	.50***	.59***
AP Chem	.13	.08	.08	.22**	.14*	.17**	.21	.18	.19
Step 2									
IM T3		.19	.20		.05	.03		−.02	.14
EM T3		.11	.11		.08	.04		−.02	−.11
PR T3		−.23*	−.22*		−.09	−.05		−.24	−.14
SD T3		.03	−.03		.11	−.03		.11	.08
SE T3		.39***	.39***		.33***	.31**		.43*	.29
AX T3		.19*	.18*		.16	.06		−.07	−.14
Step 3									
RE T3			−.03			.03			−.10
EL T3			−.05			−.07			.21
ORG T3			−.03			−.22*			−.05
CT T3			−.04			−.02			−.00
MET T3			.07			.15			−.58*
TSE T3			.14			.04			.49
ER T3			−.09			.19			−.04
PL T3			.01			−.02			−.08
HS T3			.08			.09			.18
R^2	.19***	.51***	.52***	.34***	.56***	.63***	.35***	.51***	.62***
ΔR^2		.31***	.02		.21***	.07**		.16*	.11

Note. IM = Intrinsic Motivation, EM = Extrinsic Motivation; PR = Personal Relevance; SD = Self Determination; SE = Self-efficacy; AX = Assessment Anxiety. MSLQ = Motivated Strategies for Learning Questionnaire; RE = Rehearsal; EL = Elaboration; ORG = Organization; CT = Critical Thinking; MET = Metacognitive Self-Regulation Skills; TSE = Time and Study Environment Management; ER = Effort Regulation; PL = Peer Learning; HS = Help-seeking. T3 = Time 3.

*** $p < 0.001$, ** $p < .01$, * $p < 0.05$.

At Time 1, all final models were significant (Table 15). For the Asian group, $F(17, 132) = 5.71$, $p < .001$, the model explained 42.4% of the variance in final course grade. For the White group $F(17, 128) = 9.36$, $p < .001$, the model explained 55.4% of the variance in final course grade. For the Other group $F(17, 38) = 3.08$, $p = .002$, the model explained 58% of the variance in final course grade. Different variables were significant predictors of final course grade for the models for each group. For the Asian group, the strongest predictors were Math SAT, self efficacy, and effort regulation. For the White group the strongest predictors were Math SAT, self-efficacy, effort regulation, and AP Chemistry. For the Other group, Math SAT, metacognitive self-regulation skills (negatively) and help-seeking significantly predicted final course grades. At Time 1, Math SAT was the strongest predictor of final course grades for all three groups.

At Time 2, all three final models were significant again (Table 16). For the Asian group, $F(17, 132) = 7.73$, $p < .001$, the model explained 49.9% of the variance in final course grades. For the White group, $F(17, 128) = 12.23$, $p < .001$, the model explained 61.9%. For the Other group, $F(17, 38) = 2.74$, $p = .005$, the model explained 55.1%. Both the predictor variables and strength of predictors differed between the groups. There was a change for the Asian group with the strongest predictor identified as self-efficacy, followed by Math SAT, relevance of learning chemistry to personal goals (in the negative direction), and AP Chemistry. For the White group, Math SAT remained the strongest predictor, followed by self-efficacy, effort regulation and AP Chemistry. Math SAT was the only significant predictor for the Other group.

Time 3 analyses continue to show differences in prediction models for the three ethnic groups. All final models were still significant and explained high percentages of variance in final course grade (Table 17). For the Asian group, $F(17, 132) = 8.42$, $p < .001$, the model predicted 52% of the variance in final course grades. For the White group, $F(17, 128) = 12.56$, $p < .001$, the model explained 62.5%. For the Other group, $F(17, 38) = 3.64$, $p < .001$, the model explained 61.9%. Significant predictors changed again for all three groups. For the Asian group the strongest predictors were self-efficacy, Math SAT, personal relevance (in the negative direction) and assessment anxiety. Math SAT was still the strongest predictor for the White group, followed by self-efficacy, organization (in the negative direction), and AP Chemistry. Finally, for the Other group, Math SAT remained the strongest predictor, while metacognitive self-regulation skills negatively explained variance in final course grades. By the end of the semester different motivation constructs and learning strategies explained the variance in final course grade for each ethnic group. Only Math SAT was common to all three groups.

Discussion

This study analyzed the predictive value of motivation and learning strategies for introductory college chemistry success as well as changes in levels of motivation and learning strategy use through the semester by levels of performance (High, Average and Low), gender, and ethnicity. While the results of the current study support findings of previous research, the use of a comprehensive set of motivation constructs and learning strategies provides more detailed information about how these variables relate to success in introductory college chemistry.

Both self-efficacy and effort regulation predicted course performance throughout the semester as expected. Assessment anxiety only predicted course success at Time 3, as students with lower anxiety earned higher final course grades. While surprising that assessment anxiety did not predict performance earlier, this finding does support previous research that reported assessment anxiety as a negative predictor of success at the end of a semester (Garcia, 1993). Intrinsic motivation had a significant medium correlation with final course grades and was included in the regression models at Times 2 and 3, but neither positively nor negatively significantly predicted course performance as it has in previous studies (Garcia, 1993; Yu, 1999). Previous achievement measured by Math SAT scores was the strongest predictor of final course grades throughout the semester. However, self-efficacy and effort regulation were stronger predictors than in-depth exposure to chemistry material measured by AP Chemistry.

Because few studies (Zusho et al., 2003) have investigated changes in levels of motivation or strategies use more than two times in a semester or between groups based on course performance, this study provides valuable insight into the beliefs and behaviors of introductory college chemistry students. As expected, the entire sample reported a decrease in motivation to learn chemistry over the semester. Total motivation scores were significantly impacted by decreases in self-efficacy and increases in assessment anxiety.

Interestingly, relevance of learning chemistry to personal goals scores increased during the semester for High performers, and in fact, is contradictory to previous research that reported a decline in value of chemistry for all students (Zusho et al, 2003). Since ‘pre-health requirement’ was the primary reason for enrolling in chemistry and this track requires advanced chemistry, students may have connected how success in introductory chemistry may assist with achieving future goals.

While all participants were highly motivated to learn chemistry, as expected, High performers reported the highest motivation and Low performers reported the lowest motivation, which decreased throughout the semester. Self-efficacy decreased for Low and Average performers which is consistent with previous findings (Zusho et al., 2003). The significant increase in assessment anxiety for Low performers has not been reported previously. Because higher self-efficacy consistently positively relates (Britner, 2008; Britner & Pajares, 2006; Zusho et al., 2003) and higher assessment anxiety consistently negatively relates with science performance (Chappel, et al., 2005; Garcia, 1993), the decrease in self-efficacy and increase of assessment anxiety for Low performers raises a warning flag that should not be ignored. While motivation levels in Average and High course performers stayed relatively constant, motivation for Low course performers started lower and continued to decrease.

While it was expected that learning strategy use would change throughout the semester, what those changes would be was unknown. Notably, this study reported significant increases in critical thinking and peer learning, variables typically not included in previous studies investigating changes in multiple learning strategies. While other studies have tested the predictive ability of time and study environment management and effort regulation (Garcia, 1993; Yu, 1999; Zusho, et al., 2003) decreases through the semester had not been previously reported. Elaboration and metacognitive self-regulation scores increased as they have in previous studies. However contrary to previous research (Zusho et al., 2003), no significant changes in rehearsal or organization were found. Finally, no significant changes were found in help-seeking, a variable not typically included in studies predicting science success. Results suggest that while effectively using some deep strategies or resources, students may not be able to manage their own schedules or implement these skills regularly throughout the semester.

Some differences in learning strategy use between High, Average and Low course performers had not been previously reported (Zusho et al, 2003). High course performers implemented more elaboration, time and study environment management, effort regulation than Low and Average course performers, and more critical thinking, metacognitive self-regulation skills, and help-seeking than Low course performers. Differences in elaboration and metacognitive self-regulation skills between Low and High course performers have not previously been reported. Results suggest that while Low course performers were willing to work with other students (peer learning) as the semester progressed, they were much less likely to seek help than High performers. While all students' effort regulation decreased, the Low performers reported the lowest scores at the beginning of the semester and these scores continued to decline. Since effort regulation is a consistent predictor of science success, (Chen, 2002; Garcia, 1993; Yu, 1999), low performers need to understand how their effort regulation impacts performance.

Levels of motivation and learning strategy use were expected to differ by gender. Males' motivation had higher intrinsic motivation and lower assessment anxiety than females' which is consistent with the research (Garcia, 1993; Yu, 1999) Males also had significantly higher intrinsic motivation and relevance of learning chemistry to personal goals scores which had not been reported in previous studies. These differences may help explain why females earned lower final course grades. Females' intrinsic motivation and self-efficacy began lower than males' and continued to decline while their assessment anxiety was higher and increased throughout the semester. The decrease in motivation scores appears to have a greater negative effect on females' performance.

Learning strategy use also differed by gender. Males reported higher critical thinking skills, a result not previously reported, and females reported higher rehearsal and organization scores which supports previous findings (Garcia, 1999; Yu, 1999). Several additional motivation and learning strategies predicted male and female success throughout the semester. At the beginning of the semester, effort regulation predicted success for males while self-determination and help-seeking were significant predictors for females. At the end of the semester, time and study environment management was a significant predictor of female success. While effort regulation significantly predicted performance for the entire sample, it was not a significant predictor of success for females. These results indicate that different motivation constructs and learning strategies impact male and female chemistry students' performance.

There are fewer differences in levels of motivation and strategies use by ethnicity than by gender. Asians' intrinsic motivation and relevance of learning chemistry to personal goals at Time 1 were higher than the Other group. While Other groups' relevance of chemistry to personal goals scores increased, their self-efficacy decreased and assessment anxiety increased, which supports previous research reporting higher anxiety among ethnic minorities (Garcia, 1993). The White group's self-efficacy scores decreased. The variables that predicted performance were different for all three groups. While at the beginning of the semester self-efficacy and effort regulation positively predicted success for Asians and Whites, effort regulation dropped out by the end of the semester. Clearly, the strength of the prediction of metacognitive self-regulation skills for the Others' lower final course grades is important at the beginning and the end of the semester. Students may not be aware of how planning, monitoring and reflecting on learning can impact performance, or even how to implement these skills.

The results of this study have practical implications for college chemistry and other science instructors in three areas. First, information about students' level of motivation and learning strategy use can be helpful in predicting the successful and at-risk students in introductory college chemistry and potentially other science classes. Second, information on the particular motivation constructs and learning strategies that significantly relate to success in introductory college chemistry can guide instructors on what approaches to promote in their classes. Third, because group differences in motivation and learning strategy use exist by performance level, gender and ethnicity at specific times of the semester, this information indicates which students need interventions and/or access to resources at certain times of the semester.

Instructors can collect and utilize data on previous achievement, motivation and learning strategy use as predictors of course success. Previous achievement is information available to instructors upon request before students enroll and can be used as a starting point to identify at-risk students. Even though self-reports at the end of the semester explain more variance in final course grades, administering self-report questionnaires on motivation to learn chemistry and learning strategy use at the beginning of the semester also can provide useful information about students' performance at the end of the semester and provide an early warning system for precautionary advising.

While delivering content knowledge is the college science instructors' primary responsibility, "science education should… also develop analytical thinking skills, offer understanding of the scientific research process, inspire curiosity, and be accessible to a diverse range of student" (Anderson et al., 2011; p. 152). In order to do this, instructors need to be involved in facilitating motivation and teaching the strategies needed for course success. In this study, higher self-efficacy and effort regulation positively predicted success for all introductory college chemistry students. Class activities that facilitate self-efficacy, such as group discussions, practice in solving problems and smaller graded quizzes or assignments, allow students to apply what they learn and receive feedback so they can assist students to more accurately determine if they need more time or support to learn the material before major exams. To promote effort-regulation, instructors may encourage students to set aside particular time to work on course content throughout the week, provide sample study schedules, or advise students to work with their peers in small groups outside of class. This encouragement may be more important as the semester progresses and students are busier. For self-efficacy and effort regulation, instructors also may consider explicitly stating that students' beliefs and behaviors affect science performance to bring this to awareness and encourage them to evaluate their own thoughts about science and the skills they have, or may need to develop.

Because assessment anxiety is a negative predictor of performance at the end of the semester, teaching students how to effectively prepare for and take exams before their first test could help improve test scores earlier and possibly reduce anxiety later in the semester. Many students do not know what to expect on a major exam, and therefore do not prepare accordingly. Students need more exposure to the types of questions or problems they will be asked to solve on major exams. When answering questions or practicing problems, they also need feedback, so they can accurately evaluate their understanding. Since many universities also employ professionals who lead workshops on test preparation and test taking skills, instructors could set up sessions with these professionals or refer students directly to them.

There were many variables that strongly correlated with the significant predictors of chemistry success. In this study, intrinsic motivation was highly correlated with self-efficacy. Instructors can foster intrinsic motivation by demonstrating exciting experiments in lectures and labs, or encouraging students to explore related real-life science material at lectures, exhibits or conferences. Additionally, self-determination, metacognitive self-regulation skills, and time and study environment management were highly correlated with effort regulation. Instructors could promote self-determination by allowing students to lead group discussions or select paper or project topics that interest them. Modeling metacognitive self-regulation skills (Rickey & Stacy, 2000) and higher order thinking skills (Anderson et al. 2011; Bao et al., 2009) can be as simple as asking students to reflect on their thinking or practice problem-solving in class and encouraging students to do more planning, monitoring and reflecting on their own. Making short announcements reminding students to find their own ideal study spaces, set specific times to work on problems, or seek assistance could help all students become more aware of the strategies that lead to successful results. Instructors need to continuously promote services such as office hours, tutoring, or supplemental instruction in a variety of ways throughout the semester. Students often internalize these messages at different points of the semester, and it may take time for them to realize they need to change strategies or seek support. Thus, repeating these messages or finding new delivery methods, such as the syllabus, e-mails and web postings is important.

Because of group differences in levels of motivation and learning strategy use, and which predict success, interventions may differ for each group. Since self-efficacy and assessment anxiety differ for females and ethnic minorities, these students may need extra support in and out of the classroom. Instructors may consider connecting students to campus groups that promote and celebrate women and minorities in the sciences to potentially connect them with mentors or positive models for success. To decrease assessment anxiety, instructors may suggest stress management or other anxiety reducing programs. Discrepancies in performance by gender or ethnicity may still be due to stereotypes (DeBacker & Nelson, 2001; Miyake et al., 2010; Nosek et al., 2009) or lack of exposure to material or skills (Lewis & Connell, 2005; Nelson, 1996). Thus instructors need to be open to having resources available for students who may need extra support.

This study could serve as a model for research that considers a broader set of variables in order to understand student success in a more holistic way.
Additional research should be conducted with high-achieving students in introductory college chemistry to compare results and potentially generalize to larger populations. Future studies also may consider other introductory science courses to determine if motivation patterns are similar in different courses or if varying strategies are needed in other science areas. Because several factors such as self-efficacy and effort regulation are consistently predictors of science success, future research needs to focus on teaching methods or interventions that promote and maintain these variables. As the demographics of students enrolled in college science continuously and rapidly change, future research should continue to utilize a comprehensive set of motivational constructs and learning strategies when investigating science success.

There are several limitations with this study. The sample consisted of high-achieving students, many of whom had previous achievement scores indicating preparation for college chemistry. While little research has focused on high-achievers, it is difficult to interpret whether their levels of motivation and learning strategy use were unique. Additionally, the majority of students indicated they enrolled in the class as a 'pre-health requirement'. It is unclear if students with different career goals would be as highly motivated to learn chemistry or report use of different strategies. Students also received extra credit for their participation, and there is potential for motivational differences between students who volunteered to participate and those who did not. Only scores from students who completed all three surveys were analyzed. Students who withdrew from the course did so before the final survey was administered, and were not included in this study.

There are several important strengths of this study. Results support previous research that identified self-efficacy, assessment anxiety and effort regulation as significant predictors of introductory college chemistry success. By investigating a broader set of motivation constructs and learning strategies, a number of variables emerged that significantly correlated to the predictors of course success. Results from this study also shed more light on how and when the highest performers were motivated and implemented strategies that can assist instructors to promoting those variables to lower performing students. This study also called attention to several differences in motivation and learning strategy use by gender and ethnicity, indicating that some groups have greater deficits in specific areas than others. Results of this study are valuable for science instructors and researchers as they strive to foster both motivation and learning strategy use with college science students.

References

Ablard, K. E., & Lipschultz, R. E. (1998). Self-regulated learning in high-achieving students: Relations to advanced reasoning, achievement goals and gender. *Journal of Educational Psychology, 90(1)*, 94-101.

Anderson, W. A., Banerjee, U., Drennan, C. L., Elgin, C. R., Epstein, I. R., Handelsman, J., …Warner, I. M. (2011, January). Changing the culture of science education at research universities. *Science, 331,* 152-153.

Andrew, S. (1998). Self-efficacy as a predictor of academic performance in science. *Journal of Advanced Nursing, 27*, 596-603.

Arendale, D. R. (Ed.). (2003-2005). Postsecondary peer cooperative learning programs: Annotated bibliography. Minneapolis, MN: College of Education and Human Development.

Association of American Medical Colleges. (2010). *Medical School Admission Requirements (MSAR)2011-2012, United States and Canada.* Washington, D.C.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: W.H. Freeman and Company.

Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., … Wu, N. (2009, January). Learning and scientific reasoning. *Science, 323*, 586-87.

Berkley, C. S., & Sproule, C. F. (1973). Test-anxiety and test-unsophistication: The effects, the cures. *Public Personnel Management, January-February*, 55-59.

Black, A. E., & Deci, E. L (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education, 84,* 740-756. doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3

Bleicher, R. E., Romance, N., & Haky, J. (2002, January). *Curriculum by design: Improving student learning in college chemistry and biology*. Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science: Charlotte, NC.

BouJaoude, S. B., & Giuliano, F. J. (1994). Relationships between achievement and selective variables in a chemistry course for nonmajors. *School Science and Mathematics, 94*, 296-302.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching, 45*, 955-970.

Britner, S. L., & Pajares, P. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43*, 485-499.

Cavallo, A.M. L., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong college physics course for life science majors. *School Science and Mathematics, 104*, 288-300.

Chapell, M. S., Blanding, Z. B, Silverstein, M. E., Takahashi, M., Newman, B., Gubi, A., & Mccann, N. (2005). Test anxiety and academic performance in undergraduate and graduate students. *Journal of Educational Psychology, 97,* 268-274. doi:10.1037/0022-0663.97.2.268

Chen, C. S. (2002). Self-regulated learning strategies and achievement in an introduction to information systems course. *Information Technology, Learning, and Performance Journal, 20*, 11-25.

Corno, L. & Randi, J. (1999). A design theory for classroom instruction in self-regulated learning? In C.M. Reigeluth (Ed.), *Instructional theories in action: Lessons illustrating selected theories and models.* (pp. 293-318). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Covington, M. V. (2000). Goal theory, motivation and school achievement: An integrative review. *Annual Review of Psychology, 51,* 171-200.

DeBacker, T. K., & Nelson, R. M. (2001). Motivation to learn science: Differences related to gender, class type, and ability. *The Journal of Educational Research, 93,* 245-254.

Duncan, T. G., & McKeachie, W. J. (2005). The making of the Motivate Strategies for Learning Questionnaire. *Educational Psychologist, 40,* 117-128. doi: 10.1207/s15326985ep4002_6

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values and goals. *Annual Review of Psychology, 53,* 109-132.

Elliott, E. S, & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54,* 5-12.

Freeman, C. E. (2004). *Trends in Educational Equity of Girls & Women: 2004 (NCES 2005–016)*. Retrieved from Washington, DC: U.S. Government Printing Office: http://nces.ed.gov/pubs2005/2005016.pdf

Garcia, T. (1993, April). *Women and minorities in science: Motivational and cognitive correlates of achievement*. Paper presented at the Annual Meeting of the American Educational Research Association. Atlanta, GA.

Garcia, T., & Pintrich, P. (1996). The effects of autonomy on motivation and performance in the college classroom. *Contemporary Educational Psychology, 21,* 477-486

Glynn, S. M., & Koballa, Jr., T. R. (2005a) Chemistry Motivation Questionnaire (CMQ). Retrieved from http://www.coe.uga.edu/smq/

Glynn, S. M., & Koballa, Jr., T. R. (2005b) Science Motivation Questionnaire (SMQ). Retrieved from http://www.coe.uga.edu/smq/

Glynn, S. M., & Koballa, T. R. (2006). Motivation to learn college science. In Joel J. Mintzes and William H. Leonard (Eds.), *Handbook of College Science Teaching* (pp. 25-32). Arlington, VA: National Science Teachers Association Press.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching, 44*, 1088-1107. Doi: 10.1002/tea.20181.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science Motivation Questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46,* 127-146. doi: 10.1002/tea.20267

Karabenick, S. A., & Knapp, J. R. (1991) Relationship of academic help seeking to the use of learning strategies and other instrumental achievement behavior in college students. *Journal of Educational Psychology, 83 (2),* 221-230.

Lavigne, G. L., Vallerand, R. J., & Miquelon, P. (2007). A motivational model of persistence in education: A self-determination theory approach. *European Journal of Psychology of Education, XXII,* 351-369.

Lent, R. W., Brown, S. D., & Larkin, K. C. (1984). Relation of self-efficacy expectations to academic achievement and persistence. *Journal of Counseling Psychology, 31*, 356-362.

Lewis, B.F., & Connell, S. (2005). African American students' career considerations for enrolling in advanced science courses. *The Negro Educational Review, 56,* 221-31.

Lin, Y. G., McKeachie, W. J., & Kim, Y. C. (2002). College student intrinsic and/or extrinsic motivation and learning. *Learning and Individual Differences, 13,* 251-258.

Linder, R. W., Harris, B. (1992, April). *Self-regulated learning and academic achievement in college students*. Paper presented at the American Educational Research Association Annual Meeting, San Francisco.

Miyake, A., Kost-Smith, L. E., Finkelstein, N. D., Pollock, S. J., Cohen, G. L., & Ito, T. A. (2010, November). Reducing the gender achievement gap in college science: A classroom study of values affirmation. *Science, 330,* 1234-1237.

Murphy, P. K., & Alexander, P. A. (2000). A motivated explorations of motivation terminology. *Contemporary Educational Psychology 25*(3), 3-53. doi: 10.1006/ceps.1999.1019

National Center for Education Statistics. (2009). *Digest of Education Statistics: 2009.* Retrieved from http://nces.ed.gov/programs/digest/d09/

National Center for Education Statistics. (2010). *Digest of Education Statistics: 2010.* Retrieved from http://nces.ed.gov/programs/digest/d10/

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543-578.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82,* 33-40.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. (Report No. 91-B-004). Ann Arbor, MI: The Regents of The University of Michigan.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53,* 801-813. doi:10.1177/0013164493053003024

Rickey, D., & Stacy, A. M. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education, 77,* 916-920.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology, 25,* 54-67. doi:10.1006/ceps.1999.1020

Schuss, D. G. (1999, May 30). Many top college students use tutors to keep an edge study sessions aren't just for catching up. *Boston Globe*, p. D5.

Schwartz, M. C., Sadler, P. M., Sonnert, G., & Tai, R. H. (2008). Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93,* 798-826. doi: 10.1002/sce.20328

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*, 323-332.

Smith, W. S., Gould, S. M., & Jones, J. A. (2004). Starting the semester at odds: Educators' versus students' reasons for studying science. *Journal of College Science Teaching, 34*, 44-49.

Spencer, H. E. (1996). Mathematical SAT test scores and college chemistry grades. *Journal of Chemical Education, 73*, 1150-1153.

Stedman, L. C. (2009, March). The NAEP long-term trend assessment: A review of its transformation, use, and findings. Paper commissioned for the 20th anniversary of the National Assessment Governing Board, 1988-2008.

Taasoobshirazi, G., & Glynn, S. M. (2009). College students solving chemistry problems: A theoretical model of expertise. *Journal of Research in Science Teaching, 46*, 1070-1089.

Tai, R. T., Sadler, P. M., & Loehr, J. F. (2005). Factors influencing success in introductory college chemistry. *Journal of Research in Science Teaching, 42*, 987-1012.

Yu, S. L. (1999). Women's motivation and strategy use in college science classes. *Journal of Staff, Program, & Organization Development, 16*, 93-101.

Zeegers, P. (2001). Approaches to learning in science: A longitudinal study. *British Journal of Educational Psychology, 71*, 115-132.

Zimmerman, B. J. (2008) Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45*, 166-83.

Zusho, A., Pintrich, P. A, & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education, 25*, 1081-1094.

APPENDIXES

APPENDIX A

Chemistry Motivation Questionnaire (Glynn & Koballa, 2005a).

1. I enjoy learning the chemistry.
2. The chemistry I learn relates to my personal goals.
3. I like to do better than the other students on the chemistry tests.
4. I am nervous about how I will do on the chemistry tests.
5. If I am having trouble learning the chemistry, I try to figure out why.
6. I become anxious when it is time to take a chemistry test.
7. Earning a good chemistry grade is important to me.
8. I put enough effort into learning the chemistry.
9. I use strategies that ensure I learn the chemistry well.
10. I think about how learning the chemistry can help me get a good job.
11. I think about how the chemistry I learn will be helpful to me.
12. I expect to do as well as or better than other students in the chemistry course.
13. I worry about failing the chemistry tests.
14. I am concerned that the other students are better in chemistry.
15. I think about how my chemistry grade will affect my overall grade point average.
16. The chemistry I learn is more important to me than the grade I receive.
17. I think about how learning the chemistry can help my career.
18. I hate taking the chemistry tests.
19. I think about how I will use the chemistry I learn.
20. It is my fault, if I do not understand the chemistry.
21. I am confident I will do well on the chemistry labs and projects.
22. I find learning the chemistry interesting.
23. The chemistry I learn is relevant to my life.
24. I believe I can master the knowledge and skills in the chemistry course.
25. The chemistry I learn has practical value for me.
26. I prepare well for the chemistry tests and labs.
27. I like chemistry that challenges me.
28. I am confident I will do well on the chemistry tests.

29. I believe I can earn a grade of “A” in the chemistry course.
30. Understanding the chemistry gives me a sense of accomplishment.

APPENDIX B

Learning Strategies questions from the Motivated Strategies for Learning Questionnaire (Pintrich et. al, 1991).

1. When I study the readings for this course, I outline the material to help me organize my thoughts.
2. During class time I often miss important points because I'm thinking of other things.
3. When studying for this course, I often try to explain the material to a classmate or friend.
4. I usually study in a place where I can concentrate on my course work.
5. When reading for this course, I make up questions to help focus my reading.
6. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.
7. I often find myself questioning things I hear or read in this course to decide if I find them convincing.
8. When I study for this class, I practice saying the material to myself over and over.
9. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.
10. When I become confused about something I'm reading for this class, I go back and try to figure it out.
11. When I study for this course, I go through the readings and my class notes and try to find the most important ideas.
12. I make good use of my study time for this course.
13. If course readings are difficult to understand, I change the way I read the material.
14. I try to work with other students from this class to complete the course assignments.
15. When studying for this course, I read my class notes and the course readings over and over again.
16. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.
17. I work hard to do well in this class even if I don't like what we are doing.
18. I make simple charts, diagrams, or tables to help me organize course material.
19. When studying for this course, I often set aside time to discuss course material with a group of students from the class.
20. I treat the course material as a starting point and try to develop my own ideas about it.

21. I find it hard to stick to a study schedule.
22. When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.
23. Before I study new course material thoroughly, I often skim it to see how it is organized.
24. I ask myself questions to make sure I understand the material I have been studying in this class.
25. I try to change the way I study in order to fit the course requirements and the instructor's teaching style.
26. I often find that I have been reading for this class but don't know what it was all about.
27. I ask the instructor to clarify concepts I don't understand well.
28. I memorize key words to remind me of important concepts in this class.
29. When course work is difficult, I either give up or only study the easy parts.
30. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
31. I try to relate ideas in this subject to those in other courses whenever possible.
32. When I study for this course, I go over my class notes and make an outline of important concepts.
33. When reading for this class, I try to relate the material to what I already know.
34. I have a regular place set aside for studying.
35. I try to play around with ideas of my own related to what I am learning in this course.
36. When I study for this course, I write brief summaries of the main ideas from the readings and my class notes.
37. When I can't understand the material in this course, I ask another student in this class for help.
38. I try to understand the material in this class by making connections between the readings and the concepts from the lectures.
39. I make sure that I keep up with the weekly readings and assignments for this course.
40. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.
41. I make lists of important items for this course and memorize the lists.
42. I attend this class regularly.
43. Even when course materials are dull and uninteresting, I manage to keep working until I finish.

44. I try to identify students in this class whom I can ask for help if necessary.
45. When studying for this course I try to determine which concepts I don't understand well.
46. I often find that I don't spend very much time on this course because of other activities.
47. When I study for this class, I set goals for myself in order to direct my activities in each study period.
48. If I get confused taking notes in class, I make sure I sort it out afterwards.
49. I rarely find time to review my notes or readings before an exam.
50. I try to apply ideas from course readings in other class activities such as lecture and discussion.