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A Mixed-Methods Study of Students’ Success and Persistence in Biology

Biscah Syombua Munyaka

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A MIXED-METHODS STUDY OF STUDENTS’ SUCCESS
AND DPERSISTENCE IN BIOLOGY

A Dissertation Submitted in Partial Fulfillment
of the Requirements of the Degree of
Doctor of Philosophy

Biscah Syombua Munyaka

College of Natural and Health Sciences
School of Biological Sciences
Biological Education

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has been approved as meeting the requirement for the Degree of Doctor of Philosophy in College of Natural and Health Sciences in School of Biological Sciences, Program of Biological Education

Accepted by the Doctoral Committee

______________________________
Mitchell E. McGlaughlin, Ph.D., Co-Research Advisor

______________________________
Teresa M. Higgins, PhD., Co-Research Advisor

______________________________
Richard Jurin, Ph.D., Committee Member

______________________________
Kevin Pugh, Ph.D., Faculty Representative

Date of Dissertation Defense ______________________________________________________________________

Accepted by the Graduate School

_____________________________________
Linda L. Black, Ed.D.
Associate Provost and Dean
Graduate School and International Admissions
ABSTRACT


Undergraduate success and persistence in Science Technology Engineering and Mathematics (STEM) fields is of critical importance to the United States (U.S.) maintenance of its position as the world leader in scientific innovations. While the total number of undergraduate degrees awarded annually has nearly tripled over the past 40 years, the same cannot be said for the proportion of degrees in Science Technology, Engineering and Mathematics (STEM) fields. The U.S. share of the world’s STEM graduates is sharply declining, on average less than 40% of incoming college freshmen elect to pursue a degree in a STEM field each year, with more than half of those individuals declaring a major in the biological sciences or a closely related area (e.g., pre-medicine, pre-health or nursing). Research indicates that, there is need to promote success and persistence among the undergraduates undertaking STEM fields. In an effort to address this call, a majority of research has employed a variety of empirically validated instruction strategies designed to promote undergraduate success and persistence in biological sciences. Although of integral importance, such studies have often not extensively explored the impact of motivational and attitudinal factors in tandem with demographic and educational characteristics, especially in the field of biology. The current study used quantitative methods utilizing Quasi experimental design to examine
the impact of motivational and attitudinal factors alongside with demographic and secondary characteristics in relation to students’ success and persistence in biology among students enrolled in two introductory biology courses (Principles of Biology and Organismal Biology) at a mid-size research and teaching university. Additionally, the study examined to what extent do such factors differentially predict success and persistence among underrepresented minority and first generation students within the aforementioned cohort. A second component of the study used qualitative inquiry and thematic data analysis techniques, to explore the persistence of both average and below average performing students in biology by examining their experiences in biology program.

Analyses examining student success found that motivational factors were equally important predictors of success among all student types. The top demographic predictors of success were: index score (a combination of high school GPA, SAT and ACT scores), minority status and first generation status, uniquely explaining 4.7%, 3.0% and 1% of variance in students’ course grade, respectively. The attitudinal predictors of students’ success were: students’ ability to apply knowledge to solve biology-specific tasks and enjoyment of the biology major each explaining 1.0% of variance in students’ final course grade. Among the underrepresented minority students, dual enrollment in an active learning-based supplemental instruction course explained 1.1% of the variance. Analyses examining predictors of persistence in biology found that self-efficacy and grade motivation were the important motivational factors predicting students’ persistence. Strategies employed by students to solve biology problems was the only attitudinal factor important for persistence in biology. Students’ final percent course grade in introductory
biology courses also emerged as a significant predictor of student persistence in biology. Interestingly, first generation students were more likely to persist in biology compared to continuing students, while minority students were less likely to persist in biology compared to non-minority students. The qualitative aspects of this study involved 12 participants, among these, 10 had persisted in biology while 2 had switched from biology to other majors. The four most important factors highlighted by the participants were: challenges associated with transitioning from high school to college, instructional aspects of the introductory biology courses, effects of participants’ social interactions and aspects of competition and weeding out in biology introductory courses.

The results and findings from this study suggests several things. First, developing and nurturing proper motivations and positive attitudes in post-secondary classrooms alongside with factoring motivational and attitudinal factors that are important for URMs and FGs success and persistence may be a step forward in addressing the critical problem of success in STEM fields in general. Second, meaningful engagement of students in solving biology related problems appears to be an essential task of educators leading first-semester biology experiences. Thirdly, approaches geared towards increasing student success in introductory courses seem to be essential in students’ persistence in specific majors. Finally, the study findings suggest that students’ success and persistence in biology may be reduced with sufficient streamlining of high school preparation to meet college level expectations with respect to what high school graduates entering college need to know and be able to do for success and persistence in college.
DEDICATED

I dedicate this dissertation to my ever-loving Mother
Beatrice Mweela Munyaka (1953-2012) and all other Mothers who went
ahead of us before witnessing success of their children.
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“I can do all things through Christ which strengthens me”
(Philippians 4:13, King James Version).
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CHAPTER I

EXAMINATION OF PREDICTORS OF SUCCESS
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Introduction

The Need for the Science Technology
Engineering and Mathematics
(STEM) Graduates

Critical to the United States (U.S.) ability to maintain its position as an economic global leader is its potency in Science, Technology, Engineering, and Mathematics (STEM). Despite its current position as renowned world leader in technological innovations, research and development, the breach compare to other countries is swiftly closing. According to the National Science Board (NSB, 2014), the share of the global research and development from the U.S. and Europe has declined from 37% to 30% since 2001. Among the reasons contributing to this decrease is the discrepancy between the number of STEM graduates in the U.S. and other countries, such as China. For instance, between 1995 and 2008 China tripled its STEM graduates (Guterl, 2014). In addition, from 2001-2014, the global share of research and development from Asian countries increased from 25% to 34%, with China leading Asian nations with its’ global share expanding from 4% to 15%. In an effort to reverse the situation, there have been many calls to action in order to reinforce the science pipeline by enrolling and graduating more students in STEM disciplines. The “science pipeline” is...
A metaphor which has often been used to describe the student’s pathway from secondary school, through tertiary education, to career entry in any of the STEM fields (Blickenstaff, 2005). The same pipeline has also been defined as notoriously leaky as students leak from the pipeline at various stages. Increasing the number of students entering STEM fields ensures that the U.S. can “continue to innovate, lead, and create future jobs” (Next Generation Science Standards, [NGSS] 2013, p. 1). Economic projections indicate that by 2018, many science and engineering occupations’ growth rates will be faster than average, and that many jobs will require post-secondary training (NSB, 2010).

Analyses point to the need for the U.S. to increase its science-based workforce within the next decade by an estimated additional one million STEM graduates (Lacey & Wright, 2009; President’s Council of Advisors in Science and Technology [PCAST], 2010, 2012). The precise estimates of required STEM graduates differ slightly based on the job descriptions and the assumptions characterized in the specific models. For instance, an analysis from the Center for Education and Workforce at Georgetown University indicates that between the years 2008-2018, STEM jobs in the U.S. will have risen from 5.0% to 5.3% (Carnevale, Smith, & Melton, 2011), such growth corresponds to one million jobs. The analysis by Georgetown University also indicates that by 2018, over 90% of STEM jobs will necessitate post-secondary training (Carnevale et al., 2011). This projection along with others are in line with President Obama’s American Graduation Initiative (AGI), which seeks to increase the U.S. post-secondary graduation rates by an additional five million graduates by 2020 (Kotamraju & Blackman, 2011).
Currently, an estimated 300,000 individuals with bachelor and associate degrees in STEM fields graduate in the U.S. annually (Radford, Berkner, Wheeless, & Shepherd, 2010). This means that, between 2012 and 2022, approximately 3 million STEM degrees can be expected to be produced. In order to achieve the goal for the required STEM graduates, the U.S. would need to graduate an additional 100,000 STEM graduates annually, this corresponds to a nearly 33% annual increase of the required STEM graduates over the current rates. In response to the national need for more STEM graduates, reports have indicated the need of increasing graduates in STEM fields as a national goal (National Academy of Science [NAS], 2005). In an increasingly technical society, any gaps in the supply of, and demand for, technically trained workers, and the continuing imbalances in the gender and race composition of these workforces, present significant social and economic problems (Rask, 2010). A strong STEM labor force is essential for future scientific and technological advancements (PCAST, 2012). Failing to support the science pipeline has the possibility of further eroding the U.S. ability to remain competitive in a worldwide economy.

**The Role of Science Technology Engineering and Mathematics (STEM) Graduates in the U.S. Economy and Beyond**

History should be our guide. The United States led the world’s economies in the 20th century because we led the world in innovation. Today, the competition is keener; the challenge is tougher; and that is why innovation is more important than ever. It is the key to good, new jobs for the 21st century. That’s how we will ensure a high quality of life for this generation and future generations. With these investments, we’re planting the seeds of progress for our country, and good paying, private-sector jobs for the American people.

--President Barack Obama, August 5, 2009 (Obama, 2011 pp.1)
Since the 20th century, the U.S. has directly depended on science, technology and higher education knowledge as drivers of its economy (PCAST, 2012). The growth of higher education and the subsequent increase of the number of individuals graduating from universities with expertise in STEM fields led to a rapid increase of research and development innovativeness, good job opportunities, new industries and strong economic performance driven by new technologies after World War II. Science-based innovations have spearheaded the U.S. economy in different perspectives ranging from improved standards of living, empowering the economic and political leadership, to job creation (Obama, 2011). Despite the clear role of science-based innovations, America’s global share in STEM based industries is waning, jeopardizing its global leadership in innovations (Toven-Lindsey, Levis-Fitzgerald, Barber, & Hasson, 2015). Empirical evidence suggest that the U.S. is unable to produce enough of its own STEM graduate workers in key scientific fields, despite the fact that it harbors the best institutions of higher education for studying such fields (Atkinson & Mayo, 2010). Nevertheless, nearly half of all yearly U.S. granted STEM doctorate degrees are awarded to foreign citizens who are filling a large number of U.S. STEM jobs (Beede et al., 2011).

The current political and economic situation coupled with demanding societal needs together call for a high number of STEM workers. Some examples which depict this demand include: the continued growth of energy needs, the need for potable water and the natural disasters, which have increased the demand for geological science specialists over and above the current supply (Gonzales & Keane, 2009). In other professions like power engineering, there are a high number of aging personnel with approximately 45% of the workforce likely to retire over the course of 10 years.
Consequently, with only a few individuals graduating with electrical engineering degrees, this could lead to a huge shortage in professionals in various engineering fields such as; design, operation, and maintenance of electrical power systems (Grice, Peer, & Morris, 2011). The role of STEM knowledge plays a crucial role in the lives of all Americans; therefore, they should all take part in contributing to this knowledge. In the face of global competition, any democratic society with a large number of its people being unfamiliar with scientific and technological development is at a great economic disadvantage.

Whereas efforts to increase the quantity and quality of the U.S. graduates in STEM based fields on its own cannot solve the problem of the U.S. declining innovation-based industries, it is a significant component of a larger national inventive approach.

Across the world, countries strive for more economic innovations for three basic reasons: economic benefits, trade and societal needs. First, innovations are essential for countries’ realization of an economy characterized by improved standards of living. This can only be realized as a result of continued levels of productivity. For example, in the U.S., technological development has been responsible for 75% of economic growth since World War II (Atkinson & Mayo, 2010). Other studies indicate that technological advancements drive up to about 90% of the U.S. per-capita growth (Helpman, 2004). The impact of innovation is achieved through empowering the productivity developments that form the foundations of economic growth (Atkinson & McKay, 2007). According to economist Edwin Mansfield, the estimated rate of societal return from investments in academic research is about 40% (Dunning, 2014). Innovations are also essential to job creation and growth. The results from a definitive review of studies by the Organization for Economic Cooperation and Development (Organization for Economic Co-operation
and Development [OECD], 2004) show that innovative technologies both create and eliminate jobs. In general they eliminate low productivity jobs while creating more productive jobs, which requires higher skills with higher pay rates (OECD, 2004).

Second, countries around the world seek technological innovations to boost the competitiveness of commercial sectors with respect to international markets; this leads to better terms of trade and increased exports (Helpman, 2004; 2011). Developments in international trade make it increasingly crucial for the U.S. to grow its economy. International interdependencies have been a central feature of the world economy for a long time. Countries economic fortunes are interwoven through trade, financial capital flow and direct foreign investing. Consequently, the production and demand relationships across countries and continents makes the supplies of a particular product in one country highly dependent on the economic activities in a number of foreign countries (Helpman, 2011). Furthermore, when regions and countries around the world transform due to technological innovations, economic trade or due to political change, the type of foreign trade changes as well.

Third, societal needs are key drivers of the nation’s motivation behind empowering innovations due to a continued need to develop new and effective ways of meeting societal and individual needs (Atkinson & Mayo, 2010). Scientific innovation has been, and will continue to be fundamental in driving developments in transportation, education, environmental protection and health care. Novelty in technology is imperative in enabling societies to address the challenges of the 21st century. Such challenges include: the impacts of climate change, achievement of sustained global prosperity, development of sustainable sources of food and energy, raising billions of people around
the world above the poverty line and the demand to meet the needs of both the growing and aging populations. This argument points to the fact that scientific and technological based innovation is in itself impossible without a workforce educated in STEM disciplines.

Education system plays a major role in supporting scientific and technological innovations because knowledge-based societies depend on a highly qualified labor-force in all sectors of the economy and society (Atkinson & Mayo, 2010). The concept of continual learning and upgrading of technological skills is key to innovations. A highly educated workforce supports innovation and productivity; therefore, higher education attainment has become a central component of economic success (Atkinson & Andes, 2009). This can be evident by the rapidly increasing access to higher education both domestically and internationally (United Nations Educational, Scientific & Cultural Organization [UNESCO], 2011). Accordingly this has led to increased competition or high paying jobs as a result of globalization and increased access to higher education. Therefore, the job market is constantly evolving.

**Factors Influencing Students Persistence in College**

The continued decline in the number of students in post-secondary education electing to study sciences warrants an investigation into the reasons associated with this disposition. As a result, the last-decade has been marked by a sharp increase in research aimed at elucidating the predictors of academic success and persistence within STEM fields (Zhang, Anderson, Ohland, & Thorndyke, 2004). Factors related to these outcomes are of particular interest especially with the declining interest in science among graduating high school students entering institutions of higher education. Besides,
African American, Native American, and Hispanic students continue to remain underrepresented in STEM majors (Engineering Workforce Commission, 2008; Eschenbach, Cashman, Waller, & Lord, 2005). The additional human cost associated with ethnic underrepresentation makes the issue critical for science majors as the demand for qualified professionals in these fields continue to outpace the available pool (Thompson & Oakes, 2006). The (PCAST (2012) report demonstrate that, promoting STEM major retention rates from just 40% to 50% is a strategy which would generate about three quarters of the U.S. goal of producing more STEM graduates (Lacey & Wright, 2009; Langdon, McKittrick, Beede, Khan, & Doms, 2011). In addition, retaining students in STEM majors is a low cost and a fast policy option of producing STEM graduates (PCAST, 2012). This strategy does not require colleges to expand the sizes of science introductory courses, which are already constrained by space and resources. Therefore, the promotion of undergraduate students’ who start as STEM majors and graduate with a STEM degree is the first step in alleviating what can be described as a chain reaction problem.

The Research on Student Retention in Institutions of Higher Education

Research into student retention in colleges and universities is not new; its roots can be traced back over 70 years (Braxton, 2000), with a majority of such research preceding 1970 (e.g., Astin, 1964; Bayer, 1968; Vaughan, 1968; Wyatt, 2011). Scholarly knowledge about student retention in institutions of higher education is informed by two seminal studies published in 1975: Tinto’s (1975) research on the interactionalist theory of student retention and Astin’s (1978) book entitled “Preventing Students from Dropping Out.” The research by Tinto (1975) established a theory that integrated
student’s aspirations for a degree, commitment to college and integration into campus social and academic life. Based on Tinto’s (1975 1987) model, a student’s commitment to college was a result of the level of integration into college academic life. Tinto’s theory was based on Durkheim’s model of suicide (Durkheim, 1951), which linked suicide rates to individuals’ low perceptions of social integration in the community. High levels of integration and commitment resulted in a higher likelihood of student retention in college (Braxton, 2000; Braxton & Lien, 2000; Tinto, 1975, 1987). On the other hand Astin’s (1975) work focused on specific student characteristics (e.g., place of residency, age and gender) and institutional variables (e.g., selectivity aspects, location of the institution and type of the institution), in relation to students’ ability to remain enrolled or to drop out of college.

According to Braxton (2000), research into the causes of students’ attrition from college-stagnated in mid-1990s, with a comprehensive acceptance of Tinto’s (1987) theory of “Leaving College.” Braxton (2000) called for fresh enquiry that would “reinvigorate scholarly inquiry into the departure puzzle” (p. 3). Braxton called for renewed research into departure puzzle probably as a result of some aspects of students’ departure from college which could not be fully explained by the Tinto’s model. Due to the current rapidly changing demographics of student populations in colleges (Keller, 2001), there is need to explore the effect of student variables that have potential in predicting persistence in college. Furthermore, there is need for more research on predictors of students’ success and persistence in college, with the hope that identification of such factors can inform measures for reversing the attrition trends, especially in STEM disciplines.
Undergraduate Attrition from Science Technology Engineering and Mathematics Fields

Attainment of a degree in higher education is often considered the doorway to a better life; this can be conceptualized as attainment of a higher standard of living as opposed to lower standards of living associated with lower level of education. Studies show that, individuals with a college degree earn about 64% more than individuals with just high school diploma (Carnevale, Rose, & Cheah, 2013). Likewise, individuals with a college degree are less likely to be unemployed than those without (D'Amico & Dika, 2013). However, the past three decades have been marked by a decline in degree completion rates among undergraduate students enrolled in STEM majors (Olson & Riordan, 2012). Furthermore, over half of individuals who graduate with an undergraduate STEM degree change to a non-STEM discipline when getting into a graduate program or when entering the job market (NSB, 2012). Currently the number of students who are completing a STEM degree is below 40% (Chen, 2013). Previous studies on students’ success and persistence in STEM disciplines has focused on high performing students (Lang, 2008; Seymour & Hewitt, 1997; Strenta, Elliott, Russell, Matier, & Scott, 1994), therefore, the number of average and below average performing students’ in STEM disciplines remains unknown.

Science careers are considered prestigious and high paying; therefore, promoting access to STEM fields has potential implications at an individual level (Handelsman et al., 2004). Multiple studies have found that on average 50-60% undergraduates who initially start college interested in STEM sciences do not complete a degree in a STEM major (Center for Institutional Data Exchange and Analysis [CIDEA], 2000; Higher
Education Research Institute [HERI], 2010; Hurtado, Eagan, & Chang, 2010). These attrition rates continue to undermine the U.S. STEM workforce (Hira, 2010; Zakaria, 2011). According to the Organization for Economic Co-operation and Development (OECD, 2004), other countries like China are taking a lead in producing graduates in STEM fields. Besides, among global institutions of higher education, the U.S. ranks 20th in the proportion of 24 year-olds earning degrees in natural science or engineering (Bybee, 2013). This has contributed to the overall decline of the U.S. global competitiveness (Xavier, Beñat, Jennifer, Marareta, & Thierry, 2011).

Strenta et al. (1994) showed that not only were the losses from science majors greater than those from non-science majors, but that, transfer rates from science majors to non-science majors was considerably higher than the reverse. Consequently, with a substantial portion of students leaving STEM majors and a smaller number of students filling those vacant spots, this contributes to the net leakage from the STEM pipeline (Seymour & Hewitt, 1997). The most noticeable effect of this leakage is the associated shortages in primary health care, certain allied health professions, some engineering professions, and, most importantly, science, technology and mathematics careers in the past two decades (Ingersoll, 2003).

According to the Chen (2013), among students who started a STEM degree between 2003 and 2009, nearly half (48%) of them had left these degrees by the spring of 2009, some left STEM fields by switching to a non-STEM field (28%), while others (20%) exited college without earning a degree or a certificate. Other studies show that although the overall number of bachelor’s degrees awarded annually in the U.S. has risen by nearly 50% over the last 20 years (National Science Foundation [NSF], 2008), the
proportion of university students achieving bachelor’s degrees in STEM fields has declined by almost 40% (Augustine, 2007).

A majority of students who leave STEM majors are academically prepared as indicated by their above average scores on standardized tests, such as the Scholastic Aptitude Test (SAT) and American College Testing (ACT), as well as exemplary success in high school science courses (Enman & Lupart, 2000; Henderson, Beach, & Finkelstein, 2011). Research suggests that future policies on increasing graduation rates in sciences should be aimed at these students as opposed to promoting the flow of students into STEM majors (Atkinson & Mayo, 2010; Seymour & Hewitt, 1997).

Reasons for Leaving Science Technology Engineering and Mathematics Majors

Literature reveals several reasons which contribute to why undergraduates leave STEM majors in large numbers such as toxic learning environments (unwelcoming learning environments; Strenta et al., 1994), competitive learning environments (students competition for grades) coupled with poor teaching methods (Seymour & Hewitt, 1997), students course grades not reflecting their knowledge of the course subject matter (Rask, 2010), and excessive course content with minimal learning gains (Strenta et al., 1994). A majority of research implicates undergraduate STEM classrooms as being unfavorable with among the most unpleasant, unmotivated, unresponsive professors, lack of opportunities to interact with the faculty, and an excessive workload (Sundberg, Dini, & Li, 1994). Seymour and Hewitt (1997) identified 23 factors contributing to undergraduate switching decisions that were also major concerns to non-switchers. The top reported factors by more than one-third of the switchers were; the belief that non-STEM majors were more interesting: the belief that STEM career rewards were not worth the effort to
get the degree; a loss of interest in STEM majors; the rejection of STEM careers and
associated lifestyles; poor teaching by STEM faculty; a shift to a more appealing non-
STEM career option and overload due to curriculum or fast pace of courses. Furthermore,
nine out of ten of the switchers and three out of four of the non-switchers described the
quality of education in STEM education as poor (Seymour & Hewitt, 1997). These
findings point to the need for examination of students’ attitudes and motivations towards
specific STEM fields as an effort to identify predictors of students’ success and
persistence in sciences.

In the ethnographic component of the study by Seymour and Hewitt (1997),
participants’ explained that the education in STEM majors was poor for three major
reasons; the STEM instructors seemed more interested in their research as opposed to
teaching; instructors seemed less supportive than instructors in non-STEM disciplines;
and the STEM instructors created a competitive and intimidating environment that
discouraged participation and discussion. A side effect of poor instruction was some of
the switchers reported rejecting STEM majors and careers because of the poor role
models their instructors provided. On the other hand, faculty attributed reasons for
student’ high attrition rates in STEM fields to lack of academic preparedness. However,
previous research has demonstrated that undergraduates entering college with an
intention to major in sciences have a high level of preparedness as illustrated by high
high-school GPA’s, and good performance in standardized tests coupled with success in
high school sciences (Henderson et al., 2011; Seymour, 2002).

The difference between student and faculty explanations with respect to reasons
for attrition in STEM fields could possibly be accounted for by different expectations by
high school and post-secondary instructors with respect to the rigor of undergraduate-entry-level courses (Daempfle 2003). Daempfle (2002; 2003) found that secondary biology teachers believed it was important for their students to possess a working vocabulary for biology: including Latin terminology; reading comprehension; note-taking skills; and biology content knowledge. College biology instructors, on the other hand, believed that it was more important for students to have good writing skills, a good command of algebra and statistics, and the ability to integrate information from different domains, and did not find biology knowledge as important. A logical explanation for this disconnect could be based upon the educational differences between high school and college biology teachers. Overall, this has implications with regard to the preparation of students entering college science courses. If high school science students are being taught by instructors who have emphasized skills or concepts that are not valued by college science instructors, then these students are likely to face difficulties adjusting to college science instruction. Therefore, by extension this means that addressing the conflict of expectations between the biology high school teachers and college biology instructors ensures that, biology students are not different from other science students at college level.

Results from a large-scale study by Strenta et al. (1994) found that, compared to other non-STEM degree programs, the learning environments in engineering and biology courses were gloomy. With respect to the lauded “chilly climate” in STEM courses, their study sought to examine whether the chilly hypothesis, the hypothesis that more women than men leave STEM sciences due to discrepancy with respect to gender treatment that favors men, is responsible for reduced retention (Strenta et al., 1994). Those who support
the chilly hypothesis indicate that the STEM learning environments demean women in a variety of ways including: disrupting women’s comments, excluding women from study groups, having less expectations from women and making suggestive sexual advances towards women (Strenta et al., 1994). In addition, high achieving students often cite boring science introductory courses as a factor in their decision to switch majors, while low achieving students with interest and aptitude in STEM fields often cite difficulty with the math required in introductory STEM disciplines with little help provided by faculty (PCAST, 2012). Furthermore, many students, predominantly members of the underrepresented groups in STEM disciplines, cite an unreceptive atmosphere from the instructors in STEM courses as the reason for their departure from those majors (Dade, 2015). As discussed above, the reasons students’ give for leaving the STEM majors directly point to urgent retention strategies to reverse the situation.

**Motivational and Attitudinal Factors Related to Student Success and Persistence**

Examination of students’ attitudes and motivations towards studying sciences has been a fundamental feature within the education science community for the past 30 to 40 years (Osborne, Simon, & Collins, 2003). The significance of the topic is of particular importance due to the continued decline in interest among undergraduates in STEM sciences (Center for Institutional Data Exchange and Analysis [CIDEA], 2000; Chang, Eagan, Lin, & Hurtado, 2009; NSB, 2008; Obama, 2010; Olson & Riordan, 2012; Seymour & Hewitt, 1997), and widespread scientific ignorance among the general population (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Miller, Pardo, & Niwa, 1997). Furthermore, there is an increased societal recognition of the economic role played by the scientific knowledge (Glynn et al., 2011). The dwindling number of
students electing to pursue science careers is now a matter of collective concern (e.g., House of Lords 2000; Lepkowska, 1996). Accordingly, research on student’s motivations and attitudes towards learning science is increasingly becoming popular.

Motivation is an internal state that arouses, directs and sustains a goal-oriented action (Glynn et al., 2011). On the other hand, based on the social cognitive model (Zimmerman, Boekarts, Pintrich, & Zeidner, 2000), motivation is a dynamic and multifaceted phenomenon comprised of different features, which has the potential to facilitate or impede learning (Linnenbrink & Pintrich, 2002). There are two dimensions of motivation: intrinsic and extrinsic motivation. Intrinsic motivation is characterized by an individual’s engagement in an activity for its own sake, whereas extrinsic motivation occurs when one engages in an activity as a means to an end (Pintrich & Schunk, 2002). Intrinsically motivated students often possess an internal locus of control. They are driven to accomplish something, usually enthusiastic to learn new things and are driven to seek intellectual stimulation (Komarraju, Karau, & Schmeck, 2009). On the other hand, extrinsically motivated students pursue education for the purpose of achieving contingent goals as opposed to learning for enjoyment sake (Komaraju et al., 2009). The two elements of motivation impact student academic success and persistence in a variety of disciplines including biological sciences and educational psychology (Hidi & Harackiewicz, 2000). In support of these findings, intrinsically motivated students seek out challenges and competitions in school while extrinsically motivated students have a low level of engagement associated with high college attrition rates (Beaudoin, 2006).

Previous research suggests that instructional methods that encourage mastery of concepts foster intrinsic motivation, whereas those which underscore performance diminish
students’ achievement and motivation (Barron & Harackiewicz, 2001). Differences in motivation and achievement levels among students influence academic success and persistence in college (Komarraju et al., 2009). In order to expedite the process of learning, it is crucial to understand student attitudes toward learning, especially learning sciences.

Pre-held attitudes, such as beliefs, confidence, self-efficacy and interests, have the potential to influence how students approach learning (e.g., critical thinking, study habits, strategies and effort in problem-solving) within a specific discipline (Partin & Haney, 2012). Studies have documented an association between students’ attitudes and demographic characteristics with respect to student learning (Partin & Haney, 2012), gender (Felder, 1993), interest (Adams et al., 2006), teaching strategies (Otero & Gray 2008) and ethnicity (Hoang, 2008). These studies underscore the rising complexity of our understanding regarding predictors of student’s success and persistence in college (Reason, 2009). In other instances, it is increasingly challenging to differentiate between correlation and causation, especially for factors like success and performance. This means that considerations must be applied when drawing conclusions from study results. However, according to Hansen and Birol (2014), it is important to determine the correlation between students’ attitudes and performance in an effort to promote strategies for improving learning.

Self-efficacy, an individuals’ belief in their ability to execute a particular activity, directly influences academic success even after controlling for ability elements like grades and test scores (Chemers, Hu, & Garcia, 2001), and can predict persistence in an activity (Bandura, 1997; Eccles & Wigfield, 2002; Pintrich & Schunk, 2002). Therefore,
by extension, educators can influence students’ success and persistence by promoting self-efficacy in different disciplinary science subjects. Lawson, Banks, and Logvin (2007) found that reasoning ability was a primary factor influencing both self-efficacy and success. Similarly, student self-efficacy in introductory biology courses for STEM majors was found to decrease over the course of the first-semester, possibly due to students’ low academic performance relative to their expectations (Mann & Golubski, 2013). Previous studies have also found a link between students’ attitudes and perceptions with academic success and career opportunities (Hammouri, 2004). In a study examining the effects of student characteristics on performance in mathematics among 8th graders participating in the Third International Mathematics and Science Study, student attitudes, educational aspirations, perceptions of the importance of mathematics and confidence in ability were the important factors contributing to variance in success in mathematics (Hammouri, 2004).

Attitudes toward science impact student performance in STEM disciplines especially in laboratory settings (Brownell, Kloser, Fukami, & Shavelson, 2012). According to Hansen and Birol (2014), students’ attitudes in biology became significantly more expert-like as students progressed through the fourth year in a program. Together these studies indicate the importance of exploring the role of non-cognitive factors such as attitudes and motivation in learning science and how such factors can be promoted and sustained among different students populations.
**Demographic Factors and Educational Characteristics Related to Students Success and Persistence in Biology**

Given the significance of student demographic characteristics, prior educational experiences and course prerequisites to student success (Tai, Sadler, & Loehr, 2005), it is paramount to explore the role of such factors in relation to success and persistence in biological sciences. Specific demographic factors like gender (Eddy, Brownell, & Wenderoth, 2014) and ethnicity (Hoang, 2008) influence student success in a variety of fields. Results by Eddy et al. (2014) regarding gender gaps in achievement and participation in several introductory biology classrooms found that despite the dominance of female gender in those classes, female students consistently underperformed compared to males with comparable GPAs. Females also had lower participation rates compared to males as measured by the percentage of voices heard responding to instructor posed questions in class (Eddy et al., 2014). If particular student characteristics (e.g., gender, ethnicity and prior educational experiences) are shown to impede learning, then targeted instruction strategies can be devised to counteract the problem.

In the field of biology, Singh and West (2014) confirmed that high school GPA and completion of high school chemistry increased the likelihood of student success in first-year biology coursework. These findings denote the importance of prior educational achievement necessary for post-secondary success. Other studies (Crisp, Nora, & Taggart, 2009; Tai et al., 2005) largely support these findings, suggesting that successful completion of pre-collegiate coursework in biology, chemistry, and physics is integral for students’ success in the respective fields at college level.
First Generation students (FGs), those students whose parent(s) or guardian(s) did not attain more than high school education (Harackiewicz et al., 2014), and Underrepresented Minority students (URM) students, which include Native American, Latino/a, Chicano/a, Pacific Islander and African-American students, are often less likely to succeed and persist in academia (Harrell & Forney 2003; Lewis, Snow, Farris, & Levin, 2000; U.S. Department of Education 2013). Research shows that, these two groups of students often present with unique challenges. For example, Pascarella, Pierson, Wolniak, and Terenzini (2004) found that FGs are more likely to be at a distinct disadvantage compared to their peers with respect to the overall knowledge about college education (e.g., application process, costs, mixed expectations about college).

Students bearing a first generation status face difficulty transitioning from high school to college compared to their peers. In addition to confronting the anxieties of dislocation and the difficulties experienced by other college students, FGs experiences often comprise considerable social, cultural and academic transitions (Pascarella et al., 2004). The investigation into the impacts of non-cognitive factors manifested through (e.g., attitudes and motivations towards learning), among the FGs and URMs is important in an effort to promote their learning. Previous research shows that prior success influences various components of motivation, which consequently influences success (Eccles & Wigfield, 2002).

**Importance of Success and Persistence in Science Technology Engineering and Mathematics Sciences (Biology)**
Diversification of participation in science careers is an important issue of concern in the U.S. (Jones, Barlow, & Villarejo, 2010). For example, in 2000 Whites occupied 75% of all physical and life science careers, while Asian occupied 16%, and Hispanic and African Americans each occupied 3% (NSF, 2004). The Underrepresented Minority students’ (URMs) have lower graduation rates in physical and life science’s compared to Whites and Asians, despite the increasing enrollment among URMs in institutions of higher education (Lewis et al., 2000; U.S. Department of Education 2013). Previous research shows that non-Asian URMs are as interested in pursuing science as their Asian and White peers (Elliott, Strenta, Adair, Matier, & Scott, 1996). In addition, the attitudes toward science, at least for African American students, are more positive compared to those of White students when holding other factors constant (Elliott et al., 1996).

However, despite the highly demonstrated interest in science among URMs, White males have dominated science careers for a long time, and only a few such careers are occupied by URM groups (NSF, 2004). Notwithstanding the increased enrollment among URMs in colleges and universities (Jones et al., 2010), they have continued to have low graduation rates in science majors in comparison with Whites and Asians (Lewis et al., 2000; U.S. Department of Education 2013). In the year 2000, only 2.5% of URMs had earned bachelors’ degrees in natural sciences compared to 6% of White students (Jones et al., 2010). As the U.S. rapidly becomes a multiracial society, the current ethnic/racial gap in STEM degree completion rate predicts a deficiency in ethnic diversity among STEM workers (National Research Council [NRC], 2005).
Efforts to increase the number of the URMs in undergraduate science programs is one practical way of increasing the proportion of the STEM workforce currently dominated by White males. Unfortunately, this solution is a major challenge to many institutions of higher education because few URM groups persist and graduate with STEM degrees nationwide (Markley, 2005). In order to impact the demographics of the STEM workforce, the populace of undergraduate’s choosing STEM disciplines must change. Previous research underscores the importance of identifying students at high risk of dropping out from college during the early stages, in order to allocate the available resources based on student needs (Lin, Imbrie, & Reid, 2009). According to Zhang et al. (2004), identification of factors that affect student retention could play an important role in the counseling and advising process for engineering students. Such avenues equip institutions of higher education to utilize the available resources with respect to specific student needs (Herzog, 2006). The scholarly literature reveals an extensive need for increasing URM undergraduate persistence in higher education (Alkhasawneh & Hargraves 2014, Nave, Frizel, Obiomon, Cui, & Perkins, 2006). Student persistence is of significant interest because of its positive impact on college reputation and workforce demographics (Alkhasawneh & Hargraves, 2014).

Biology is a popular major (Lang, 2008; Princeton Review, 2007) constituting the largest part of the natural science undergraduate degrees (NSB, 2008). However significant ethnic differences exist in biology at the undergraduate level (NSB, 2008; NSF, 2004) these differences continue to be exaggerated at higher levels of degree attainment. For example, even though URMs obtained 13% of undergraduate degrees in biology, they only earned 8% and 5% of masters and doctoral degrees, respectively.
Moreover, the number of U.S. citizens with doctoral degrees in biology is diminishing as the number of foreign-born students with doctoral degrees in biological sciences is increasing (NSB, 2008). These data shows that, if appropriate precautions are not taken to address the racial discrepancies in attainment of STEM degrees, especially in biology, the number of workers with diverse ethnic backgrounds in STEM sciences will continue to decline. Recent data indicate that, the number of URMs in biological sciences account for only 7.1% in the workforce, despite accounting for 27.9% of the total U.S. population (Burrelli, Arena, Fort, & Shettle, 1996).

According to reports (Crisp et al., 2009; Hurtado et al., 2010), despite the fact that URMs are as likely as their White peers to enter colleges with intentions of majoring in sciences, on average they have lower persistence rates in sciences. For example; in 2009, 37.5% of the majority White and Asian-American students completed their STEM science degrees after 5 years, whereas the completion rates for URMs in the sciences on average was 19.8% (Toven-Lindsey et al., 2015). This persistence gap results in fewer URMs entering the STEM workforce. A report by the National Academy of Sciences (NAS, 2005), entitled *Expanding underrepresented minority participation: America’s Science and Technology Talent at the Crossroads*, demonstrates that the projected growth in new jobs will require STEM skills and that URM groups have the highest growth rate in the general population. Moreover, according to this report, the current number of URMs in sciences needs to be tripled in order to balance their proportion in the general population.

The strategies to reform STEM education have faced the challenge of creating meaningful and productive learning opportunities accessible to a wide range of students
The National Academy of Sciences (NAS) recommends a near-term goal of doubling the overall number of URMs in sciences in order to achieve a long-term equality in the training of a diverse workforce. In general, these reports suggest that the underrepresentation of minority students is not due to a lack interest in sciences, rather it because of a decline in completion rates of science degrees (A. C. Johnson, 2007).

In an effort to reduce the existing gaps in enrollment, success and retention within various student population groups, especially among the URM groups, it is important to unearth and understand the kind of predisposing factors that impact the URMs inclination and tendency to learn. Researchers suggest that, it is important to purposively design studies which explore similarities and differences within different racial student groups or by use of analytical methods, which allow the disaggregation of data to investigate how different factors affect different student groups, especially URMs, in an effort to reform STEM education within post-secondary education (Lopez, Nandagopal, Shavelson, Szu, & Penn, 2013). These recommendations by extension point to the need of investigating the specific factors, which predict success and persistence among the URMs.

Results from different studies attribute the high attrition rates among underrepresented minority students in sciences to multiple factors. With respect to social perspectives, a majority of URMs encounter a variety of challenges as they enter college (Museus & Quaye, 2009), partly because they are most likely to also be FGs (Engle & Tinto, 2008). As previously discussed, such challenges have the potential to be aggravated by the perceptions of the unwelcoming academic cultures in STEM majors (Beasley & Fischer, 2012). Previous studies indicate that due to insufficient high school preparation, URM’s struggle to complete science introductory courses (Chang,
Sharkness, Hurtadp. & Newman, 2014). This is in addition to the documented challenges associated with staying engaged in large introductory lecture-style courses, which have limited or no opportunities for interaction with professors (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Labov, Reid, & Yamamoto, 2010).

According to Graham, Frederick, Byars-Winston, Hunter, & Handelsman (2013), factors such as early research experience, establishment of learning communities, and active learning in science introductory courses are critical components for effective learning, especially among URMs. Feeling like a scientist is essential for promoting success and persistence among URMs in sciences. However, research shows that introductory science courses can be a major drawback to persistence of URMs in STEM (Fries-Britt, Younger, & Hall, 2010). It follows that studies focusing on examination of predictors of success and persistence among the URMs in introductory core science curriculum can be an essential component in contributing to the much-needed STEM graduates nationwide (PCAST, 2012).

Factors Associated with First Generation Students’ Success and Persistence in Science Technology Engineering and Mathematics

Research into higher education widely documents that, being a FGs student is an impediment to degree achievement due to a variety of challenges (Choy, 2001). Although the FGs populace is regularly thought-of as a subgroup with special needs, in most four-year institutions and community colleges, at least half of their incoming new students are made up FGs (D'Amico & Dika, 2013). With an increasing population of the FGs in institutions of higher education, it is important for education researchers to investigate the predictors of success and persistence among the FGs population. In addition, some FGs
also happen to be minority students, who have to deal with issues of racial isolation (Richardson & Skinner, 1992). In the following paragraphs I will focus on the literature on barriers to success and persistence in college among the FGs.

**Cultural shift.** Foundational studies indicate that as FGs begin postsecondary studies, they face a myriad of challenges with respect to cultural shift. For FGs, attending college is associated with a departure from the norms and patterns previously established by family and friends, who may in turn become non-supportive because of non-familiarity with college life (Hsiao, 1992). First Generation students’ face confusion, opposing views from both the home and collegiate cultures, and isolation (London, 1989). As they advance in their educational careers, they lie on the margins of different cultures becoming less sensitive to their customary place within the family setting, and at the same time not quite fitting into the institutional lifestyle (London 1992). First Generation students not only confront the concerns of dislocations, and the difficulties faced by other college students, their experiences often involve substantial social, academic and cultural transitions. Similarly, Terenzini et al. (1994) found that the disparities between college and home environments results in both FGs failing to establish strong bonds with college friends and also losing high school friends. The negotiation of the rigor of the college classroom by FGs may also be limited by their cultural shift. Based on Collier and Morgan (2008), gaining of an understanding of the role of a college-student is a cultural capital (i.e., a non-financial asset that promotes social mobility beyond economic means), and FGs may face more challenges in grasping this new role and understanding the expectations from the faculty compared to their non-FGs peers.
Financial issues. Compared to their peers, FGs face unique financial difficulties that are likely to impede their academic progress. FGs are less likely to receive financial support from parents, tend to be older and are more likely to have multiple financial obligations outside college, which tend to limit their full participation in the college experience (Engle & Tinto, 2008). All these factors taken together lower the FGs chances of persisting in college to graduation. Due to limited resources and low-income, FGs are more likely to work fulltime while taking part-time classes, and live and work off-campus, limiting the amount of time they spend on campus. In addition, research shows unmet financial needs for FGs, that remain even after applying for financial aid (Lewis et al., 2000). Consequently, FGs work and borrow money which has negative consequences with respect to their college completion. Similarly, results from the Volle and Federico (1997) showed that, majority of FGs were financially independent compared to their peers. FGs students are also likely to have financial dependents, resulting in more financial responsibility while in college (Inman & Mayes, 1999).

Academic factors. Prior educational background is important in the studies of predictors of success and persistence in college (e.g., Lotkowski, Robbins, & Noeth, 2004). A majority of research point that as FGs transit from high school to college, they have lower levels of academic preparation as indicated by their SAT/ACT scores and high school GPA (Martin Lohfink & Paulsen, 2005; Martínez, Sher, Krull, & Wood, 2009). Higher levels of prior educational preparation among FGs has been associated with increased likelihood of college success and persistence (Ishitani 2006; Warburton, Bugarin & Nuñez, 2001). Other studies, which control for prior academic preparation, show that FGs can attain similar levels of academic success as their peers (Brown &
Burkhardt, 1999). Overall, the weight of evidence indicates that, compared to their peers, FGs present a distinct disadvantage with respect to success and persistence in college. In general, FGs students are often less prepared academically for college coursework compared to their peers. Furthermore, often times, FGs have insufficient knowledge with respect to time-management techniques and the economic realities of college life.

Factors Predicting Student Persistence in College

Previous research on students persistence in sciences indicate that a number of undergraduates with potential to become future STEM workers eschew science majors in college (Chang, et al., 2009; Seymour & Hewitt, 1997). Collectively this makes the number of students entering and being retained in STEM majors to be below the projected national need (Chang et al., 2009; Obama, 2010). This number is even likely to be less among the average and below performing students in sciences, since previous research on STEM sciences has tended to focus on high performing students (Lang 2008; Seymour & Hewitt, 1997). From an economic standpoint, increased attrition from STEM fields lead to a paradox in which the demand for well-trained STEM individuals in the U.S. workforce far exceeds the supply (Doyle, 2002). This, in turn, calls for science educators to examine the contributory factors to the high rate of departure from undergraduate STEM sciences.

Despite the fact that more students than ever join institutions of higher education, the decision to stay enrolled or dropout prior to obtaining a degree remains a significant hurdle for both institutions and students. The highest student dropout period from college is usually between the first and second year. For example in the year 2010, almost a third (26.6%) of first-year undergraduates dropped out from private 4-year colleges (American
College Testing [ACT], 2010). The foundational study by Tinto (1975) on students persistence in college articulates that the aspect of student “persistence in college is not simply the outcome of student individual characteristics, prior experiences, or prior commitments to college, but also the outcome of a longitudinal process of interactions between the individual and the institution in which one is registered” (p. 103).

Theoretical perspectives on student college development and retention bear a strong focus on the relationships between student persistence, integration and engagement (Astin, 1978; Spady, 1971). On the other hand, Astin (1993) emphasized the role of social support in student persistence in college, noting that, “the students peer group is the single most potent source of influence on growth and development during the undergraduate years” (p. 398). Astin’s work underscores the role of friendship circles above that of faculty-student support and also points to ways in which such relationships may strengthen the connection between the student and the institution. Other studies have investigated the effect of other factors on student persistence, such as academic success based on academic measures such as high school GPA and ACT test scores (Allen, 1999; Mattern, Shaw, & Kobrin, 2010). The effect of demographic factors such as race and gender on student persistence in college have also been examined (Tinto, 1975).

**Success in introductory courses.** A series of seminal studies, including the work by Tinto (1993) and Seymour and Hewitt (1997) have often described the STEM fields as a “leaky pipeline,” attributing student attrition in STEM domains to a myriad of demographic, contextual, and performance-based factors. Among the contributing factors, a lack of success in introductory STEM coursework is, perhaps the most frequently cited (Ost 2010; Rask, 2010).
Students’ success in post-secondary introductory courses is a good indicator of whether or not students will persist in their major (Rask & Tiefenthaler, 2008). These studies point to the importance of promoting students’ success in college introductory courses with the potential to contribute to efforts reviving the U.S. economy and its reputation as the renowned worldwide leader of scientific innovation (Mervis, 2010). Based on this knowledge, there is a need to investigate the factors associated with students’ success and persistence in STEM disciplines as they proceed through college based on introductory courses. The most important finding in Seymour and Hewitt’s (1997) study was that switchers (those who switched from STEM majors) and non-switchers (those who persisted in STEM majors) were remarkably similar in their behaviour, concerns, and performance in their STEM courses. They found that the main difference between switchers and non-switchers was that non-switchers differed in their attitudes and the degree to which they reacted to the concerns that made switchers leave (Seymour & Hewitt, 1997). The non-switchers had embraced “particular attitudes (e.g., continuing to work on a biology problem until they figure out the answer and not giving up) and coping strategies (not giving up when faced with challenges)” (p.30) that allowed them to persist in the face of the same difficulties that led switchers to leave their STEM major.

**Early research experiences.** Early student research experience is an important aspect in persistence in STEM majors. Despite the well-documented benefits of student undergraduate research experience, most students are not offered research opportunities until late in college, after the critical stage of attrition from STEM majors (Russell, Hancock, & McCullough, 2007). Students’ who engage in research within the first two
years of college have a high probability of persisting in STEM majors (Gregerman, Lerner, von Hippel, Jonides, & Nagda., 1998). Research experience is not only a powerful learning tool; it also engages students in the learning process as it helps in stimulating science curiosity. Student participation in research encourages professional identification because students view themselves as scientists as opposed to just studying products of other people's science (Graham et al., 2013). The report by PCAST (2012) clearly advocates implementation of undergraduate research courses.

Undergraduate research courses are essential in providing students with the feeling of project ownership and the associated intellectual challenges of experimental pursuit. Undergraduate research courses encourage students to engage in authentic investigations which involves designing experiments, data collection and analysis, which sometimes may lead to meaningful discoveries (Hatfull et al., 2006). Therefore, students involved in undergraduate research courses have an added advantage of increased learning gains and positive attitudes toward science (Hunter, Laursen, & Seymour, 2007; Lopatto et al., 2008). Successful research courses have been implemented at both large and small institutions of higher education. One example of such is the multi-institutional HHMI–Science Education Alliance (SEA) PHAGES in which undergraduates uncover new bacteriophages from soil (Hatfull et al., 2006). Likewise, the University of Texas at Austin has demonstrated that undergraduate research initiatives can be cost effective when taken on a large scale to replace traditional introductory lab courses. In the case of the Austin model, faculty members provide projects to students, derived from their own research, which forms a basis for student research projects in lab sections composed of between 20 to 30 students.
**Active learning in introductory courses.** Research has shown that, many talented undergraduates dropout of STEM majors due to lack of interest in introductory science courses as they find these courses uninspiring (Seymour & Hewitt, 1997). Researchers point out that this problem can be remedied through incorporation of classroom instruction methods that engage students in the learning process, also known as “active learning,” an approach which has been shown to reduce attrition from STEM majors (Haak, HilleRisLambers, Pitre, & Freeman, 2011). The tenets of active learning require instructors to include types of activities whereby students think, create, or solve problems. Such activities may include a brief lecture combined with opportunities for students to process their knowledge, especially in large classrooms (Handelsman, Miller, & Pfund, 2007). The concept of active learning improves student retention of learning materials and conceptual understanding (PCAST, 2012); moreover, it helps students to identify themselves as scientists since they are involved in scientific thinking together with peers who are part of the scientific community. Based on this understanding, it is crucial for faculty members to seek professional development in order to effectively implement the evidence-based instruction methods (Pfund et al., 2009). Additionally, the concept of active learning has been incorporated into supplemental support courses also known as supplemental instruction (SI). In this kind of format, the specific course, which is being supported by the SI unit, is taught with incorporation of active learning approaches. Students learn approaches of problem-solving, study skills, troubleshooting skills, collaborative learning skills, among others (Arendale, 1997). Supplemental instruction have been associated with increased students success in the specific supported course (e.g., Arendale, 1997).
Membership in Science Technology Engineering and Mathematics learning communities. Learning communities can be physical or virtual structures that provide students’ with opportunities to work with and learn from each other (Light & Micari, 2013). Establishing classroom-learning communities might either involve ensuring that all learners have access to a study group outside of class or providing students with online discussion groups. This ensures that learners are stimulated intellectually. Students’ involvement with other students also aspiring to be scientists reinforces professional identity leading to increased learning gains.

Effect of supplemental instruction on underrepresented minority and first generation students. The effect of Supplemental Instruction (SI) as an education intervention has been documented by various studies. Although SI was initially designed to improve the performance of low performing students (Martin & Arendale, 1992), it can also be used in high-risk courses whereby students work cooperatively on materials to supplement and augment the course material. Previous research has indicated specific benefits and outcomes of the effectiveness of SI (e.g., Martin & Arendale, 1992). Students who participate in SI sessions perform better in the supported course compared to those who opt not to, both in terms of successful course completion with a passing grade and average grade point (Hensen & Shelley, 2003). Furthermore, students who participate in SI are more likely to graduate from college compared to non-SI participants (Arendale, 1997). SI within the sciences has been shown to be more effective among URMs who participated in SI compared to those who did not (Rath, Peterfreund, Xenox, Bayliss, & Carnal, 2007). Additionally, the frequency of attendance at SI sessions was a stronger predictor of academic achievement among URMs compared to White
students (Rabitoy, Hoffman, & Person, 2015). These studies suggest important implications of SI on student success, especially among URM students.

Generally, educational interventions such as SI have been shown to positively impact students’ success but with disproportionate effect on FGs and URM students (Dawson, van der Meer, Skalicky, & Cowley, 2014). The proportion of URM and the FGs students is rapidly increasing in institutions of higher education; therefore, college instructors can utilize the advantages of the SI in promoting success and persistence among these students groups. Most studies have also found that SI is equally effective with all genders and racial/ethnic groups (Arendale, 1997). At San Francisco State University (SFSU) SI was strongly associated with both improved achievement in Introductory Biology courses and higher college graduation rates (Rath et al., 2007). In the case of the SFSU, the improvements were more profound among URM students compared to non-URMs. It appears that SI is important in introductory courses such as biology by enhancing learning outcomes as well as being instrumental in alleviation of attrition among the URM students in biology and presumably in other STEM majors.

Towards Transforming the Science Introductory Courses

Some methods, which have been suggested as important in transforming the introductory science courses, include but not limited to; presentation of broad conceptual themes, use of student centered instruction methods (e.g., learner centered) and creation of conducive and open learning environments where students can make mistakes and learn from them (e.g., Derting & Ebert-May, 2010). Studies focusing on students in reformed classrooms (classrooms which are taught using a variety of inquiry-based methods involving types of constructivist perspectives), cite higher levels of student
satisfaction and engagement in addition to improved learning gains (e.g., Derting & Ebert-May, 2010).

Derting and Ebert-May (2010) examined the impact of classroom reforms on students’ long-term learning gains and attitudes towards biology. In their study, they compared students who took the unreformed (traditional lecture-based) introductory biology course with those who took the same introductory courses with reformed teaching methods. The results showed students in the reformed classroom had higher positive attitudes toward biology and showed improvement in content biology knowledge as compared to those in traditional lecture based classrooms. This study and others (Sawada et al., 2002) calls upon college instructors to examine ways in which they can promote favorable attitudes and cultivate student’s motivations in STEM fields with respect to conceptual understanding (Sundberg et al., 1994), prevention of course overload (e.g., Strenta et al., 1994; Sundberg et al., 1994), and creation of conducive learner-centered environments (Derting & Ebert-May, 2010). Additionally diversified instruction methods, which make introductory science courses to be interesting are needed. Science instructors also need to offer more help to students experiencing academic challenges especially in introductory science courses, and establish a community of STEM learners in classrooms. A large growing body of research shows that STEM education can be enriched considerably through a diversification of instruction methods.

Success and persistence among the average and below average performing students
in Science Technology Engineering
and Mathematics

A majority of average and below average performing students, defined as the junior and senior students whose sophomore GPA was 3.0 and below in biology, who are capable of handling sciences upon matriculation to college choose to eschew from them (Tobias, 1990). Education scientists have proposed and developed several strategies to increase the persistence and performance of the average and below average performing students in college; e.g., curriculum and course specific restructures (S. Freeman et al., 2014), implementation of active learning (Haak et al., 2011), adoption of flipped learning classrooms and supplemental instruction (Martin & Arendale, 1992), amongst other strategies (Baepler, Walker, Driessen, 2014). However studies show there is already a substantial flow of science talent into colleges and that the main problem is the attrition of that talent over the course of the college years, especially when students first experience introductory science courses. This raises pertinent questions such as: Why and how do we lose science talent? Who should be doing science? What happens within introductory science courses that determine who stays in sciences and who leaves? With reference to such questions, the head of education and human resources programs at the American Association for the Advancement of Science (AAAS) once made the comments below.

Who will do science? That depends on who is included in the talent pool. The old rules do not work in the new reality. It’s time for a different game plan that brings new players in off the bench.

__________Shirley M. Malcom
(American Association for the Advancement of Science [AAAS], 2010, p. 7)

An understanding of the attrition of potential would- be science employees at the college level, especially among average and below average performing students, is an
important subject of concern. This calls for education researchers to think about students who are capable of handling STEM majors but choose to eschew from them. Previous research underscores critical questions with respect to a new thinking regarding who is going to do science and why? Such thinking could challenge education scientists at the college level to grapple with aspects, which they previously had not considered before. Such aspects may involve focusing on how to recruit, teach and cultivate “a different type of students who are not a younger version of themselves” (Tobias, 1990, p. 9) into the sciences. Normally scientists are less likely to think about recruitment and retention of students in sciences as long as they keep expecting the next generation of STEM workers to rise to the top just as they did. By extension, this might explain why there has been neglect in creating a sense of community among average and below average performing students in sciences and why science introductory courses have been dominated by competitive and intimidating learning environments, designed to weed out all except the top performing students (Seymour & Hewitt, 1997; Tobias, 1990). In order to solve the shortfall of science workers, the scientific community is obliged to think not just about who can do science and why, but also about who is not doing sciences and why.

**The Loss of the Would-be Scientists**

The loss of potential science workers can be interpreted through three different ways. First, we can assume that the loss of science talent is inevitable and, therefore, we should increase the diameter of the science pipeline of the incoming freshmen interested in science and not worry about the losses. Second, we can also assume that those who could do science will eventually do science and, therefore, focus on increasing the precollege preparation so that the incoming freshmen interested in science are better
prepared to tackle science. Lastly, it can be assumed that not all students who choose not to do sciences cannot handle sciences and that majority of them deliberately choose not to do science.

The problem with the science pipeline model of loss is that it only provides the net effects of loses from the sciences, but it does not provide the reasons behind the loss. Serious interventions of recruiting different kinds of students into science requires that we get to know the students who opt not to pursue science, this way we can have informed ideas as to why they prefer other fields and what strategies are best for wooing them back to a science track. A complete analysis of the reasons for not doing science will be necessary; e.g., how much of the reasons are attributable to lack of ability in science, lack of pre-collegiate science preparation, poor classroom cultures or the reasons associated to how the science courses are taught.

**Exclusion of the Average and Below Average Performing Students in Research**

The national action plan addressing the critical need for the U.S. STEM education system advocates for undergraduate science education for all students (NSB, 2007). This call promotes the efforts to ensure inclusivity among all student types in STEM training for the acquisition of knowledge and skills necessary to confront the challenges of the 21st century. Furthermore, PCAST (2012) underscores the need to provide all students with the tools necessary to excel in STEM fields.

Despite the nation’s effort and call to provide all students with STEM skills (PCAST, 2012), a majority of previous research on students’ persistence in STEM fields has not been comprehensive. The research has mostly focused on high performing
students in sciences (Lang, 2008; Seymour & Hewitt, 1997), leaving out the average and below average performing cohort. The argument behind this research focus has been that the high performing students who leave STEM sciences could have made valuable contributions in the STEM workforce had they stayed (Lowell, Salzman, Bernstein, & Henderson, 2009; Seymour & Hewitt, 1997). This kind of research bias presumes that STEM disciplines are a preserve for the most successful students. However, in order to contribute to the national projected need of STEM graduates, education scientists should think about alternative means of either recruiting more students into STEM sciences or maintaining the number of students already interested in sciences. Such approaches will require utilization of strategies above the traditional focus on curriculum restructuring (Tobias, 1990).

Traditionally, education scientists have emphasized various strategies geared towards promoting students persistence in STEM fields such as curriculum restructuring, course design, recruitment, rewards and provision of research opportunities in science, with an overall goal of attracting students who can do science, but opt for other majors (Seymour & Hewitt, 1997; Tobias, 1990). Such approaches may be crucial in attracting average and below average performing students who can contribute to the STEM workforce (PCAST, 2012). According to Felder (1993), average and below average-performing students who enter college with the initial intention to major in a STEM field but instead opt for other non-science majors, may be enough to counter the U.S. shortage of STEM graduates. Previous research shows that there has been little to no attempt of creating a sense of community (a sense of belonging) among average and below average performing students (Seymour & Hewitt, 1997; Tobias, 1990). In contrast, the high
performing students are characterized by a shared value of being the top performers (Tobias, 1990). They belong to a community, which possess the highly prized behavioral attributes cherished by the scientific community.

Furthermore, a majority of research on student success and persistence has focused on student departure from STEM majors, almost at the exclusion of student persistence in those majors (Tinto, 2012). There is a need to focus on both those students who stay in STEM specific fields and those who leave STEM disciplines for other non-STEM disciplines. The few studies that have looked at student persistence in STEM fields have found greater similarities than differences between those who persist and those who leave in various aspects (Glogowska, Young, & Lockyer, 2007; Seymour & Hewitt, 1997). Such findings provide a rationale for education scientists to shift from one-sided research questions on why students leave STEM majors to include questions of why students remain in those majors. This is because knowing why students leave STEM disciplines is not equivalent to knowing why students stay in the STEM sciences, and also that the process of leaving is not a mirror image of the process of staying (Tinto, 2012). There are many reasons to focus on the persistence of average and below average performing students in colleges. Mainly, the institutions of higher education admit the average and below average performing students in order to give them an educational opportunity to develop skills and knowledge necessary for the job market, as well as to increase their institutional funding (Salinitri, 2005).

**Focus of My Study**

Introductory science courses provide a foundation for advanced coursework and the necessary science literacy for all students enrolled in those courses (Druger, 2002). In
my view, students’ in their first year in college are not yet science majors and, therefore, introductory science courses acts as the students’ first exposure to post-secondary science and is a pre-requisite for many college degrees. Given the role of introductory science courses in students’ attrition from science majors, it is paramount to examine students’ motivations and attitudes in combination with demographic and prior educational characteristics in predicting success and persistence in science majors based on these introductory courses.

My dissertation was based on students’ success and persistence during the first two years in college for two main reasons. First, college administrators rely on first-year success and persistence as standard measures of academic quality as well as measures of institutional effectiveness in meeting students’ needs (Bailey, Calcagno, Jenkins, Leinbach, & Kienzl, 2006). Second, success and persistence in science majors during the first two years of college is a good predictor of students’ persistence in those majors over subsequent years. Specifically, the aim of this dissertation was to identify the predictors of student success and persistence in biology for the purpose of informing instruction strategies which have potential to promote critical thinking and quantitative reasoning skills. The overall objective was to develop a profile of predictors of success and persistence in biology among students enrolled in introductory biology courses (Principles of Biology and Organismal Biology with a focus on average and below average performing students as categorized by student GPA at the end of the sophomore year. Identification of predictors of success and persistence, and examination of average and below average performing students’ experiences in biology has the potential to contribute to the nationwide need for more graduates in STEM sciences.
In an effort to reverse the traditions of past research perspectives, average and below average performing students, referred as the “murky middle group,” was the focus of my dissertation. I argue that if we can “get to know” such a group of students, understand their experiences and reasons for both leaving and staying in STEM sciences (in my case biology), listen to their opinions and incorporate their opinions into strategies of promoting persistence in biology, we have has the potential to reverse their migration from biology to other disciplines. By extension, this approach can contribute to the required increases of STEM graduates, and possibly stem the massive loss of potential STEM graduates that occurs in post-secondary institutions (Seymour & Hewitt, 1997; Tobias, 1990).

When students enter college as freshmen and elect their initial majors, they already possess educational characteristics, demographic factors, attitudes and different motivational dispositions with varied college experiences; together these have the potential to influence their success and persistence in their majors (Brookhart & Freeman, 1992). With this background knowledge, my dissertation examines to what extent such factors contribute to students’ success and persistence in biology. Results from my dissertation are expected to inform instructional strategies essential to promote success and persistence in biology within UNC and beyond.

My dissertation study combined evidence-based elements of students’ departure from and persistence in STEM disciplines. This original study delivered the following outcomes all under the main objective of providing a deeper understanding of why students persist or leave biology Major, which have potential to impact overall success and retention in STEM fields and in biology in particular. 1) Informed teaching practice
and policy in regards to promotion of learning and retention in biology. 2) Addressed the national attrition problem in biology and STEM fields in general. 3) Contributed to an understanding of what matters with respect to success and persistence among the URMs and FGs and 4) Contributed to an understanding of the experiences of average and below average performing student’s major decision making process and informed their retention strategies.

Why Focus on Biology?

There are many reasons to promote student success and persistence in biology. First, empirical evidence shows that “advancements in biological sciences hold tremendous promises for surmounting many of the major challenges confronting the U.S. and the World at large” (NRC, 2009, p.3). Besides, Philip A. Sharp, the co-chair of New Biology for the 21st Century (Sharp, 2014), indicates that “innovation in life science will be the major driver in meeting the four major societal challenges: challenges of climate, challenges of food, challenges of energy and challenges of health” (Sharp, 2014, p.1490). Furthermore, while the current state of attrition in STEM fields is alarming, a closer look shows that compared to other STEM majors, the biology discipline suffers the highest attrition rate (Lang, 2008; NSB, 2012; Princeton Review, 2007; Rask, 2010). About half of all students who enter college initially interested in biology switch out of biology by the end of their sophomore year (Higher Education Research Institute [HERI], 2010). Ironically, biology is among the most popular STEM majors nationally (Princeton Review, 2007). In an effort to reverse this trend, education researchers have employed a variety of empirically validated instruction strategies such as active learning as a means to promote success and persistence in biological sciences (S. Freeman et al., 2007; Haak
et al., 2011; NRC, 2003; Wood, 2003). Although of integral importance, such studies have often not extensively explored the impact of motivational and attitudinal factors as they relate to demographic or pre-college predictors of student success and persistence during the first two years of college. Moreover, even though several studies have attempted to address attrition in STEM fields in general, none of them has centrally focused on biology.

Consequently, it is critical to explore other factors, which have previously been shown to predict students’ success and persistence in fields other than biology (Krumrei-Mancuso, Newton, Kim, & Wilcox, 2013), such as students’ motivations and attitudinal factors, and how they relate to student demographic characteristics in predicting success and persistence in biology. In the background of this understanding, it is critical to examine and explore both the non-cognitive factors and student characteristics, which predict success and persistence in biology along with exploration of experiences by the average and below average performing students in biology. This was the first step in developing strategies to increase both student success and persistence in STEM fields. It is also important to qualitatively explore the reasons as to why the average and below average performing students persist or switch from a biology major. The continued exclusion of the average and below average performing students from research regarding success and persistence in STEM sciences masks the types of impediments such students’ face in an attempt to complete a degree in their chosen careers; this ultimately makes it difficult for any intervention strategies to be designed.
Why the First Two Years of College?

The first two years of college experience presents the greatest risk at which student’s switch majors or dropout from college (American College Testing [ACT], 2002; G. Johnson, 1994; Tinto, 1993), and from biology in particular (Lang, 2008; NSB, 2008). Attrition related to the first two years of college is responsible for half of all college attrition (Lukic, Broadbent, & Maclachlan, 2004; Pattengale & Schreiner, 2000; Toven-Lindsey et al., 2015). The first two years of college also present a difficult transition for college students (Nora, Barlow, & Crisp, 2005). Regardless of a variety of emotional stressors, social and academic difficulties, some students successfully cope with a complex of new acquired life roles and persist in their chosen majors to achieve academic success. On the other hand, many students fail to successfully manage the transition and eventually switch their majors or leave the institutions of higher education during their first two years. Previous studies indicate that approximately 40% of undergraduate college students leave institutions of higher education without earning a degree (Porter, 1989), with a majority of such students (75%) leaving within the first two years of college (Tinto, 1987). Undergraduate attrition within the first year of college is typically higher than any other academic years (DeBerard, Dpielmans, & Julka, 2004).

There is a variety of adverse consequences of leaving college without earning a degree. First, institutions of higher education incur costs in unrealized tuition, fees, and alumni contributions for each student who leaves college before completing their degree. Second, there are deleterious economic implications, such as earning less in a lifetime of work (Leonhardt, 2005). In spite of the widely documented adverse implications on attrition from college for both colleges and students, students’ attrition from the science
fields and from colleges have not significantly changed over the last few decades (Porter, 1989).

Previous research cites consistent relationships between student academic success and persistence, with higher achieving students having higher persistence in college compared to their average and below average performing peers (Kirby & Sharpe, 2001; McGrath & Braunstein, 1997). It is, therefore, paramount to examine the predictors of student success and persistence among students with different levels of achievement in science specific disciplines in order to best develop targeted intervention programs. My dissertation employed a new perspective by examining a number of potentially predictive factors of academic success and persistence in biology. The goal of my dissertation was to create a multidimensional model that would optimize prediction of both student success and persistence in biology.

**Research Questions**

The overall goal of this study, based on the assumption that identification of predictors of success and persistence in biology is important in informing future instruction strategies which promote students critical thinking and quantitative skills was to examine the role of motivational and attitudinal factors as predictors of students success and persistence in biology as they relate to students demographic characteristics and prior educational characteristics.

In this study, there were three overarching objectives, as discussed below. The first objective involved an examination of predictors of student success in biology during the first year in college. The second objective was to determine the predictors of students’ persistence in biology into the second year of college. The third objective involved
qualitative exploration of experiences of the average and below average performing students in biology and by extension, how those experiences are associated with persistence in biology focusing on both students’ who persisted in or switched from biology at the end of their sophomore year.

The following research questions guided this study

Q1 What demographic, attitudinal, and motivational factors are predictive of success (students’ percent course grade in cell and molecular biology course) for students’ enrolled in a first-year introductory cellular and molecular biology course (Principles of Biology- Bio 110)?

Q2 To what extent do these factors differentially predict success among underrepresented minority and first generation students within the aforementioned cohort?

Q3 What demographic, attitudinal, and motivational factors are predictive of persistence (enrollment into biology coursework into second year) for students enrolled in introductory biology courses (Principles of Biology- Bio 110 and Organismal Biology- Bio 111) within the first two years of college?

Q4 To what extent do these factors differentially predict persistence among the underrepresented minority and first generation students within the aforementioned cohort?

Q5 How do average and below average performing students (with sophomore GPA of 3.0 and below) describe their experiences in biology?

Q6 How do social interactions among average and below average performing students influence their decision to persist or switch from biology?

Q7 What are the reasons that make average and below average performing students’ persist in biology regardless of their performance?

Q8 What are the reasons that make average and below average performing students’ switch from biology for other majors?

Quasi-experimental design (an empirical study design used to estimate the causal impact of an intervention on its target population without random assignment), was used for the quantitative part of this study (Chapter II and III). Under this design, in order to
determine the predictors of success and persistence two validated instruments, the Colorado Learning Attitudes about Science Survey- CLASS-BIO (Semsar, Knight, Birol, & Smith, 2011) and the Science Motivation Questionnaire-SMQ (Glynn et al., 2011), were administered to students over different semesters as described under the specific method sections. Qualitative inquiry (Chapter IV) was used as an exploratory tool to provide deep insights into the quantitative study with regard to why average and below average performing students either chose to persist in biology or opted out of biology for other majors.

**Theoretical Perspectives**

The design of this study assumes a mixed methods approach; therefore, two different theoretical frameworks were employed in order to address all the study research questions. The expectancy-value theory of achievement (Eccles, 1983, Wigfield & Eccles, 2002) was used to address the quantitative research questions, while the sociocultural theoretical framework (Engeström, 1987; Lemke, 2001) was used to address the qualitative research questions. Each theoretical framework is discussed below.

**The expectancy-value theory of achievement.** With respect to studies which support student success and persistence in STEM majors, two motivational beliefs seem to be crucial: value beliefs and competence beliefs. These two motivational beliefs are central to Eccles’ Expectancy-Value Theory of achievement (Eccles, 1983; Wigfield & Eccles, 2002). Eccles’ Expectancy-Value Theory of achievement (Figure 1) was used to understand the quantitative data in this study. The theory combines students’ self-efficacy (beliefs about behavioral outcomes combined with expectations of one’s ability to engage in, execute, persist in and be successful in a specific task) and their perceived value of a
particular task. According to the theory, an individual’s perceived competency (expectations for success) and the value of the task (task value) are important predictors of academic success and career choices (Eccles, 1983). Students’ belief on whether or not they will be able to succeed at a particular task is known as expectancies. Expectancies are components of a bigger category of competence related beliefs including self-concept, perceived competence and self-efficacy. Previous research indicates that paradigms from this extensive category of competence beliefs are critical predictors of success and persistence compared to other motivational beliefs in different disciplines (Wigfield & Cambria, 2010). Student expectancies for success are associated with the choice actions, for instance student decisions to persist (Wigfield & Cambria, 2010). Task value is the second aspect of the expectancy-value theory. Task value is divided into four types of task values (Eccles, 1983): (a) intrinsic value or interest value which relates to the internal satisfaction a person experiences from performing a task; (b) utility value, refers to how well a given task relates to personal current or future goals e.g., career goals; (c) attainment value, relates to the personal importance of performing well on a given task (Battle 1967); and (d) cost value, which can be conceptualized with reference to the negative impacts which result from engaging in a task. Prior research shows that value-related beliefs are good predictors of academic success engagement (Schiefele 2001), as well as future career goals (Wigfield & Cambria, 2010; Wigfield & Eccles 2002).
In my dissertation, from the perspectives of expectancy-value theory, it was expected that both student perceived task value and competence in biology are vital for inspiring students to choose careers in a biological field. Increased perceived competence is expected to assist students to better confront the challenges associated with the undergraduate Biology major, leading to high levels of success and persistence in biology programs. On the other hand task values are important elements of students’ resolutions to persist in biology and career-related beliefs in biology. Empirical research shows strong support for the expectancy-value theory with respect to predicting retention in STEM fields. For example, students who value STEM majors and perceive less cost task
value are more likely to persist in STEM majors (Andersen & Ward, 2014; Wang & Degol, 2013). Other research show that students’ low self-efficacy in STEM fields has been associated with high attrition rates in STEM majors (Raelin et al., 2014).

Previous studies have shown that positive perceptions of ability (competencies) and self-efficacy predicts success in English and Mathematics, whereas task-values were shown to predict persistence in Physics, English and Mathematics, along with involvement in sports activities, even after controlling for prior academic performance (Meece, Wigfield, & Eccles, 1990). Individual expectations for success and task-value predict career choice (Eccles, 1983). The social cognitive variables like self-efficacy influence the development of the four components of task values described above (Bandura, 1997). Taken together, such findings afford support for the idea that enhancing student perceived task value and competence while decreasing their perceived task value costs may be useful in supporting undergraduates’ success and persistence in STEM fields.

**Sociocultural theoretical framework.** The qualitative part of this dissertation draws from sociocultural theory in understanding experiences of average and below average performing students in biology and decisions they made whether or not to persist in biology as a social activity conducted within institutional and cultural frameworks (Engeström, 1987; Lemke, 2001). This approach was assumed in order to provide insights into the complex nature of a social phenomenon. Instead of viewing students’ decisions as detached from complex social organizations, my study views their decisions as participation within a larger system that works collectively to influence student practices and their individual actions. According to the sociocultural theory, social human
activity is only possible because we all grow up and live within larger-scale social organizations or institutions depicted by interpersonal interactions.

The researcher views these social institutions and their associated social networks as tools which average and below average performing students use in making sense of whether to persist or switch from biology, in relation to their interpersonal social interactions within these social institutions. In the context of this study, social institutions including but not limited to institutions of higher education (college environment), classroom environments, laboratory settings and home/family environments, along with the social organizations within these social institutions. The social organizations refer to the patterns of relationships between and among average and below average performing students and their peers, faculty, TAs, mentors, family members, friends and significant others belonging to different social institutions.

I utilized the sociocultural theoretical framework to examine how such social interactions and experiences in biology influence the major decision choices among the average and below average performing students. From this perspective, there are distinct benefits for analyzing the average and below average performing students’ choices through the lens of sociocultural activity theory. When viewed from social activity perspective, student choices to persist in or switch from biology becomes an artifact mediated activity, which is a network of components and collective actions, rather than a single program completed by an individual (Derry, 1996).

By viewing students’ predispositions as an activity system broadens the context of student major choices past simple individual choices to include student experiences situated within local and larger institutional, social, cultural, and historical contexts (Lave
Furthermore, the socio-cultural lens explains how individual mental functioning is related to cultural, institutional, and historical contexts. Hence, the focus of the sociocultural perspective is on the roles that participation in social interactions and culturally organized activities play in influencing psychological predispositions. According to this approach, what an individual thinks and does is based on his or her socio-cultural background. A socio-cultural approach takes into account more than the individual in attempting to understand cognitive processes. Therefore, I believe that taking a theoretical perspective would better explain the reasons as to why average and below average performing students chose to persist or switch from biology and further provide insights into informing retention strategies in the biology department at the University of Northern Colorado and beyond.

**Study Limitations and Assumptions**

There are several study limitations, which surrounded my dissertation. First, the quasi-experimental designs; due to the nature of this approach it was not possible to control for the experimental confounders, additionally, students self-selected themselves to the different classes within the duration of the study. Second, it was not possible to determine what attitudinal and motivational predispositions the students had before enrolling to the introductory classes, which the study was based on. On the other hand, since the data on students’ attitudes and motivations towards biology was collected towards the end of the semester, it was assumed that the responses were more college-like as opposed to high school-like experiences, since at that time students had acclimatized to college. A further assumption was that all the students were truthful and put forth their best effort in completing the survey questionnaires. Lastly, with respect to
the qualitative aspect of this study, it was assumed that students’ responses represented their honest experiences in biology regardless of whether or not they had persisted in biology.
CHAPTER II

QUANTITATIVE EXAMINATION OF MOTIVATIONAL, ATTITUDINAL, DEMOGRAPHIC AND EDUCATIONAL PREDICTORS OF STUDENT SUCCESS IN BIOLOGY

Abstract

Undergraduate success in Science Technology Engineering and Mathematics (STEM) fields is of critical importance to the United States (U.S.) maintenance of its position as the world leader in technological innovations. Research indicates that, there is need to promote success among the undergraduates undertaking STEM fields. In an effort to address this call, a majority of research has employed a variety of empirically validated instruction strategies designed to promote undergraduate success in biological sciences. Although of integral importance, such studies have often not extensively explored the impact of motivational and attitudinal factors in tandem with demographic and educational characteristics, especially in the field of biology.

The purpose of the current research was to examine the predictors of students’ success in an introductory biology course based on motivational and attitudinal variables, considered alongside demographic and educational characteristics. In addition the study sought to explore to what extent do such factors differentially predict success among underrepresented minority and first generation students within the aforementioned cohort. A total of 882 undergraduate enrolled in a first year Principles of Biology course participated in this study through surveys. Quantitative methods were utilized in the study employing multiple linear regression for data analysis. Results revealed that motivational
factors were equally important predictors of success among all the student types including both underrepresented minority and first generation students. The top demographic predictors of success were: index score, minority status and first generation status, uniquely explaining 4.7%, 3.0% and 1% of variance in students’ course grade, respectively. Students’ ability to apply knowledge to solve biology-specific tasks (i.e., problem-solving difficulty) and student enjoyment of the biology major were the attitudinal factors important for success in biology each explaining 1.0% of variance in students’ final course grade. Additionally, self-efficacy and self-determination explained 3.1% of variance in students’ final course grade. Self-determination and grade motivation were the motivational factors which were significant in students success, predicting 3.3%, 1.3% and 1% of variance in students’ final course grade, respectively. Among participants who had a dual enrollment in an active learning-based supplemental instruction course uniquely explained 1.1% of the variation in URMs success. By enhancing proper motivations and positive attitudes in post-secondary classrooms, and factoring motivational and attitudinal factors that are important for URMs and FGs success may be a step forward in addressing the critical problem of success in STEM fields in general.

Introduction

The United States (U.S.) has developed as a global leader in large part through its strong workforce trained in Science, Technology, Engineering and Mathematics (STEM). As the world increasingly becomes complex and competitive, it is imperative for individuals undertaking post-secondary education to be equipped with the knowledge and skills necessary to decipher challenges, gather and evaluate data for evidence, and be able
to make sense of information (U.S. Department of Education, 2015). Empirical evidence shows that U.S. is falling behind internationally in terms of success in sciences, ranking 29th in mathematics performance and 22nd in science performance among industrialized countries (e.g., Kuenzi, 2008; U.S. Department of Education, 2015). Additionally, evidence suggests that few undergraduates are graduating with degrees in STEM field, this comes at a time when economic projections of STEM jobs indicate an increasing trend (Figures 2 and 3). This study contributes to the efforts of understanding why there is declining student success in STEM fields by focusing on biology majors. The results from my study will be useful in improving success among undergraduates, through incorporation of strategies that improve success in introductory science courses and promote student self-efficacy.

Students’ success in STEM disciplines has both far-reaching and immediate career implications. Success in STEM fields is associated with student persistence in those fields and in college (Tinto, 2012). Demand for successful individuals in STEM fields is high and is projected to increase in the future (Jones et al., 2010; Kena et al., 2014; U.S. Department of Education, 2015). Moreover, success in STEM fields is key to technological innovations and a force behind economic affluence (President’s Council of Advisors on Science and Technology [PCAST], 2012). Despite the need for individuals in STEM fields, the overall proportion of students graduating with STEM degrees has gradually declined (Jones et al., 2010; Kena et al., 2014; Toven-Lindsey et al., 2015). The achievement gap (disparity in academic performance between groups of students) among college students in STEM fields, especially in biological sciences, is particularly large in
student groups such as underrepresented minority students (URMs) and first generation students (FGs; George, Neale, Van Horne, & Malcolm, 2001).

Many studies on predictors of student success have been dominated by the question of “What variables are important in predicting students’ success in college?” Research shows that, students’ success, especially in STEM fields, is influenced by several factors such as high school GPA, motivational factors, prior education success and parental education (Crisp et al., 2009; Harackiewicz et al., 2014). Parental involvement in student learning is important in sparking student interest in STEM fields; this subsequently positively influences student success. Other research shows the effect of combined high school GPA and standardized test scores as better predictors of student success in STEM fields during the first year of college (e.g., Crisp et al., 2009; Singh & West, 2014). These findings illustrate the importance of comprehensively examining the
effect of different predictors of student success as opposed to focusing on a single predictor in isolation. My study examines the role of introductory biology courses in explaining the overall success in biology majors. Seminal research (Seymour & Hewitt, 1997) on why students leave sciences has found that enrollment and performance in STEM gatekeeper courses (lowest college-level courses students take in a subject such as sciences, reading, or writing) negatively influence the completion of a STEM degree (Seymour & Hewitt, 1997). Additionally, both competition and lack of student engagement in the process of learning within science introductory courses have been described as key setbacks in STEM classrooms (Seymour & Hewitt, 1997). Other factors which have been associated with students’ success in STEM sciences include: student-cultural congruity (a match of ones culture with that of the university or the chosen major) coupled with college experiences (Cole & Espinoza, 2008).

Student demographic characteristics such as being an URM, FG, or student gender generally influence success in college (House, 2000; Tai et al., 2005). Tinto (1993) called for research focusing on specific student population groups (e.g., UMRs and FGs) with respect to student success. Eddy et al. (2014), in their study on gender gaps in success and participation in introductory biology courses found that despite the high dominance of female students in biology classrooms, females perform poorly on exams compared to their male peers. These findings point to the need for examination of the effect of demographic characteristics such as minority status, generational status and gender on student success in biological sciences.

Student attitudinal and motivational factors towards academic disciplines can affect their ultimate learning (Osborne et al., 2003). Non-cognitive factors such as self-
determination and perceptions of self-competency in science influence student performance in biology based laboratory settings (Brownell et al., 2012; House, 1995). Furthermore, there is evidence suggesting that the positive relationship between motivational factors and success can be obtained even after controlling for aptitude variables (Harackiewicz et al., 2014). In order to understand the predictors of student success in biology, it is important to investigate the role of non-cognitive factors with a focus on how they can be promoted in biology classrooms.

In an effort to promote success in STEM fields, especially in biological sciences, a majority of research has focused on addressing the question of what instructors can do in order to promote students’ success through the use of instructional approaches which actively engage students in the process of learning (S. Freeman et al., 2007). However, though of integral importance to student success, such instructional approaches do not factor in students prior non-cognitive characteristics (e.g., attitudes and motivations) which they bring to class, that have the potential to influence success (Osborne et al., 2003). Previous studies have failed to extensively examine the impact of motivational and attitudinal factors in the context of demographic and educational characteristics as predictors of student success, nor have they uniquely focused on the field of biology (e.g., Crisp et al., 2009; Harackiewicz et al., 2014). A comprehensive examination of non-cognitive factors in combination with demographics and prior educational achievements is important in promoting success and learning in biological sciences (Tai et al., 2005). The current study examined the effect of some non-cognitive factors (motivational and attitudinal variables) in tandem with students’ demographic characteristics in relation to students’ success in biology.
Based on the evidence from previous research (e.g., Creech & Sweeder, 2012, Singh & West, 2014), I anticipated that students demographic factors such as index score (a combination of high school GPA, ACT and SAT scores), extra curricular activities and number of working hours per week would emerge as significant predictors of success in a cell and molecular introductory biology course designed for both biology majors and non-majors. Furthermore, I also anticipated that some components of student attitudes towards learning biology and various motivational elements such as grade motivation, real world connections and beliefs about the relevance of biology to everyday life would also emerge as predictors of success in biology, given their significant role in student performance in biology and other STEM fields (Ferrell & Barbera, 2015; Lawson et al., 2007; Mann & Golubski, 2013). With respect to URMs and FGs, my prediction was that factors such as freshman status, working 30 plus hours and involvement in extra curriculum activities for 20 plus hours would serve as the primary demographic predictors of success. These predictions were based on previous reports identifying such factors as influential among URMs and FGs choice to pursue a STEM degree (Crisp et al., 2009) and the subsequent success in STEM coursework (Harackiewicz et al., 2014; Harrell & Forney, 2003).

Factors Influencing Student Success

**Demographic and educational background characteristics.** Given the significance of student demographic characteristics and prior and present educational experiences on student success (House, 2000; Tai et al., 2005), it is paramount to explore the role of these factors in student success in biological sciences. Demographic factors such as gender (Eddy et al., 2014; Graunke & Woosley, 2005) and ethnicity (Hoang,
2008) have been shown to influence student success in various STEM majors. In the field of biology, Singh and West (2014) confirmed that high school GPA and completion of high school chemistry increase the likelihood of success in first-year biology coursework. Other studies (Crisp et al., 2009; Gibson, 1993; Mitchell & Lawson, 1988; Tai et al., 2005; Tamir 1969) largely support these findings suggesting that successful completion of pre-collegiate coursework in biology, chemistry, and physics is integral for success in the respective fields.

First generation and URMs are often less likely to succeed in academe in general (Harrell & Forney, 2003). For example, compared to their peers FGs are at a distinct disadvantage with respect to their overall knowledge about college education (Pascarella et al., 2004). Research on the role played by non-cognitive factors, with respect to social and cultural implications among FGs and URMs, is important in promoting their learning. Rath et al. (2007) in their study on the impact of Supplemental Instruction (SI), an academic support strategy for improving student success and retention, especially in challenging majors, found that about 80% of URM students participating in SI sessions received a passing grade compared to 55% of the same group who were not concurrently participating in SI. In addition, the frequency of attendance in SI sessions was a stronger predictor of academic achievement among URMs than white students (Rabitoy et al., 2015). In general, educational interventions like SI positively affect students’ success with disproportionate effect on FG and URM students (Dawson et al., 2014).

**Motivational and attitudinal factors related to student success.** According to Glynn et al. (2011), motivation is an internal state that arouses, directs and sustains a goal-oriented action. Student motivational dynamics towards academic disciplines
influence their learning (Osborne et al., 2003). Based on social cognitive theory, motivation is a dynamic and multifaceted phenomenon composed of both intrinsic and extrinsic components, which both have potential to facilitate or impede learning (Linnenbrink & Pintrich, 2002).

Intrinsic motivation involves engaging in a task for its own sake, whereas extrinsic motivation involves engaging in a task as a means to an end (Pintrich & Schunk, 2002). The two elements of motivation have been shown to influence academic success and persistence in both biological sciences and in education psychology (Hidi & Harackiewicz, 2000). In my study I examined aspects of student motivation using a questionnaire. For example, extrinsic motivation was explored under the construct of grade motivation, e.g., questions like “is getting a good grade in biology important to you?” This construct explains the extrinsic reasons for engaging on a particular task even though the task itself may not be inherently interesting (Deci & Ryan, 1985). Questions that tested the aspects of intrinsic motivation were under the construct of enjoyment, e.g., statements like “I am curious about new discoveries in biology.” I also examined the effect of self-efficacy (personal beliefs regarding how well they will do on a given task (Eccles & Wigfield, 2002). Example of statements that tested the aspects of self-efficacy include; I believe I can earn a grade of “A” in biology and I am confident I will do well on biology tests.”

Self-efficacy directly influences the actual success and persistence in particular tasks individuals choose to engage in, e.g., students continuing to work on biology problems until they understand why things work the way they do (Bandura, 1997; Eccles & Wigfield, 2002, Pintrich & Schunk, 2002). In a study by Lawson et al. (2007),
reasoning ability was a primary factor influencing both self-efficacy and success. Similarly, student self-efficacy in an introductory biology course for STEM majors decreased over the course of the first-semester, possibly due to students’ low academic performance relative to their expectations (Mann & Golubski, 2008). An individual’s self-efficacy is assumed to be influenced by social and cognitive constructs such as competence, and perceived difficulty of tasks coupled with individual goals (Wigfield & Eccles, 2002).

Students’ attitudes and perceptions towards teaching in STEM fields is an important field of research that has dominated the field of education research for the past 40 years (Osborne et al., 2003). This area of research is particularly important for three main reasons. First, there is a widespread decline in interest in STEM fields among undergraduates (Seymour & Hewitt, 1997; Toven-Lindsey et al., 2015). Second, science education literature shows a widespread scientific ignorance by the general population (Miller et al., 1997). Finally, there is a widespread recognition of the value of scientific knowledge in solving societal challenges of the 21st century, which are matters of global concern (Toven-Lindsey et al., 2015). To contribute to this understanding, my study examined students’ motivations, attitudes and perceptions about learning biology in an effort to ascertain to what extent such factors are associated with academic success and future career opportunities in biology and to determine what motivational attributes are important in students’ interest and success in biology. Previous research shows that students’ attitudes, educational aspirations, perceptions of the importance of mathematics and confidence in mathematics ability were important factors contributing to variance in success in mathematics (Hammouri, 2004).
Research Questions

The following two research questions were the focus of this research.

Q1 What demographic, attitudinal, and motivational factors are predictive of success (students’ percent course grade in cell and molecular biology course) for students’ enrolled in a first-year introductory cellular and molecular biology course (Principles of Biology- Bio 110)?

Q2 To what extent do these factors differentially predict success among underrepresented minority and first generation students within the aforementioned cohort?

Methods

Research Context and Participants

Course context. The cell and molecular biology is an introductory course designed for both biology majors and non-majors. However, biology majors are required to take the cell and molecular biology course within the first year of college. The average enrollment per lecture section ranged from 100-250 students with a three-hour laboratory component. The laboratory enrollment ranged between 20-24 students per section per semester, with laboratory experiences being led by graduate teaching assistants (GTAs) and students completing traditional (“cookbook”), scripted laboratory exercises (Dickey, 2003). There were a total of seven laboratory sections.

The study context. In the study institution, the total undergraduate student enrollment is about 10,000, with one third of undergraduate enrollment in the College of Natural and Health Sciences (NHS). The School of Biological Sciences (SBS) is one of the largest among the science programs with respect to student enrollment, with about 500 students. This number is spread out among the four areas of emphasis; Pre-Health and Biomedical Sciences, Cell and Molecular biology, Ecology and Evolutionary Biology, and Secondary Teaching, with a majority of students being enrolled in Pre-
Health and Biomedical Sciences. The Principles of Biology course is a prerequisite course for a variety of majors, while the Organismal Biology course is only a requisite for biology majors. The two courses are offered year round, but enrollment fluctuates with the highest enrollment occurring in the fall semester for Principles of Biology and the spring semester for Organismal Biology. Both courses are 16-weeks long, taught for a 50-minute period three times a week with a separate three-hour laboratory component per week. In both courses over 40% of students’ who attain a grade of B graduate with a biology degree at the study institution, making these two introductory courses crucial for research examining predictors of student persistence in biology especially at the study institution.

**Participants Descriptive Statistics**

The 882 survey results in these data came from students enrolled in Principles of Biology, with a majority of participants, 76.3% (n = 673), being female (Table 1). It is important to mention that 30.3% (n = 268) of the participants were URM students (non-Caucasian), while almost an equal number, 32.9% (n = 292) of the participants were FG students. A majority (78.9%) of the participants were in their first year of college, 79.0% of URM students were in their first year while a similar percentage (79.7%) of all FG students were in their first year. Students majoring in the nursing program were the majority (41.5%) in this study, while 28.3% majored in liberal arts, 20.2% majored in biology and 10% majored in other STEM fields other than biology.

Participants were invited from a convenience sample consisting of all students enrolled in the three sections of an introductory cell and molecular biology course (hereafter referred to as Cell and molecular biology course) at a mid-size Rocky
Mountain Region university. The total potential participants sample size was estimated to be 1093, composed of both biology majors and non-majors. See Table 1 for descriptive data on research participants. Participation in this study was entirely voluntary as specified by the guidelines of research with human subjects (Appendix A). This study was approved by the institutional Review Board (IRBNet ID# 494383-9; Appendix B). In this study success was defined as students’ numerical final course grade (percent course grade) as an outcome continuous variable with values ranging between 0-100. The study instrument contained the explanatory variables which included students’ attitudes (e.g., enjoyment in biology and problem solving effort), motivational factors (e.g., grade motivation and self-efficacy) and student demographic characteristics (e.g., gender and index score) were examined in relation to the variance explained by student success in biology (Appendix C).
Table 1

*Descriptive Data Regarding Research Participants*

<table>
<thead>
<tr>
<th>Category</th>
<th>Comprehensive</th>
<th>URM</th>
<th>First Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>78.9%</td>
<td>79.0%</td>
<td>79.7%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>15.1%</td>
<td>14.7%</td>
<td>14.5%</td>
</tr>
<tr>
<td>Junior</td>
<td>3.6%</td>
<td>2.4%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Senior</td>
<td>2.3%</td>
<td>3.8%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Major</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>20.2%</td>
<td>22.4%</td>
<td>20.6%</td>
</tr>
<tr>
<td>Nursing</td>
<td>41.5%</td>
<td>42.7%</td>
<td>45.5%</td>
</tr>
<tr>
<td>Liberal Arts</td>
<td>28.3%</td>
<td>24.8%</td>
<td>25.5%</td>
</tr>
<tr>
<td>STEM (non-biology)</td>
<td>10.0%</td>
<td>10.1%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23.7%</td>
<td>25.5%</td>
<td>22.6%</td>
</tr>
<tr>
<td>Female</td>
<td>76.3%</td>
<td>74.5%</td>
<td>77.4%</td>
</tr>
<tr>
<td>Minority Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non- URMs</td>
<td>69.7%</td>
<td>-</td>
<td>47.6%</td>
</tr>
<tr>
<td>URM</td>
<td>30.3%</td>
<td>-</td>
<td>52.4%</td>
</tr>
<tr>
<td>First Generation Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Generation</td>
<td>32.9%</td>
<td>56.8%</td>
<td>-</td>
</tr>
<tr>
<td>Continuing Generation</td>
<td>67.1%</td>
<td>43.2%</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 1 (continued)

<table>
<thead>
<tr>
<th>Category</th>
<th>Model</th>
<th>Comprehensive</th>
<th>URM</th>
<th>First Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employment (Hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 or more hours</td>
<td></td>
<td>5.4%</td>
<td>7.7%</td>
<td>5.2%</td>
</tr>
<tr>
<td>15-29 hours</td>
<td></td>
<td>21.4%</td>
<td>22.0%</td>
<td>26.8%</td>
</tr>
<tr>
<td>1-4 hours</td>
<td></td>
<td>18.3%</td>
<td>23.4%</td>
<td>17.4%</td>
</tr>
<tr>
<td>Not employed</td>
<td></td>
<td>54.9%</td>
<td>46.9%</td>
<td>50.6%</td>
</tr>
<tr>
<td><strong>Extracurricular Participation (Hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 or more hours</td>
<td></td>
<td>5.7%</td>
<td>5.2%</td>
<td>5.8%</td>
</tr>
<tr>
<td>10-19 hours</td>
<td></td>
<td>11.5%</td>
<td>9.4%</td>
<td>8.1%</td>
</tr>
<tr>
<td>1-9 hours</td>
<td></td>
<td>32.2%</td>
<td>31.8%</td>
<td>31.3%</td>
</tr>
<tr>
<td>Not participating in extracurricular activities</td>
<td></td>
<td>50.6%</td>
<td>53.6%</td>
<td>54.8%</td>
</tr>
</tbody>
</table>

*Note: URM = Underrepresented Minority Students, STEM = Science Technology Engineering and Mathematics, Non-URM = Non-underrepresented Minority Students*

Principles of Biology was taught by two instructors divided into three sections (instructor A and instructor B) during the semesters: Fall 2013, Spring 2014, and Fall 2014. Of the original sample size of \(N = 1093\) participants, 211 participants were listwise deleted (Allison, 2001) from the analysis for missing some of the variables included in the final model. The study response rate was 78% with a final sample size of \(N = 882\), comprising of participants who consented to participate and completed all the survey instruments. All the participants were completing Principles of Biology for the first time, including both the lecture and laboratory components of the course. The two
faculty instructing the course adopted a mixture of both traditional and evidence-based pedagogical approaches in the classroom (e.g., lecture, use of case studies and Clickers).

**Data Sources**

**Course grade.** One of the data sources was students’ success in cell and molecular biology course. In this study, success was defined as students’ numerical final course grade (percent course grade) as an outcome continuous variable with values ranging between 0-100. The percent course grade was preferred over student letter grade because it was able to show variations in performance from student to student.

**Supplemental instruction.** Under this study, supplemental instruction represented a support course for cell and molecular introductory biology course. The instruction in this course assumes some level of active learning, where by students are engaged in various aspects of problem solving. Additionally, students enrolled in this course are also equipped with study skills. Students had a choice of either enrolling into the course or not.

**Demographic information.** With their consent, participants were asked to provide information regarding their gender, race and ethnicity, first generation status, and participation in extracurricular activities. Additional student data, including students’ index score (composed of students’ high school GPA, SAT and ACT scores) and freshmen status (whether they were first years or not), were obtained through the universities institutional reporting platform.

**Colorado Learning Attitudes About Science Survey (CLASS-Bio).** To assess the relationship between students’ attitudes about learning biology and overall course performance, participants were asked to complete the Colorado Learning Attitudes about
Science Survey-Biology (CLASS-Bio; Semsar et al., 2011; Appendix C). Initially, the survey instrument was developed to assess students’ perceptions about biology based on a novice-expert continuum (Hammer 1994). The instrument serves as a non-course specific assessment of students’ perceptions toward biology (Semsar et al., 2011). This instrument consists of 31, Likert-item questions with responses ranging from Strongly Agree to Strongly Disagree. The 31 Likert-item questions were designed to test the seven categories (sub-scales) of students’ attitudes towards studying biology. These were: (a) real world connections (ability to make real world connections with biology), (b) problem solving difficulty (ability to solve difficulty problems), (c) enjoyment (enjoying learning biology discipline), (d) problem solving effort (amount of effort applied in solving biology problems), (e) conceptual connections/memorization (an understanding of whether biology concepts are structured on concepts or they isolated and basically required memorization), (f) problem solving strategies (ability to apply different strategies to solve biology problems), and (g) reasoning (ability to apply reasoning skills to solve biology problems). The questions were designed to examine the degree to which students agree with expert responses on the seven constructs described above in the biology domain. When the CLASS- Bio instrument was initially developed and validated, it was tested on both undergraduate biology major students and persons with Ph.D.’s within biology fields. The reliability statistics for the CLASS- Bio survey instrument were as follows; percent-favorable, \( r = 0.97 \) and percent unfavorable, \( r = 0.97 \). The percent-favorable refers to the degree to which students had a favorable response or a similar response with the experts and vice versa. To clarify on the tests of reliability a
reliability of $r = 0.80$ is usually considered high reliability; this means that the instruments reliabilities represents a high reliability.

Responses from persons with Ph.D.s in biology were considered to be the “expert” responses. The idea behind the design was to be able to determine how students think about biology in comparison to an individual considered an expert in biology. A favorable score was given to students in questions where their response was comparable to that of the experts. For instance, if the experts strongly disagreed and the student also strongly disagreed, then the student response was counted as favorable. Moreover, if the expert strongly disagreed and the student disagreed (or vice versa) the student response was also scored as favorable. On the other hand, unfavorable score was given to students in questions where their response was not comparable to that of the experts. For instance, if the experts strongly disagreed and the student strongly agreed, then the student response was counted as unfavorable. Moreover, if the expert strongly disagreed and the student agreed (or vice versa) the student response was also scored as unfavorable.

During the initial instrument validation process, students’ qualitative interviews indicated a wide variation in the reasons for either choosing Agree versus Strongly Agree or Disagree versus Strongly Disagree between individual students. For this reason, during the analysis of student responses, responses such as; Agree and Strongly Agree were coded equally as well as responses such as Disagree and Strongly Disagree. In this respect, data in this dissertation was coded in a similar manner in agreement to the novice-expert continuum (Hammer, 1994).

**Science Motivation Questionnaire II (SMQ II).** During the same class meeting, students were also asked to complete a modified version of the Science Motivation
Questionnaire II (SMQ II; Glynn et al., 2011; Appendix C in which the term “science” was replaced with the term “biology” so as to eliminate ambiguity in the scientific discipline being referenced. The SMQ II, was developed to assist instructors in understanding which students’ lack motivation and why in learning science. This diagnostic consists of 25 Likert-item questions, with five questions under each of the five constructs (sub-scales) testing different types of students’ motivations (intrinsic motivation- being inherently interested in biology, career motivation- being motivated to study biology in order to get into a biology related career, self-determination- being in control of learning biology, self-efficacy-belief in one’s self to be successful in biology and grade motivation- being motivated in obtaining a good grade in biology). The reliability statistics for the survey instrument were; self-determination (0.88), intrinsic motivation (0.89), career motivation (0.92), grade motivation (0.81), and self-efficacy (0.83).

The two validated study instruments (CLASS- Bio and SMQII), were selected for use because they were explicitly designed to measure attitudinal and motivational variables shown to impact student success across STEM disciplines. Both surveys were administered during the second to last week of the semesters in order to best capture students’ views about biology after they had acclimatized to the college environment, rather than based on pre-existed beliefs regarding their high school biology experiences. Survey items were administered in one, 45-minute block at the beginning of a laboratory period; students recorded their responses directly on a Scantron form. The Scantron data were entered directly into SPSS vs. 23 (IBM®) for analyses.
Analyses

Multiple linear regression was utilized for the analyses by considering the predictors of success in Principles of Biology from three distinct categories: demographic characteristics, attitudinal and motivational characteristics. The dependent variable was student percent final course grade.

Given the significant potential for correlation between the input variables, collinearity diagnostics were tabulated. These diagnostics indicated that the variance inflation factor (VIF) values for each predictor were below 5.0 (C. Robinson & Schumacker, 2009), confirming that it was appropriate to proceed using a standard multiple linear regression approach. The analytical procedures allowed the consideration of the contribution of each individual predictor included in the regression models along with their specific change in explaining the variance of the dependent variable. In total three regression models were performed; a comprehensive model including all the student types \( n = 882 \), a model for the underrepresented minority students \( n = 268 \) and a model for the first generation students \( n = 292 \). All of the three regression models on average accounted for about 50% of variance dependent variable.

Results

Predictors of Success Among All Students

To determine the factors impacting student success in Principles of Biology among all the participants, the final percentage course grade \( (M = 77.40; SD = 11.64) \) was regressed on demographic data as well as scores obtained from each of the twelve scales represented on the CLASS-Bio and SMQ II survey instruments (Table 2). All the independent variables were entered in the model and run with a single analysis. Taken
together, these factors explained approximately 48% of the variance in students’ course performance, \( F (27,854) = 28.665; \ p < 0.001 \). Participants’ index score, minority status, first generation status and class standing were among the top demographic predictors of performance, uniquely explaining 4.7%, 3.0%, 1% and 1.4% of variance in students’ course grade, respectively, when all remaining factors were held constant. Class standing was negatively associated with students success in that being a freshmen was negatively associated with success, \( \beta = -3.803, t(854) = -4.798, \ p < 0.001 \).

The unstandardized regression coefficient (\( \beta \)) for index score, \( \beta = 0.148 (t(854) = 8.737, p < 0.001) \), indicates that for each unit increase in participants’ index score, their final grade in Principles of Biology increased by approximately one-tenths of a percent, controlling for all other demographic and non-cognitive variables. Though contributing less to the overall variance in student performance, data on minority status indicated that the non-minority students were more likely to succeed in biology, \( \beta = 4.813, t(854) = 7.011, p < 0.001 \), further suggest that Caucasian participants’ overall course grade was nearly one-half a letter grade higher than their non-Caucasian counterparts, controlling for all other factors.
Table 2

*Predictors of Success for All Students Enrolled in Principles of Biology*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>$t$-value ($df = 854$)</th>
<th>$p$-value</th>
<th>$sr^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Standing</td>
<td>-3.803 (0.793)</td>
<td>-0.131</td>
<td>-4.798</td>
<td>&lt; 0.001</td>
<td>1.4%</td>
</tr>
<tr>
<td>Nursing Major</td>
<td>1.333 (0.961)</td>
<td>0.057</td>
<td>1.387</td>
<td>0.166</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Liberal Arts Major</td>
<td>-0.391 (1.055)</td>
<td>0.015</td>
<td>-0.371</td>
<td>0.711</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>STEM (non-bio) Major$^1$</td>
<td>1.090 (1.224)</td>
<td>0.029</td>
<td>0.890</td>
<td>0.374</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.283 (0.749)</td>
<td>-0.010</td>
<td>-0.378</td>
<td>0.705</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Non-URMs</td>
<td>4.813 (0.686)</td>
<td>0.190</td>
<td>7.011</td>
<td>&lt; 0.001</td>
<td>3.0%</td>
</tr>
<tr>
<td>Non-FGs</td>
<td>-2.083 (0.668)</td>
<td>-0.084</td>
<td>-3.177</td>
<td>0.002</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Index Score$^2$</td>
<td>0.148 (0.017)</td>
<td>0.229</td>
<td>8.737</td>
<td>&lt; 0.001</td>
<td>4.7%</td>
</tr>
<tr>
<td>Employment(H)$^3$</td>
<td>-0.456 (1.373)</td>
<td>-0.009</td>
<td>-0.332</td>
<td>0.740</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(M)</td>
<td>-0.396 (0.766)</td>
<td>-0.014</td>
<td>-0.517</td>
<td>0.605</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(L)</td>
<td>0.496 (0.784)</td>
<td>0.017</td>
<td>0.633</td>
<td>0.527</td>
<td>&lt; 1.0%</td>
</tr>
</tbody>
</table>
Table 2 (continued)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>( \beta )</th>
<th>( t )-value ((df = 854))</th>
<th>( p )-value</th>
<th>(sr^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracurricular(H)(^4)</td>
<td>-1.418 (1.372)</td>
<td>-0.027</td>
<td>-1.033</td>
<td>0.302</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(M)</td>
<td>-0.828 (0.970)</td>
<td>-0.023</td>
<td>-0.854</td>
<td>0.394</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(L)</td>
<td>0.917 (0.657)</td>
<td>0.037</td>
<td>1.396</td>
<td>0.163</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Supplemental Instruction</td>
<td>1.951 (1.044)</td>
<td>0.052</td>
<td>1.869</td>
<td>0.062</td>
<td>&lt; 1.0%</td>
</tr>
</tbody>
</table>

**Attitudinal**

<p>| Class Standing            | -0.013 (0.024)    | -0.034     | -0.538                        | 0.590        | &lt; 1.0%  |
| Problem-Solving Difficulty| 0.042 (0.016)     | 0.103      | 2.632                         | 0.009        | &lt; 1.0%  |
| Enjoyment                 | 0.063 (0.019)     | 0.186      | 3.406                         | 0.001        | &lt; 1.0%  |
| Problem-Solving Effort    | -0.020 (0.027)    | -0.055     | -0.760                        | 0.448        | &lt; 1.0%  |
| Conceptual Connections    | -0.013 (0.018)    | -0.030     | -0.704                        | 0.482        | &lt; 1.0%  |
| Problem-Solving Strategies| 0.007 (0.016)     | 0.021      | 0.427                         | 0.669        | &lt; 1.0%  |
| Reasoning                 | -0.010 (0.021)    | -0.027     | -0.454                        | 0.650        | &lt; 1.0%  |</p>
<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>t-value (df = 854)</th>
<th>p-value</th>
<th>sr²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motivational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>-0.089 (0.130)</td>
<td>-0.034</td>
<td>-0.686</td>
<td>0.493</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Career Motivation</td>
<td>-0.234 (0.091)</td>
<td>-0.103</td>
<td>-2.564</td>
<td>0.011</td>
<td>1.0%</td>
</tr>
<tr>
<td>Self-Determination</td>
<td>0.493 (0.108)</td>
<td>0.166</td>
<td>4.577</td>
<td>&lt; 0.001</td>
<td>1.3%</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>0.796 (0.112)</td>
<td>0.290</td>
<td>7.142</td>
<td>&lt; 0.001</td>
<td>3.1%</td>
</tr>
<tr>
<td>Grade Motivation</td>
<td>0.408 (0.104)</td>
<td>0.127</td>
<td>3.932</td>
<td>&lt; 0.001</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

*Note.* Non-URMS = Non-underrepresented Minority Students, Non-FGS = Non-First Generation Students


2Index score is a national measure of high school preparedness calculated based on students’ high school GPA and standardized exam (SAT/ACT) performance.

3Participants’ employment status is classified based on hours worked per week. (H) = 30 or more hours; (M) = 15-29 hours; (L) = 1-14 hours.

4Participants’ extracurricular status is classified based on hours the individual participates in extracurriculars each week. (H) = 20 or more hours; (M) = 10-19 hours; (L) = 1-9 hours.
Attitudinal characteristics which emerged as significant positive predictors of student success were: students’ ability to apply knowledge to solve biology-specific tasks (i.e., problem-solving difficulty; \( \beta = 0.042, t(854) = 2.632, p = 0.009 \)), explaining \(~1.0\%\) of variance in students’ final course grade, and student enjoyment of the biology major, \( \beta = 0.063, t(854) = 3.406, p = 0.001 \), explaining 1% of variance in students’ final course grade, after controlling for the remaining demographic CLASS-Bio and SMQ II measures. On the other hand the motivational characteristics which emerged as significant positive predictors of success among the all student type were: self-efficacy, \( \beta = 0.796, t(854) = 7.142, p < 0.001 \), predicting 3.1% of variance in students’ final course grade, self-determination, \( \beta = 0.493, t(854) = 4.577, p < 0.001 \), predicting 1.3%, of variance in students’ final course grade, grade motivation. \( \beta = 0.408, t(854) = 3.932, p < 0.001 \), predicting 1% of variance in students’ final course grade, and career motivation. \( \beta = -0.234, t(854) = -2.564, p < 0.011 \), predicting 1.0%, of variance in students’ final course grade after controlling for all other input variables.

**Predictors of Success Among Underrepresented Minority Students**

About one third (30.3%) of the study participants identified themselves as members of an underrepresented minority group. Among URM students, index score, \( \beta = 0.286, t(241) = 6.608, p < 0.001 \), and class standing, \( \beta = -5.026, t(241) = -2.838, p = 0.005 \), were the positive demographic predictor of success explaining 10.2% and 1.9%, respectively of student final course grade (Table 3). Supplemental instruction was also an important factor for this group of students with reference to success, \( \beta = 5.000, t(241) = 2.162, p < 0.032 \), explaining 1.1% of student final course grade. Interestingly, among
URM students all the motivational variables that were positive predictors of success among the all student population (self-efficacy, self-determination and grade motivation) emerged as positive predictors of success among this cohort as well. On the other hand, none of the attitudinal characteristics seemed to be important in student success among URM students in this study.

**Predictors of Success Among the First Generation students’**

Among the study participants, 32.9% identified themselves as first generation students. First generation students (FGs) refer to those individuals whose parent(s) did not receive a four-year college degree. Among FGs, the demographic factors which were important in explaining student success were: index score, $\beta = 0.193$, $t(265) = 5.475$, $p < 0.001$, predicting 6.2% of the student final course grade, minority status, $\beta = 4.986$, $t(265) = 4.225$, $p < 0.001$, predicting 3.7% of the student final course grade and class standing also emerged as a predictor for students success among the FGs in that being a freshmen was negatively associated with success in principles of biology, $\beta = -3.944$, $t(265) = -2.525$, $p = 0.012$; see Table 4). Similarly, like the case for URM students, all the motivational variables important among all students were significant predictors of success among this cohort, with grade motivation explaining a larger proportion (2.1%) of variance in student final course grade. Interestingly, as opposed to the case of URM students enjoyment of biology was the single attitudinal predictor of success among the FGs, $\beta = 0.079$, $t(854) = 2.073$, $p < 0.039$, explaining 1% of variance in the student final course grade.
Table 3

*Predictors of Success for Underrepresented Minority Students Enrolled in Principles of Biology*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>t-value (df = 854)</th>
<th>p-value</th>
<th>sr²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Standing</td>
<td>-5.026 (1.771)</td>
<td>-0.159</td>
<td>-2.838</td>
<td>0.005</td>
<td>1.9%</td>
</tr>
<tr>
<td>Nursing Major</td>
<td>1.822 (2.018)</td>
<td>0.070</td>
<td>0.903</td>
<td>0.367</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Liberal Arts Major</td>
<td>2.899 (2.339)</td>
<td>0.095</td>
<td>1.240</td>
<td>0.216</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>STEM (non-bio) Major¹</td>
<td>2.217 (2.648)</td>
<td>0.054</td>
<td>0.837</td>
<td>0.403</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.846 (1.616)</td>
<td>-0.063</td>
<td>-1.142</td>
<td>0.255</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>First Generation</td>
<td>-2.107 (1.372)</td>
<td>-0.081</td>
<td>-1.535</td>
<td>0.126</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td><strong>Index Score²</strong></td>
<td>0.286 (0.043)</td>
<td>0.349</td>
<td>6.608</td>
<td>&lt; 0.001</td>
<td>10.2%</td>
</tr>
<tr>
<td>Employment(H)³</td>
<td>0.309 (2.611)</td>
<td>0.006</td>
<td>0.118</td>
<td>0.906</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(M)</td>
<td>-0.333 (1.753)</td>
<td>-0.011</td>
<td>-0.190</td>
<td>0.850</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(L)</td>
<td>1.007 (1.639)</td>
<td>0.033</td>
<td>0.615</td>
<td>0.539</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(H)⁴</td>
<td>3.587 (3.253)</td>
<td>0.060</td>
<td>1.103</td>
<td>0.271</td>
<td>&lt; 1.0%</td>
</tr>
</tbody>
</table>
Table 3 (continued)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>t-value ( df = 854 )</th>
<th>p-value</th>
<th>sr²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracurricular(M)</td>
<td>-1.762 (2.380)</td>
<td>-0.039</td>
<td>-0.740</td>
<td>0.460</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(L)</td>
<td>0.425 (1.445)</td>
<td>0.015</td>
<td>0.294</td>
<td>0.769</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td><strong>Supplemental Instruction</strong></td>
<td><strong>5.000 (2.313)</strong></td>
<td><strong>0.123</strong></td>
<td><strong>2.162</strong></td>
<td><strong>0.032</strong></td>
<td><strong>1.1%</strong></td>
</tr>
<tr>
<td><strong>Attitudinal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real-World Connections</td>
<td>-0.006 (0.057)</td>
<td>-0.015</td>
<td>-0.112</td>
<td>0.911</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Problem-Solving Difficulty</td>
<td>0.045 (0.034)</td>
<td>0.099</td>
<td>1.320</td>
<td>0.188</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>0.072 (0.043)</td>
<td>0.184</td>
<td>1.590</td>
<td>0.092</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Problem-Solving Effort</td>
<td>-0.095 (0.058)</td>
<td>-0.227</td>
<td>-1.646</td>
<td>0.101</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Conceptual Connections</td>
<td>-0.015 (0.038)</td>
<td>-0.031</td>
<td>-0.398</td>
<td>0.691</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Problem-Solving Strategies</td>
<td>0.036 (0.035)</td>
<td>0.093</td>
<td>1.022</td>
<td>0.308</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Reasoning</td>
<td>-0.003 (0.049)</td>
<td>-0.007</td>
<td>-0.054</td>
<td>0.957</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Predictor</td>
<td>(Standard. Error)</td>
<td>$\beta$</td>
<td>$t$-value ($df = 854$)</td>
<td>$p$-value</td>
<td>$sr^2$</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>Motivational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>-0.108 (0.300)</td>
<td>-0.036</td>
<td>-0.359</td>
<td>0.720</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Career Motivation</td>
<td>-0.016 (0.190)</td>
<td>-0.007</td>
<td>-0.086</td>
<td>0.932</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td><strong>Self-Determination</strong></td>
<td><strong>0.573 (0.230)</strong></td>
<td><strong>0.180</strong></td>
<td><strong>2.497</strong></td>
<td><strong>0.013</strong></td>
<td><strong>1.4%</strong></td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td><strong>0.782 (0.256)</strong></td>
<td><strong>0.263</strong></td>
<td><strong>3.051</strong></td>
<td><strong>0.003</strong></td>
<td><strong>2.2%</strong></td>
</tr>
<tr>
<td>Grade Motivation</td>
<td><strong>0.478 (0.215)</strong></td>
<td><strong>0.148</strong></td>
<td><strong>2.228</strong></td>
<td><strong>0.027</strong></td>
<td><strong>1.1%</strong></td>
</tr>
</tbody>
</table>

*Note. STEM = Science Technology Engineering and Mathematics*


2Index score is a national measure of high school preparedness calculated based on students’ high school GPA and standardized exam (SAT/ACT) performance.

3Participants’ employment status is classified based on hours worked per week. (H) = 30 or more hours; (M) = 15-29 hours; (L) = 1-14 hours.

4Participants’ extracurricular status is classified based on hours the individual participates in extracurriculars each week. (H) = 20 or more hours; (M) = 10-19 hours; (L) = 1-9 hours.
Table 4

Predictors of Success for Underrepresented Minority Students Enrolled in Principles of Biology

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>sr²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td></td>
<td></td>
<td>(df = 854)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Standing</td>
<td>-3.944 (1.562)</td>
<td>-0.130</td>
<td>-2.525</td>
<td>0.012</td>
<td>1.3%</td>
</tr>
<tr>
<td>Nursing Major</td>
<td>-1.348 (1.987)</td>
<td>-0.056</td>
<td>-0.678</td>
<td>0.498</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Liberal Arts Major</td>
<td>-3.432 (2.169)</td>
<td>-0.122</td>
<td>-1.582</td>
<td>0.115</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>STEM (non-bio) Major¹</td>
<td>1.043 (2.572)</td>
<td>0.024</td>
<td>0.405</td>
<td>0.685</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.805 (1.533)</td>
<td>-0.063</td>
<td>-1.177</td>
<td>0.240</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Non FG-URMs</td>
<td>4.986 (1.180)</td>
<td>0.206</td>
<td>4.225</td>
<td>&lt; 0.001</td>
<td>3.7%</td>
</tr>
<tr>
<td>Index Score²</td>
<td>0.193 (0.035)</td>
<td>0.263</td>
<td>5.475</td>
<td>&lt; 0.001</td>
<td>6.2%</td>
</tr>
<tr>
<td>Employment(H)³</td>
<td>-2.491 (2.692)</td>
<td>-0.045</td>
<td>-0.925</td>
<td>0.356</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(M)</td>
<td>-0.954 (1.397)</td>
<td>-0.035</td>
<td>-0.683</td>
<td>0.495</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Employment(L)</td>
<td>2.142 (1.597)</td>
<td>0.068</td>
<td>1.341</td>
<td>0.181</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(H)⁴</td>
<td>-0.556 (2.659)</td>
<td>-0.011</td>
<td>-0.209</td>
<td>0.835</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Predictor</td>
<td>(Standard. Error)</td>
<td>β</td>
<td>t-value (df = 854)</td>
<td>p-value</td>
<td>sr²</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------</td>
<td>-------</td>
<td>-------------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>Extracurricular(M)</td>
<td>-3.208 (2.293)</td>
<td>-0.070</td>
<td>-1.399</td>
<td>0.163</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Extracurricular(L)</td>
<td>1.192 (1.287)</td>
<td>0.046</td>
<td>0.926</td>
<td>0.355</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Supplemental Instruction</td>
<td>1.073 (2.085)</td>
<td>0.030</td>
<td>0.515</td>
<td>0.607</td>
<td>&lt; 1.0%</td>
</tr>
</tbody>
</table>

**Attitudinal**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(Standard. Error)</th>
<th>β</th>
<th>t-value (df = 854)</th>
<th>p-value</th>
<th>sr²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-World Connections</td>
<td>-0.052 (0.049)</td>
<td>-0.134</td>
<td>-1.055</td>
<td>0.292</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Problem-Solving Difficulty</td>
<td>0.042 (0.031)</td>
<td>0.099</td>
<td>1.378</td>
<td>0.169</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td><strong>Enjoyment</strong></td>
<td><strong>0.079 (0.038)</strong></td>
<td><strong>0.219</strong></td>
<td><strong>2.073</strong></td>
<td><strong>0.039</strong></td>
<td><strong>1.0%</strong></td>
</tr>
<tr>
<td>Problem-Solving Effort</td>
<td>0.004 (0.055)</td>
<td>0.011</td>
<td>0.080</td>
<td>0.936</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Conceptual Connections</td>
<td>-0.010 (0.034)</td>
<td>-0.023</td>
<td>-0.297</td>
<td>0.767</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Problem-Solving Strategies</td>
<td>-0.033 (0.033)</td>
<td>-0.093</td>
<td>-0.999</td>
<td>0.319</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Reasoning</td>
<td>0.051 (0.042)</td>
<td>0.146</td>
<td>1.200</td>
<td>0.231</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Predictor</td>
<td>(Standard. Error)</td>
<td>β</td>
<td>t-value (df = 854)</td>
<td>p-value</td>
<td>sr²</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------</td>
<td>------</td>
<td>--------------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Motivational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>-0.164 (0.273)</td>
<td>-0.061</td>
<td>-0.603</td>
<td>0.547</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Career Motivation</td>
<td>-0.224 (0.182)</td>
<td>-0.098</td>
<td>-1.233</td>
<td>0.219</td>
<td>&lt; 1.0%</td>
</tr>
<tr>
<td>Self-Determination</td>
<td>0.481 (0.207)</td>
<td>0.161</td>
<td>2.327</td>
<td>0.021</td>
<td>1.1%</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>0.647 (0.226)</td>
<td>0.228</td>
<td>2.870</td>
<td>0.004</td>
<td>1.7%</td>
</tr>
<tr>
<td>Grade Motivation</td>
<td>0.636 (0.202)</td>
<td>0.196</td>
<td>3.155</td>
<td>0.002</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

*Note.* STEM = Science Technology Engineering and Mathematics, FG-URMs = First Generation Underrepresented Minority Students


2Index score is a national measure of high school preparedness calculated based on students’ high school GPA and standardized exam (SAT/ACT) performance.

3Participants’ employment status is classified based on hours worked per week. (H) = 30 or more hours; (M) = 15-29 hours; (L) = 1-14 hours.

4Participants’ extracurricular status is classified based on hours the individual participates in extracurriculars each week. (H) = 20 or more hours; (M) = 1-19 hours; (L) = 1-9 hours.
Discussion

Collegiate success is a complex phenomenon explained by a variety of factors both intrinsic to the students and extrinsic in their external environments. Research has shown that in addition to development of content knowledge and academic skills, students must develop a set of motivational and attitudinal variables essential for academic success (Farrington et al., 2012). In this study I examined what demographic, attitudinal, and motivational factors are predictive of success for students enrolled in a first-year introductory cellular and molecular biology course, and further investigated to what extent such factors differentially predict success among underrepresented minority and first generation students. My results indicate that motivational factors were equally important predictors of success among all student types including both underrepresented minority and first generation students.

Self-efficacy contributed highly to student success among all the non-cognitive factors examined, explaining 3.1% of final course grade (Table 2). Previous empirical studies have focused on the independent contributions of attitudinal and motivational factors to student performance in STEM disciplines, largely focusing on the constructs of self-efficacy and domain-specific reasoning skills. In agreement with my study results, in their analysis of the relationship between these variables in the context of college biology, Lawson et al. (2007) found that “intellectual development continues for some students during the college year and reasoning ability was a primary factor influencing both self-efficacy and achievement” (p. 706). Similarly, the findings generated from Mann and Golubski’s (2013) study on first-year biology majors are also in agreement with the current study results, suggesting that students’ perceived self-efficacy
significantly decreases over the course of the first-semester for STEM majors, likely due to students’ low academic performance relative to their expectations. In addition, Bowen, Chingos, and McPherson (2009) suggested that beyond assessing the mastery of content, student final course grades reveal qualities of motivation and perseverance, as well as time management skills and good study habits. Furthermore, a recent study on the effect of problem-based learning on student achievement (Bilgin, Karakuyu, & Ay, 2015), found that self-efficacy increased within the course of the study period; these findings emphasize the impact of self-efficacy on student success consistent with the current study. Finally, consistent with my findings and those of Wigfield and Eccles (2002) expectancy-value theory of achievement model, students’ positive perception of their own capabilities for learning biology was positively associated with their success in biology. In line with my results, the broader notions of self-efficacy and attitudes toward science have been shown to impact student performance in STEM lecture and laboratory settings (e.g., Brownell et al., 2012; House 1995). Student success in STEM fields is a national concern; therefore, capitalizing on developing student self-efficacy in introductory science might be important in students’ success in STEM fields.

Consistent with my findings, students ability to apply biological principles to solve difficult problems (problem solving-difficulty), an attitudinal variable, has been shown to be associated with student success in biology (Allen & Tanner, 2005). These findings suggest that developing students’ ability to apply knowledge to solve biology-specific tasks and positive students’ attitudes in laboratory science settings with respect to solving specific biology problems may be essential in promoting long-term educational success in biology.
In the current study, index score, a variable composed of a combination of a student's high school GPA, ACT and SAT scores was positively associated with students’ success in biology. Index score is a prior educational characteristic which explained the most variance among all student types (4.7%) in the response variable (Table 2). In light of the extensive literature on demographic and educational predictors of student success in STEM and non-STEM contexts, my findings are not atypical. Consistent with my results, in their analysis of pre-college, college, and environmental factors predicting Hispanic student persistence in or transfer to a STEM major, Crisp et al. (2009) note that students’ high school achievement and performance on standardized exams (e.g., SAT) were directly related to their STEM outcomes at the collegiate level. The authors acknowledge, however, that future research is needed to further examine course enrollment and withdraw patterns, particularly in “gatekeeper” courses, and their impact on STEM student outcomes at predominantly minority-serving institutions (Crisp et al., 2009). Similarly, in agreement with the current study results, Singh and West (2014) demonstrated that the likelihood of students succeeding in biology majors pre-requisite courses was almost twice that of their peers if the former group possessed a high-school GPA greater than 2.7 and had completed high school chemistry. Comparably my results indicated that the unstandardized regression coefficient (β) for index score was 0.148, t(854) = 8.737, p < 0.001, which indicates that for each unit increase in a participants’ index score, their final grade in Principles of Biology increased by approximately one-tenths of a percent, controlling for all other demographic and non-cognitive variables (Table 2). A myriad of previous studies (Gibson 1993; Mitchell & Lawson 1988; Tamir 1969), including the work of Tai et al. (2005), supports this conclusion, suggesting that
successful completion of pre-collegiate coursework in biology, chemistry, and physics is integral for preparing students’ to complete college classes in the same fields.

Previous studies have found an individual's gender is an important factor in predicting students’ academic success in college (Eddy et al., 2014; Lin et al., 2009). Contrary to these findings, in the current study gender was not a statistically significant predictor for students’ success in biology. My results are not atypical, previous research by Tai et al. (2005) determined that gender was not an important predictor of students’ success in introductory chemistry. I argue that these findings could be a result from a disproportionate number of females being enrolled in Principles of Biology relative to males, a common occurrence nationally across universities (Eddy et al., 2014), as well as cross-enrollment in the course by students outside the major (e.g., pre-nursing; Singh & West, 2014).

In agreement with previous studies which show that FGs and URMs are often less likely to succeed in academe (Harrell & Forney, 2003), in my study the non-minority students had a half letter grade higher performance compared to their minority peers (Table 2). In addition, being FGs was negatively associated with success in biology. My results support previous studies which indicate that, compared to their peers FGs are at a distinct disadvantage with respect to their overall knowledge about college education (Pascarella et al., 2004), and this have potential of negatively affecting their success in college. My results may point to the need of an in-depth investigation of the role played by non-cognitive factors with respect to social and cultural implications among the URMs and FGs in promoting their learning.
To the best of my knowledge, the research presented herein is the first to generate a more comprehensive model including both demographic, attitudinal and motivational predictors as they relate to students’ academic success in introductory biology. Furthermore, as compared to research that has historically focused on pre-collegiate predictors of post-secondary performance, the attitudinal and motivational factors identified as significant predictors of success in this context are of greater practical value because such characteristics can be directly developed and enhanced in classroom instruction during the first-year introductory biology series at colleges nationwide.

**Predictors of Success among Underrepresented Minority Students (URMs)**

In accordance with previous findings (e.g., Crisp et al., 2009), my data indicate a strong association between participants’ racial/ethnic background and their performance in Principles of Biology. To further explore this relationship, I sought to identify those factors specifically influencing success among students within the study sample who self-identified as non-Caucasian. It is notable that numerous factors identified as significant predictors of performance in the comprehensive model remained significant predictors when the data were stratified by participants’ racial/ethnic status (i.e., Caucasian vs. non-Caucasian). These include: index score, self-determination, self-efficacy and grade motivation (Table 2). The repeated presence of these characteristics and attributes suggests that they might be of more global importance to student success both within and outside of the STEM disciplines. Indeed, previous research across a wide array of disciplines has indicated a strong, positive relationship between the aforementioned factors and student performance (Crisp et al., 2009; Mann & Golubski, 2013; Harrell & Forney, 2003; Toven-Lindsey et al., 2015).
The results from my study revealed interesting findings in that none of the attitudinal factors were important in predicting success among the URMs. I did not delineate the different minority groups, instead analyzing the minority students as one block, which may have had an impact on the results if attitudes varied among minority groups. There are several plausible explanations to this observation, first participation in SI sessions was an important predictor of success in biology among the URMs so that might have “taken the place” of the problem-solving attitudinal measures. Second, the sample might have been low for the URMs that there was not enough “resolution” regarding the attitudinal variables. Finally, there might not have been enough range of variation in the attitudinal measures for the URMs and, therefore, none of the attitudinal measures were predictive of success. I suggest further research with a larger URM sample size to investigate the effect of attitudinal measures on success with elimination of SI as a predictor variable.

A closer analysis of my data further reveals that, unlike the comprehensive model, dual enrollment in an active learning-based supplemental instruction course (BIO 112) uniquely explained 1.1% of the variation in URMs success. The unstandardized regression coefficient ($\beta$) for participation in BIO 112 (5.000; Table 2) indicates that the minority students’ overall course performance in cell and molecular introductory biology course increased by one-half a letter grade relative to their peers if they had concurrently completed the recitation (not enrolled in supplemental instruction course). Though the present model focuses exclusively on students identified as belonging to an underrepresented minority group, supplemental instruction (SI) has been shown to have a positive and beneficial impact on student learning across a diverse array of contexts.
(Dawson et al., 2014). Similarly, Rath et al. (2007) noted that, among URM students enrolled in SI, 80% received a passing grade ("C" or better) as compared to 55% of URM students who were not concurrently participating in the SI session. In addition, Rabitoy et al. (2015) revealed that frequency of attendance at SI sessions was a “much stronger predictor of academic achievement among the minority students in comparison with white students” (p. 9), and furthermore indicated that URM students enrolled in SI sections led by a URM leader were significantly more likely to succeed than those who were not. Though certain facets of this latter study are outside the scope of my current investigation (e.g., frequency of attendance, race/ethnicity of SI leaders), these data, in conjunction with evidence generated from my research, suggest that it is important to not only consider demographic and non-cognitive attributes of minority students themselves but also the broader contextual and instructional factors related to student success. In addition based on the effect of SI on URMs success, my findings suggest that, addressing some key factors such as (encouraging minority students to enroll in supplemental instruction courses), while students are still in college can significantly diminish the racial disparities in STEM achievement (Chang et al., 2014).

**Predictors of Success Among First-Generation Students (FGs)**

First generation students (FGs) account for approximately 15-20% of the total student body at universities nationwide (Harackiewicz et al., 2014), and represented more than one-third of all participants surveyed in the present study. Research has posited that FGs are often less likely to succeed in academe for a myriad of reasons (Harrell & Forney 2003). In an effort to contribute to this growing body of research, I sought to identify and make sense of predictors directly impacting FGs success in Principles of Biology. Similar
to both the comprehensive and URM models analyzed previously, index score, self-determination, self-efficacy and grade motivation remained strong predictors of success, explaining 6.2%, 1.7% 1.1%, and 2.1% of the variability, respectively (Table 3).

Three additional findings emerged from this analysis. First, FG students who identified as Caucasian scored approximately five percent higher overall in Principles of Biology than FG students co-classified as members of the underrepresented minorities (Table 3). These results reveals that FGs whom are also URMs stand at a disproportionate disadvantage of being successful in college science introductory courses and that more research is required to examine ways in which these students can be supported for successful navigation through science introductory coursework. The research of Harackiewicz et al. (2014) regarding the social class achievement gap in undergraduate biology revealed that minority students, whether first generation or continuing generation, performed poorer in introductory biology than those students who were majority-continuing generation. These data, as well as my own, suggest that it is imperative both from a theoretical and practical perspective to be mindful of the independent contributions of students’ generational and minority statuses when constructing social-psychological interventions as well as educational interventions aimed at reforming classroom-learning environments. Indeed, Harackiewicz and others have demonstrated that increased course structure, frequency of active learning, and focus on cross-cutting concepts in the STEM disciplines can differentially impact the achievement gap observed among students belonging to the aforementioned populations (Haak et al., 2011; Harackiewicz et al., 2014; Momsen, Long, Wyse, & Ebert-May, 2010, Ruiz-Primo, Briggs, Iverson, Talbot, & Shepard, 2011).
Second, FG students who indicated a greater enjoyment for the biological sciences were more successful in Cell and molecular biology course than those who did not. Specifically, this attitudinal factor, which reflects students’ degree of natural curiosity about the living world (Semsar et al., 2011), explained ~1.0% of the variance in participants’ final course grade after controlling for all other variables (Table 3). Importantly, this same relationship was observed for the comprehensive model, suggesting a commonality between FGs, URMs and those who are majority continuing generation. This might demonstrate an inherent desire and curiosity in pursuing careers with prospects of giving back to the community by FGs following graduation as previously reported (Harackiewicz et al., 2014). While this might be the case according to Harackiewicz et al. (2014), I acknowledge that the relationship noted in my study might also be attributable to the differences in the lived experiences of various FGs within my study sample (e.g., greater enjoyment of the biological sciences due to increased participation in pre-collegiate STEM opportunities). I argue that this is a topic that merits continued qualitative exploration in subsequent studies.

Finally, though observed to be a significant predictor previously, grade motivation was found to uniquely explain a larger percentage of variance in FGs overall success in Principles of Biology (2.1%; Table 3), as compared to both the comprehensive and URM models. There are several plausible rationales for this finding. It could simply be the case, that a disproportionate number of pre-health and/or pre-nursing majors, those individuals who, historically, have often been found to be highly extrinsically motivated due to competitive professional program admissions (Horowitz, 2009), were also first generation college students within the study sample. On the other hand, there was no
statistically significant association between students’ major and their generational status. In light of this evidence, it appears more likely, that cultural and contextual factors could have mediated the predictive relationship noted in my study. Such cultural and contextual factors might include: (a) additional pressure placed on FG students by their family, friends, and/or peers; (b) pressure FG students place upon themselves due to the belief that they must succeed in order to provide for their family; or (c) self-motivation on the part of the student to overcome the perception that they belong to a cohort of individuals that has traditionally been perceived as underperforming. Though I do not claim to provide an exhaustive list of possible explanations for this phenomenon, previous research lends credence to my assumptions. Studies conducted by London (1989) and Harrell and Forney (2003) reveal that the personal and professional experiences of first generation parents can often have dramatic negative and positive consequences on their children’s long-term educational success. Through his vignettes, London (1989) conveys the dynamism of first generation families who, on one hand, “took their child’s (completed college applications) to the post office the next morning and drove (their children to college interviews)” (p. 150), and, on the other hand, struggled with the fear of having their children lose their cultural identity and place within the family system.

In agreement with my findings, research also suggests that beliefs and attitudinal perceptions about learning biology held by FGs are predictive of their success in STEM. Harackiewicz et al. (2014) report that first generation undergraduate biology students place significantly more value on factors, such as assisting their family once they have completed college and showing others that people with their background can do well, than a similar cohort of continuing generation students. While the authors did not
explicitly measure students’ grade motivation, they note that it is especially critical that FG students have a positive experience in introductory biology, as a grade of “C” may very well indicate to them that they cannot make it in the field whereas a grade of “B” signals that they can (Harackiewicz et al., 2014). In this regard, an implicit desire to perform well in science courses, influenced by cultural and contextual factors in the individual’s environment, likely exert a gross effect on FG students’ likelihood of success in the STEM disciplines. In relation to this information, the current study explored to what extent motivational, attitudinal, educational and demographic characteristics were important for success among the first generation students.

**Implications for Teaching and Learning**

According to the report by (PCAST, 2012), student success in STEM fields appears to be paramount to the overall national agenda of combating the paucity of individuals graduating with STEM degrees. Therefore, factors associated with student success are important in informing reform strategies for success and persistence in STEM fields. Results from the present research confirm the importance of students’ index score, racial/ethnic background, and first generation status in predicting success in undergraduate biology, a finding replete in the literature (Crisp et al., 2009; Harrell & Forney, 2003; Singh & West, 2014). I believe, therefore, that my findings regarding the impact of attitudinal and motivational factors on student success, when considered in tandem with demographic and secondary achievement variables, provide more immediate and relevant implications for teaching and learning at the post-secondary level. Across both the comprehensive and first generation models, for instance, problem-solving difficulty (Table 2) and enjoyment of the biological sciences emerged as significant
predictors of course performance. Providing students with the opportunity to develop these attitudes appears to be an essential task of educators leading first-semester biology experiences. For several decades, in order to promote student success, various strategies including active learning pedagogies have been utilized (e.g., Armbruster, Patel, Johnson, & Weiss, 2009). I suggest a more nuanced evaluation of teaching strategies, including a range of pedagogies represented across the traditional-constructivist continuum, to better understand which teaching methods are ideal for different student populations.

In addition to attitudinal predictors of success, motivational factors, such as self-efficacy, self-determination, and grade motivation, were also observed to impact student performance in Principles of Biology, although to a lesser degree than those factors of demographic nature (demographic factors explained ~12% of variance in each model relative to ~5% explained by motivational factors; Table 2). While discussion of these factors, self-efficacy in particular, is widespread (House, 1995; Lawson et al., 2007), their continued significance in the present study reinforces the necessity to measure such outcomes concurrent with assessment of student learning following implementation of reformed curricula. My data reveal, for instance, that minority students’ success in Principles of Biology was predicted by co-participation in an active learning-based supplemental instruction course accompanying the lecture. Likewise, recent efforts to incorporate course-based undergraduate research experiences into the biology curriculum (e.g., Brownell et al., 2012) provide additional opportunities to assess how such interventions impact students’ attitudes and motivation in the discipline. Finally, the importance of motivational and attitudinal factors identified in this study in relation to student success raises two important questions to educators with respect to (a) How can
these factors be developed in a classroom setting? and (b) What is the role of classroom environments and instructor practices in shaping these factors?

Limitations

Despite the imperative nature of the aforementioned analyses, I acknowledge that there are limitations to the current study. First the study was conducted at a single university and, therefore, the findings may not be generalizable to other populations or other college environments. Second, the study population can be looked at as being unique in the aspect that over a third of the participants were composed of either FGs or URMs, further complicating the generalizability of the study results. In addition, constraints on participant sample size prevented further stratification of the underrepresented minority and first generation cohorts to examine unique factors contributing to student success among those subpopulations (e.g., between African American and Hispanic participants; between majority continuing generation students and majority FG students). Despite these challenges, consistent with previous research in this field (S. Freeman et al., 2007; Haak et al., 2011), the current study provides necessary future research areas with respect to students success in biology especially for educators seeking to better understand and enhance student success in introductory STEM courses. Lastly, the CLASS-Bio instrument which was used in this study to assess students’ attitudes towards biology was developed, validated and tested on individuals with Ph.D.’s within biology fields as experts in the field (Semsar et al., 2011). This was done in order to provide baseline for assessing the undergraduate responses. However the instrument does not provide information about the demographics of the experts in the biology field; therefore, since one third of participants in the current study were either
URMs or FGs, the expert responses may not perfectly align with those of the two students groups in the current study with respect to their motivations and attitudes towards biology.

**Conclusions**

1. My results indicate that motivational factors were equally important predictors of success among all the student types including both underrepresented minority and first generation students.

2. Participants’ index score, minority status and first generation status were among the top demographic predictors of performance, uniquely explaining 4.7%, 3.0% and 1% of variance in students’ course grade, respectively.

3. Attitudinal characteristics which emerged as significant positive predictors of student success were; students’ ability to apply knowledge to solve biology-specific tasks (i.e., problem-solving difficulty), explaining ~1.0% of variance, and student enjoyment of the biology major, explaining 1% of variance in students’ final course grade.

4. Motivational characteristics which were important in students’ success in biology were: self-efficacy, explaining 3.1% of variance in students’ final course grade, self-determination, predicting 1.3%, of variance in students’ final course grade, and grade motivation predicting 1% of variance in students’ final course grade.

5. Dual enrollment in an active learning-based supplemental instruction course uniquely explained 1.1% of the variation in URMs success, controlling for all other potential predictors.
6. FGs students who identified as Caucasian scored approximately five percent higher overall in Principles of Biology than FG students co-classified as members of the underrepresented minorities.

7. Finally, self-efficacy contributed highly to student success among all the factors examined.

Each of the predictors of student success in Principles of Biology demonstrated in the current study is important in its own right and educators in post-secondary institutions should strive to develop and enhance these predictors among their students. If students are to excel in biology as a STEM field, then they need proper motivations and positive attitudes to encourage them to prepare for class and participate in class activities. By enhancing students motivations and attitudes, and taking into consideration the specific motivational and attitudinal factors important for URMs and FGs success may be a step forward in addressing the critical problem of success in STEM fields in general. The current study indicates that the impact of attitudinal and motivational factors on student success, when considered in tandem with demographic and secondary achievement variables, provide immediate and relevant implications for teaching and learning at the post-secondary level. In conclusion, though each of the independent models presented explains approximately 50% of the variance observed in participants’ overall course performance in Cell and molecular biology course, it is necessary to consider what factors are contributing to the remaining 50% of variance that is currently unexplained. One perspective would be to examine students’ prior attitudes and motivations towards learning biology and perform student matching in an effort to minimize confounder effects.
CHAPTER III

QUANTITATIVE EXAMINATION OF MOTIVATIONAL, ATTITUITIONAL, DEMOGRAPHIC AND EDUCATIONAL PREDICTORS OF STUDENT PERSISTENCE IN BIOLOGY FROM TWO INTRODUCTORY BIOLOGY CLASSES

Abstract

While the total number of undergraduate degrees awarded annually has nearly tripled over the past 40 years, the same cannot be said for the proportion of the degrees in Science Technology, Engineering and Mathematics (STEM) fields. The U.S. share of the world’s STEM graduates is sharply declining, on average less than 40% of incoming college freshmen elect to pursue a degree in a STEM field each year, with more than half of those individuals declaring a major in the biological sciences or a closely related area (e.g., pre-medicine, pre-health or nursing). Graduates in STEM fields are important in maintaining the U.S. economy and technological innovations. The current study examines the impact of motivational and attitudinal factors alongside with demographic and secondary characteristics in relation to students’ persistence in biology among students enrolled in two introductory biology courses (Principles of Biology and Organismal Biology) at a mid-size research and teaching university. Additionally, the study examined to what extent do motivational and attitudinal factors examined in tandem with demographic and secondary characteristics differentially predict persistence among under represented minority and first generation students. A Generalized Linear Mixed Model (GLMM) was utilized for data analysis. Results indicate that self-efficacy
and grade motivation were the important motivational factors predicting students’ persistence in biology. The attitudinal characteristic which was important for students’ persistence was strategies for solving biology problems. Additionally, students’ final percent course grade in introductory biology courses also emerged as a significant predictor of student persistence in biology. Interestingly, the first generation students were more likely to persist in biology compared to continuing generation students while the minority students were less likely to persist in biology compared to majority students. This work contributes to our understanding of factors related to students’ persistence in biology, suggesting that developing and nurturing positive attitudes alongside with meaningfully engaging students in solving biology related problems appears to be an essential task of educators leading first-semester biology experiences. Approaches geared towards increasing student success in introductory courses are essential in students’ persistence in specific majors. Finally the results suggest that different ways of retaining underrepresented minority students in science are needed.

Introduction

Science, technology, engineering, and mathematics (STEM) fields are widely recognized as crucial for the U.S. economy and scientific innovations. Producing adequate numbers of graduates who are well prepared for STEM occupations has become a national priority. While the U.S. has long been held as the global scientific and technological leader, with a pre-eminent market economy giving the U.S. a competitive advantage within the worlds’ economies (R. B. Freeman, 2006), it is facing severe international competition in producing the STEM graduates (National Science Board 2010). Many students enter post-secondary institutions with an initial interest in a STEM
field but leave STEM degrees by either switching to a non-STEM degree or leaving college without earning a degree within the first two years of college (Chen, 2013). Economic models predict that, an additional one million graduates in STEM are required above the current production rate (President’s Council of Advisors on Science and Technology [PCAST], 2010; 2012). Graduates in STEM fields are important in maintaining the U.S. position as the world’s leader in science and technology (Hira, 2010; Tovien-Lindsey et al., 2015). The U.S. share of the world’s STEM graduates is sharply declining; on average, less than 40% of incoming college freshmen elect to pursue a degree in a STEM field each year (Chen, 2013; Higher Education Research Institute [HERI], 2010), with more than half of those individuals declaring a major in the biological sciences or a closely related area (e.g., pre-medicine, pre-health or nursing). In addition, the cohort of students entering college initially interested in STEM have relatively high levels of preparedness as indicated by above average scores on standardized tests, such as the Scholastic Aptitude Test (SAT) and American College Testing (ACT), collectively known as index score, as well as exemplary success in secondary science courses (Enman & Lupart, 2000). However, among the undergraduates who initially undertake coursework leading to a bachelor’s degree in STEM, less than 60% persist in those majors, with highest attrition rates observed at the end of the first semester (Maltese & Tai, 2011). The attrition rates continue up to the end of the second academic year as students choose to pursue non-STEM disciplines or leave college without earning a degree (Chen, 2013). This, in turn, urges us to consider why this may be the case and what factors might be contributing to high rates of departure within this population.
The phenomenon of students’ departure from sciences is an ill-structured problem (Braxton & Mundy, 2001) that defies a single solution and necessitates multifaceted approaches. The biological sciences, in particular, suffer the greatest from this phenomenon, with a less than 50% retention rate observed across a four-year time span (Rask, 2010). Despite the fact that biological sciences bears the highest attrition rate among all STEM disciplines (National Science Board [NSB], 2012; Rask, 2010), there are no studies which have focused on examining factors associated with student attrition from biology with respect to the impact of motivational and attitudinal factors in tandem with demographic and pre-college characteristics. In this research, I examined factors associated with persistence in biology within the first two years of college. In this context, persistence was defined as student enrollment into biology courses at the start of the fall semester of the first year through the second year.

**Concerns of Students’ Attrition from Science Technology Engineering and Mathematics Fields**

Student attrition from institutions of higher education has been a matter of concern for educators for several decades (Braxton, 2000). In spite of this, knowledge about student attrition processes, especially from the sciences, is limited (Braxton & Hirschy, 2005). The continued growth in demand for STEM graduates in the STEM workforce coupled with student attrition from those fields makes the subject of student persistence in sciences of particular concern (National Science Foundation [NSF], 2004; NSB, 2007). Estimates by the U.S. Bureau of Labor indicate a threefold growth in the number of jobs in science careers compared to other non-science professions (Langdon et al., 2011). Due to variations in data collection, the number of students retained in
sciences is particularly hard to articulate, but studies that track individual students for retention, are usually more effective (U.S. Department of Education, 2013). Additionally, there is a broad consensus that science students experience higher attrition rates than other fields, while underrepresented minority students (URMs) have higher attrition rates compared to majority students (Smith, 2000). Additionally, the first generation students (FGs -students whose parent/s do not have a four year college degree) have also been shown to have low retention rates in sciences (Choy, 2001). Institutions of higher education are especially interested in understanding why highly qualified undergraduate students choose to leave sciences for non-science majors and, therefore, it is imperative to examine the factors that influence students’ decisions to leave science.

**Importance of Persistence in Biology Among the Underrepresented Minority Students’**

Building a diverse STEM workforce is increasingly important, especially in sustaining the U.S. economic strength and productivity (Jones et al., 2010). Traditionally, the U.S. STEM workforce has been dominated by White and non-Hispanic men. For example, in 2000 Whites occupied 75% of all physical and life science careers, while Asian occupied 16%, and Hispanic and African Americans each occupied 3% (NSF 2004). The U.S. Census Bureau indicates that by the year 2050 White males are estimated to be 26% of the overall workforce (Day, 1996), while in 1997 they represented nearly 70% of the STEM workforce (Day, 1996). This is expected to leave a big gap in the U.S. STEM workforce, which will need to be filled (Figures 4, 5, and 6). Non-white men form an untapped reservoir of talent that could possibly be developed to add to the STEM workforce (George et al., 2001). Underrepresented Minority students (URMs) also
present a good reservoir for STEM jobs, and need to be encouraged to persist in STEM majors. Traditionally, URMs have lower graduation rates in physical and life science’s compared to Whites and Asians, despite the increasing enrollment among URMs in institutions of higher education (Lewis et al., 2000, U.S. Department of Education, 2013). Previous research shows that non-Asian URMs are as interested in pursuing science as their Asian and White peers (Elliott et al., 1996). In addition, the attitudes toward science of African American students are more positive compared to those of White students, when holding other factors constant (Elliott et al., 1996). However, despite the demonstrated interest in science among URMs, White males have dominated science careers for a long time, and only a few such careers are occupied by URM groups (George et al., 2001; NSF 2004). This is because despite the increased enrollment among URMs in colleges and universities (Jones et al., 2010), they have continued to have low graduation rates in science majors in comparison with Whites and Asians (Lewis et al., 2000; U.S. Department of Education, 2013). In the year 2000, only 2.5% of URMs earned bachelors’ degrees in natural sciences compared to 6% of White students (NSB, 2004). As the U.S. rapidly becomes a multiracial society, the current ethnic/racial gap in STEM degree completion rates predicts a deficiency in ethnic diversity among STEM workers (George et al., 2001; NAS, 2005). Furthermore, despite the changing demographics in the U.S., the participation of the URMs in STEM have remained low and they often have low persistence rates (Fries-Britt et al., 2010). For example, while African American, Native Americans, and Latinos make up over 30% of the undergraduate student population in the U.S., less than 12% of degrees in sciences are awarded to individuals from these racial groups (Frehill, Di Fabio, & Hill, 2008).
Figure 4. Racial distribution of Science Technology Engineering and Mathematics doctoral degrees in 1997 (Day, 1996).

Figure 5. Racial distribution of the United States Science Technology Engineering and Mathematics workforce in 1997 (Day, 1996).
Figure 6. Projected declining population of the Whites in Science Technology Engineering and Mathematics workforce between 1995 and 2015 (Day, 1996).

Efforts to increase the number of the URMs in undergraduate science programs is one practical way of increasing the proportion of the STEM workforce currently dominated by White males. Unfortunately, this solution is a major challenge to many institutions of higher education because few URM groups persist and graduate with STEM degrees nationwide (Markley, 2005).

Biology is a popular major (Lang, 2008; Princeton Review, 2007,), constituting the largest part of natural science undergraduate degrees (NSB, 2008). However significant ethnic differences exist in biology at the undergraduate level (NSB, 2008; NSF, 2004); these differences continue to be exaggerated at higher levels of degree attainment from undergraduate through doctorate level. For example, even though URMs obtained 13% of undergraduate degrees in biology, they only earned 8% and 5% of masters and doctoral degrees, respectively (Jones et al., 2010). These data shows that if
appropriate precautions are not taken to address the racial discrepancies then, the labor pool in biology may continue to diminish in diversity. A report by the National Academy of Sciences (NAS, 2005) entitled “Expanding underrepresented minority participation: America’s Science and Technology Talent at the Crossroads,” demonstrates that the projected growth in new jobs will require STEM skills and that URM groups have the highest growth rate in the general population. Moreover, the current number of URMs in sciences needs to be tripled in order to balance their proportion in the general population (NAS, 2005).

The strategies to reform STEM education have faced the challenge of creating meaningful and productive learning opportunities accessible to a wide range of students (Talanquer, 2014). The National Academy of Sciences (NAS) recommends a near-term goal of doubling the overall number of URMs in sciences in order to achieve long-term equality in the training of a diverse workforce (NAS, 2005). In general, these reports suggest that the underrepresentation of minority students is not due to a lack of interest in sciences, rather it because of a decline in completion rates of science degrees (A. C. Johnson, 2007).

In an effort to reduce the existing gaps in enrollment, success and retention within various student population groups, it is important to unearth and understand the kind of predisposing factors that impact the URMs inclination and tendency to learn. Researchers suggest that it is important to purposively design studies that explore similarities and differences within different racial student groups or by use of analytical methods, which allow the disaggregation of data to investigate how different factors affect different student groups (Lopez et al., 2013). These recommendations by extension point to the
need to investigate the specific factors that are important for persistence in STEM majors among the URMs.

Results from different studies attribute the high attrition rates among URMs in sciences to multiple factors. According to Graham et al. (2013), factors such as early research experiences, establishment of learning communities, and active learning in science introductory courses are critical components for effective learning, especially among URMs. Feeling like a scientist is essential for promoting success and persistence among URMs in sciences. However, research shows that competitive and unfriendly learning environments in science introductory courses can be a major drawback to persistence of URMs in STEM (Fries-Britt et al., 2010; Seymour & Hewitt, 1997). It follows that studies focusing on examination of predictors of success and persistence among the URMs in introductory core science curriculum can be an essential component in contributing to the much-needed STEM graduates nationwide (PCAST, 2012).

**Factors Associated with First Generation Students Persistence in Science Technology Engineering and Mathematics**

Research into higher education has widely documented that being a First Generation (FG) student is an impediment to degree achievement due to a variety of challenges (Choy, 2001). First generation students are also less likely to persist in academe, even after controlling for factors such as; income, educational expectations, peer influence, academic preparation and parental involvement, the level of parents education was a predictor of student admission to four year degree colleges and ultimate persistence towards degree completion (Choy, 2001). On the other hand studies suggest that, FGs persist in college, their academic success in terms of writing, reading, critical
thinking, candidness and comprehension skills match those of non-FGs. Although the FG populace is regularly thought-of as a subgroup with special needs, in most four-year institutions and community colleges, at least half of their incoming students are made up FGs (D’Amico & Dika, 2013). With an increasing population of FGs in institutions of higher education, it is important for education researchers to investigate the predictors of success and persistence among the FG population. In addition, many FGs also happen to be minority students, who have to deal with issues of racial isolation (Richardson & Skinner, 1992). The following paragraphs focuses on the literature regarding the barriers to success and persistence in college among the FGs.

**Cultural shift.** Foundational studies indicate that as FGs begin postsecondary studies they face a myriad of challenges with respect to cultural shift (London, 1989; Terenzini et al., 1994). For FGs, attending college is associated with a departure from the norms and patterns previously established by family and friends, who may in turn become non-supportive because of non-familiarity with college life (Hsiao, 1992). First Generation students (FGs) face confusion, opposing views from both the home and collegiate cultures, and isolation (London, 1989). As they advance in their educational careers, they lie on the margins of different cultures becoming less sensitive to their customary place within the family setting, and at the same time not quite fitting into the institutional lifestyle (London, 1992). FGs not only confront the concerns of dislocations, and the difficulties faced by other college students, their experiences often involve substantial social, academic and cultural transitions. Terenzini et al. (1994) found that the disparities between college and home environments results in both FGs failing to establish strong bonds with college friends and also losing high school friends. The
negotiation of the rigor of the college classroom by FGs may also be limited by their cultural shift. Based on Collier and Morgan (2008), gaining an understanding of the role of a college-student is a cultural capital (i.e., a non-financial asset that promotes social mobility beyond economic means), and FGs may face more challenges in grasping this new role and understanding the expectations from the faculty compared to their non-FGs peers.

**Financial issues.** Compared to their peers, FGs face unique financial difficulties that are likely to impede their academic progress. FGs are less likely to receive financial support from parents, tend to be older and are more likely to have multiple financial obligations outside college, which tend to limit their full participation in the college experience (Engle & Tinto, 2008). All these factors together lower FGs' chances of persisting in college to graduation. Due to limited resources and low-income, FGs are more likely to work full-time while taking part-time classes, and live and work off-campus, limiting the amount of time they spend on campus. In addition, research shows that there are unmet financial needs for FGs, that remain even after applying for financial aid (Lewis et al., 2000). Consequently, FGs work and borrow money, which has negative consequences with respect to their college completion. Similarly, results from the Volle & Federico (1997) showed that a majority of FGs were financially independent compared to their peers. FG students are also likely to have financial dependents, resulting in more financial responsibility while in college (Inman & Mayes, 1999).

**Academic factors.** Prior educational background is important in the studies of predictors of success and persistence in college (e.g., Lotkowski et al., 2004). A majority of research highlights that as FGs transit from high school to college they have lower
levels of academic preparation as indicated by their SAT/ACT scores and high school GPA (Martin Lohfink & Paulsen, 2005; Martínez et al., 2009). Higher levels of prior educational preparation has been associated with an increased likelihood of college success and persistence among FGs (Ishitani 2006; Warburton et al., 2001). Other studies, which control for prior academic preparation show that FGs can attain similar levels of academic success as their peers (Brown & Burkhardt, 1999). Overall, the weight of evidence indicates that, compared to their peers, FGs present a distinct disadvantage with respect to success and persistence in college. In general, FGs students are often less prepared academically for college coursework than their peers. Furthermore, FGs often have insufficient knowledge with respect to time-management techniques and the economic realities of college life (Rivera, Sarete, & Wiggam, 2013).

Research into Departure from Science Technology Engineering and Mathematics Fields

Research on students’ departure from STEM sciences faces two challenges discussed in detail below that have some bearing on my research. First, there exists a connotation at institutions of higher education that it is okay for students to leave STEM sciences; this is based on the concept of weeding-out students who are ill prepared to handle sciences (Seymour & Hewitt, 1997). Second, research into students’ attrition from sciences have overlooked the reasons as to why certain students persist in STEM sciences and have focused more on why students leave sciences, rather than the more important question of what leads students to persist.

The weeding-out of the ‘lazy students’ in sciences by faculty and institutions of higher education has traditionally been practiced (Seymour & Hewitt, 1997). In their
study on why undergraduate leave sciences, Seymour and Hewitt (1997) noted that the departure from sciences by a substantial number of students was part of a “weed-out” approach within institutions of higher education. Based on this approach it appears that the focused rigor of the introductory science courses is not only to sufficiently train students for advanced coursework, but also to eliminate the seemingly academically underprepared students from science majors. Seymour and Hewitt (1997) described this as “cruel to be kind” (p. 393), a kind of measure of “weeding out” students by letting them figure out that they are in the wrong major early. This prevents them from wasting time and effort in working toward a career path they are not adequately prepared for. Based on this assumption, is the notion that students willingly leave sciences due to interest in other majors or due to poor achievement, as opposed to being pushed out of the sciences for reasons beyond their control. This becomes a self-sustaining cycle, whereby faculty who approve this belief educate students whom in turn embrace the same belief. The major drawback with this theory is that it makes research into students persistence in science seem pointless, this is because it makes the faculty believe that student weed out is normal, while education researchers view it as an intricate matter. Consequently, a majority of previous research in the area has focused on the institutional reasons as a basis for students’ departure from sciences (Seymour & Hewitt, 1997; Strenta et.al., 1994). Surprisingly none of these studies involved average and below average-performing students, therefore, this weakens the effect of achievement and capability in the switching choices. For example in the Seymour and Hewitt’s (1997) study, they chose only the high performing students as characterized by a math SAT score of 650 or higher. This kind of research bias presumes that STEM sciences are a
preserve of the high performing students. This bias leads to researchers ignorance of two critical groups of students: students who leave their science majors due to poor or average and below average achievement and those students who persist in their science major despite poor or average and below average achievement.

Previous studies (e.g., Lang, 2008) show that students who persist in the sciences have plenty of reasons to leave their respective science majors just like their peers who switch from sciences. Therefore, it is critical to understand and systematically explore the dynamics of students’ departure from sciences. As Tinto (2012) points out, knowing why some students’ leave sciences does not translate into knowing why others persist, and that the process of leaving is not a mirror image of the process of staying in sciences.

**Undergraduate Attrition from Sciences**

To provide more background through literature review, in this section the following aspects related to students attrition from sciences will be discussed: 1) Students persistence in biology 2) Pedagogical learning styles and retention and 3) Climate and belonging. The three aspects discussed are by no means exhaustive of all the factors which play into students switching decisions from sciences.

**Students’ persistence in biology.** Our general understanding of the processes of students’ persistence and attrition within biology is informed by Seymour and Hewitt’s (1997) study on why undergraduates leave sciences. Their study identified different categories of students, including those who leave biological sciences due to disappointment with the curriculum and those who leave due to failure to cope with competitive learning environments coupled with loss of academic self-confidence. Studies on students persistence in biology cite attrition from biology as the largest within
the STEM sciences (Rask, 2010). In his study on the impact of college environments on the educational pipeline in the sciences, Astin (1993), showed a 57.5% drop in the number of undergraduate biology majors between freshman and senior years of college, with the majority of the leavers switching to non-STEM disciplines. Likewise, a report by the NSB (2008) indicated a 51.1% decrease among the 115,300 biological science majors who had began college in 1995. Similarly, at the University of Texas, among the undergraduates who started college as biology majors in the fall semesters of 2000 through 2002 and persisted through to degree completion, the retention rate in biology major was 55.2% (Lang, 2008). Nevertheless, biological sciences comprise the largest portion of science undergraduate degrees (NSB, 2008). Attrition from biological sciences presents a complex case because students’ departure from the major is camouflaged by a concurring front-loading of freshmen into the major (Lang, 2008). This is likely due to students’ general acquaintance with biology, combined with the appeal of the wide medical professions associated with a biology degree.

**Pedagogical, learning styles and retention in science majors.** Research cites instructional strategies used by some faculty as one of the reasons that students turn away from STEM sciences (Blickenstaff, 2005). The format of lectures in a majority of science classrooms, especially in introductory classrooms, are unfavorable because they build barriers between instructors and students. The unwelcoming learning environments in science classrooms detach students from the sciences. This can be evident as expressed by African-American female students in A. C. Johnson’s (2007) study regarding how science instructors unintentionally discouraged them from continued enrollment and participation in science classrooms. According to these students, both the lecture format
and the competitive nature of science classrooms distanced them from the instructor and science courses in general. Similarly, in J. G. Robinson and McIlwee’s (1991) research pertaining to the culture of engineering, women study participants raised negative impacts of the competition in engineering classrooms.

The typical instructional approaches prominent in a majority of STEM science classrooms may not be consistent with different learning approaches utilized by students. Bernold, Spurlin, and Anson (2007) followed a cohort of freshmen in an engineering program for a period of 3 years, analyzing the relationship between student learning styles, GPA, persistence, gaining an entry into an engineering major and success in first year courses. Their results suggested that, students who possessed a learning style oriented towards conceptual understanding and real world applications had higher grades and exhibited low attrition rates from the program compared to students who exhibited surface learning styles characterized by rote memorization of facts (Bernold et al., 2007). On the other hand, closely related to the teaching style in science classrooms, students’ ease of approaching an instructor for either social or academic support contributes to students’ overall evaluation of sense of belonging in science majors, and ultimately, likelihood of being successful and persisting in these majors. These results suggest a couple things, first the importance of aligning instruction approaches with students learning styles and development of students critical thinking along with fostering positive learning environments in science classrooms may foster student success and persistence (S. Freeman et al., 2014).

The “climate” in STEM majors and the feeling of belonging. “Climate” in the classroom can be defined as the emotional, physical and social aspects of the classroom.
The aspect of classroom climate mainly focuses on the interactions that take place between and among students and the instructor. The climate in science learning environments has been associated with student’s feelings of belonging or lack of it, and in turn this has the potential to foster or deter students’ persistence in those majors. Previous studies have described the climate within STEM disciplines as “chilly” and competitive, characterized by unwelcoming learning environments (Sandler, Silverberg, & Hall, 1996; Seymour & Hewitt, 1997). Generally, such learning environments have been associated with differential treatment of men and women, with adverse effects on women in particular. Largely, the interactions between the faculty and students are part of the critical aspects of climate and have potential impact on student persistence.

Studies on faculty-student interaction indicate that distant student-faculty relationships have adverse effects on student GPA, self-efficacy and academic confidence, which potentially impact student retention in their specific majors (Vogt, 2008). Similarly, Seymour and Hewitt (1997) associated the high attrition rates in science majors, in part, with the lack of faculty-student interactions due to faculty unavailability to students. As the hypothesis of the chilly climate proposes (Seymour & Hewitt, 1997), faculty interactions with students may be perceived as discriminatory among diverse undergraduate student groups. For example DiAngelo’s (2006) study showed that instructors’ marginalization of students of color and female students involved predominantly Asian students. On the other hand, Walden and Foor (2008) found that a majority of immigrant women students in an engineering program mentioned a friendly climate as an important influence on their choice to transfer into industrial engineering from other STEM sciences. Ultimately, student-instructor interactions are important in
STEM sciences especially where instructors provide recommendation letters to students alongside provision of academic research opportunities essential for professional progression (A. C. Johnson, 2007).

**Research Questions**

The following two research questions formed the focus of the students’ persistence section of this dissertation.

Q3 What demographic, attitudinal, and motivational factors are predictive of persistence (enrollment into biology coursework into second year) for students enrolled in introductory biology courses (Principles of Biology-Bio 110 and Organismal Biology-Bio 111) within the first two years of college?

Q4 To what extent do these factors differentially predict persistence among the underrepresented minority and first generation students within the aforementioned cohort?

**Description of the Study**

In this study the main focus was to examine undergraduates’ persistence in a Biology program into the second year based on two biology introductory courses. The two introductory courses are a requirement for a Biology degree but students are not strictly required to take both courses within the first year of college. Students in the study institution traditionally take Principles of Biology within the first year because it is a prerequisite for many required upper level biology courses.

**Methods**

The overarching research questions asked in this study sought to determine the predictors of students’ persistence in biology. This study received University of Northern Colorado Institutional Review Board Approval (IRBNet ID# 494383-9; Appendix B). Data were collected from participants who consented to participate; the participants
consent form can be found in appendix section (Appendix A). Explanatory variables including students’ attitudes (e.g., enjoyment in biology and problem solving effort), motivational factors (e.g., grade motivation and self-efficacy), and student demographic characteristics (e.g., gender and index score), were examined in relation to the variance explained by student persistence in biology. In addition, students’ percent final course grade in the biology introductory courses was used as an additional predictor variable. The cell and molecular biology course was taught by two instructors divided into three sections (with one instructor teaching two sections, and the other one teaching one section), during the semesters: Fall 2013, Spring 2014, and Fall 2014. In total, the study covered a maximum period of 3 consecutive semesters. The organismal biology course was co-taught by two instructors during the semesters: Fall 2013, Spring 2014, Spring 2015 and Fall 2015, where by one instructor taught the course during the first half of the semester and the other one taught the course over the last half of the semester. In total the study covered a maximum period of two years (Fall 2013-Spring 2015).

Participants

There were several inclusion and exclusion criteria for the study participants. First, the participants needed to be biology majors, this was important in order to examine the persistence rates in biology major in particular. Second, the participants needed to have been freshmen, this was important in order to assess persistence rates into the second year. Finally, the study participants needed to have successfully completed all the two study survey instruments.

The study participants included students enrolled in two introductory biology courses (Principles of Biology and Organismal Biology), at a mid-sized Rocky-Mountain...
University. The study sample size was distributed among the study semesters as follows; Fall 2013 \((n = 70)\), Spring 2014 \((n = 54)\), Fall 2014 \((n = 89)\), and Spring 2015 \((n = 50)\). The total sample size was \((n = 263)\), of the original sample size of \((N = 1093)\) participants. Majority of the participants, were female (66.9%), while the rest (33.1%) were male, over one third of the participants were first generation students (34.2%), while 30.4% belonged to members of the underrepresented minority groups in sciences. From the original sample size, 830 potential participants were listwise deleted from the analysis for not having met the four inclusion criterion: being freshmen, being biology majors, being within the study period, and having completed data for all variables included in the final model. At the institution at which the study was conducted a majority of students are traditional students with about a third of students being either first generation students (FG) or Underrepresented Minority (URM) students. Participation in the study was entirely voluntary as specified by the guidelines for research with human subjects (Appendix A) and, therefore, participation was not based on any factors such as demographic characteristics.

**Descriptive Statistics**

The 263 surveys in these data came from students enrolled in two introductory biology courses. A majority of study participants (66.9%) were female, while slightly over a third (33.1%) was male (Table 5). The age of the study participants ranged from 17 to 28 years. In this study, over one third (34.2%) of the participants were first generation students, while almost an equal number (30.4%) of the participants were underrepresented minority students.
The Study Context

In the study institution, the total undergraduate student enrollment is about 10,000, with one third of undergraduate enrollment in the College of Natural and Health Sciences (NHS). The School of Biological Sciences (SBS) is one of the largest among the science programs with respect to student enrollment, with about 500 students. This number is spread out among the four areas of emphasis; Pre-Health and Biomedical Sciences, Cell and Molecular biology, Ecology and Evolutionary Biology, and Secondary Teaching, with a majority of students being enrolled in Pre-Health and Biomedical Sciences. The Principles of Biology course is a prerequisite course for a variety of majors, while the Organismal Biology course is only a requisite for biology majors. The two courses are offered year round, but enrollment fluctuates with the highest enrollment occurring in the fall semester for Principles of Biology and the spring semester for Organismal Biology. Both courses are 16-weeks long, taught for a 50-minute period three times a week with a separate three-hour laboratory component per week. In both courses over 40% of students’ who attain a grade of B graduate with a biology degree at the study institution, making these two introductory courses crucial for research examining predictors of student persistence in biology especially at the study institution.
Table 5

Descriptive Data Regarding Research Participants

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Table 5 (continued)

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<td>Extracurricular Participation (Hours per week)</td>
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<td>20 or more hours</td>
<td></td>
<td>8.4%</td>
<td>6.3%</td>
<td>5.6%</td>
</tr>
<tr>
<td>10-19 hours</td>
<td></td>
<td>10.3%</td>
<td>13.8%</td>
<td>17.8%</td>
</tr>
<tr>
<td>1-9 hours</td>
<td></td>
<td>32.3%</td>
<td>35.0%</td>
<td>32.2%</td>
</tr>
<tr>
<td>Not participating in extracurricular activities</td>
<td></td>
<td>42.2%</td>
<td>38.8%</td>
<td>37.8%</td>
</tr>
</tbody>
</table>

*Note. URMs = Underrepresented Minority Students*

**Data Sources**

**Course grade.** One of the data sources was students’ success in cell and molecular biology course. In this study, success was defined as students’ numerical final course grade (percent course grade) as an outcome continuous variable with values ranging between 0-100. The percent course grade was preferred over student letter grade because it was able to show variations in performance from student to student.

**Supplemental instruction.** Under this study, supplemental instruction represented a support course for cell and molecular introductory biology course. The instruction in this course assumes some level of active learning, where by students are engaged in various aspects of problem solving. Additionally, students enrolled in this course are also equipped with study skills. Students had a choice of either enrolling into the course or not.
**Demographic information.** With their consent, participants were asked to provide information regarding their gender, race and ethnicity, first generation status, and participation in extracurricular activities. Additional student data, including students’ index score (composed of students’ high school GPA, SAT and ACT scores) and freshmen status (whether they were first years or not), were obtained through the universities institutional reporting platform.

**Colorado Learning Attitudes About Science Survey (CLASS-Bio).** To assess the relationship between students’ attitudes about learning biology and overall course performance, participants were asked to complete the Colorado Learning Attitudes about Science Survey-Biology (CLASS-Bio; Semsar et al., 2011; Appendix C). Initially, the survey instrument was developed to assess students’ perceptions about biology based on a novice-expert continuum (Hammer, 1994). The instrument serves as a non-course specific assessment of students’ perceptions toward biology (Semsar et al., 2011). This instrument consists of 31, Likert-item questions with responses ranging from Strongly Agree to Strongly Disagree. The 31 Likert-item questions were designed to test the seven constructs of students’ attitudes towards studying biology: real world connections, problem solving difficulty, enjoyment, problem-solving effort, conceptual connections/memorization, problem-solving strategies and reasoning. The questions were designed to examine the degree to which students agree with expert responses on the seven constructs described above in the biology domain. When the CLASS-Bio instrument was initially developed and validated, it was tested on both undergraduate biology major students and persons with Ph.D.’s within biology fields. Responses from persons with Ph.D.’s in biology were considered to be the “expert” responses. The idea
behind the design was to be able to determine how students think about biology in comparison to an individual considered an expert in biology. A favorable score was given to students in questions where their response was comparable to that of the experts. For instance, if the experts strongly disagreed and the student also strongly disagreed (or vice versa), then the student response was counted as favorable. On the other hand an unfavorable score was given to students in questions where their response was not comparable to that of the experts. For instance, if the experts strongly disagreed and the student strongly agreed (or vice versa), then the student response was counted as unfavorable. During the initial instrument validation process, students’ qualitative interviews indicated a wide variation in the reasons for either choosing Agree versus Strongly Agree or Disagree versus Strongly Disagree between individual students. For this reason, during the analysis of student responses, responses such as; Agree and Strongly Agree were coded equally as well as responses such as Disagree and Strongly Disagree. In this respect, data in this dissertation was coded in a similar manner. The statistics of instrument reliability are: percent-favorable, $r = 0.97$ percent neutral responses, $r = 0.91$, and percent unfavorable, $r = 0.97$.

Science Motivation Questionnaire II (SMQ II). During the same class meeting, students were also asked to complete a modified version of the Science Motivation Questionnaire II (SMQ II; Glynn et al., 2011; Appendix C), in which the term “science” was replaced with the term “biology” so as to eliminate ambiguity in the scientific discipline being referenced. The SMQ II, was developed to assist instructors in understanding which students’ lack motivation and why, in learning science. This diagnostic consists of 25 Likert-item questions, with five questions under each of the five
constructs testing different dynamics of students’ motivations: intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation.

The two validated study instruments (CLASS- Bio and SMQII), were selected for use because they were explicitly designed to measure attitudinal and motivational variables shown to impact student success across STEM disciplines. Both surveys were administered during the second to last week of the semesters in order to best capture students’ views about biology after they had acclimatized to the college environment, rather than based on pre-existed beliefs regarding their high school biology experiences.

Survey items were administered in one, 45-minute block at the beginning of a laboratory period. Students recorded their responses directly on a Scantron form. The Scantron data were entered directly into SPSS vs. 23 (IBM®) for analyses. The Science Motivation Questionnaire II instrument reliabilities (internal consistencies) of the scales as measured by Cronbach’s alphas, were as follows: self-determination (0.88), intrinsic motivation (0.89), career motivation (0.92), grade motivation (0.81), and self-efficacy (0.83).

The Outcome Variables

In this study the response variable was a categorical outcome variable with two options (persistence and non-persistence coded as 1 or 0, respectively). Persistence was defined as the overall retention in the biology program measured by registration for biology course-work during the fall semester into sophomore year, i.e., fall 2014 and fall 2015, while non-persistence was defined as non-enrollment into biology major courses in the fall of the sophomore year.
Analysis

**Paired t-test.** In this study, there were a total of 263 participants and among these, 69 participants were in the data set twice as a result of either taking both of the introductory courses or taking either of the two courses twice. Due to some participants appearing in the data set twice, a paired t-test was performed in order to examine if there were significant differences in the response variable between the two data observation points. The results from the Paired t-test (Table 6) indicated that there were indeed statistically significant differences in the response variable among the two data observation points (Table 6). These results confirmed that it was not appropriate to proceed using a standard multiple logistic regression approach, because the assumption of independent observations would have been violated. Therefore, Generalized Linear Mixed Model (GLMM) was applied with the whole data set \((n = 263)\).
Table 6

*Paired t-test Samples Correlations for Individuals in Data Set Twice*

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>N</th>
<th>Correlation</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Intrinsic Motivation</td>
<td>69</td>
<td>.584</td>
<td>0.000</td>
</tr>
<tr>
<td>2. Intrinsic Motivation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Index Score</td>
<td>69</td>
<td>0.759</td>
<td>0.000</td>
</tr>
<tr>
<td>2. Index Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Problem Solving Difficulty</td>
<td>69</td>
<td>0.624</td>
<td>0.000</td>
</tr>
<tr>
<td>2. Problem Solving Difficulty</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Career Motivation</td>
<td>69</td>
<td>0.453</td>
<td>0.008</td>
</tr>
<tr>
<td>2. Career Motivation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Self-Determination</td>
<td>69</td>
<td>0.39</td>
<td>0.023</td>
</tr>
<tr>
<td>2. Self-Determination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Self-Efficacy</td>
<td>69</td>
<td>0.538</td>
<td>0.001</td>
</tr>
<tr>
<td>2. Self-Efficacy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Grade-Motivation</td>
<td>69</td>
<td>0.539</td>
<td>0.001</td>
</tr>
<tr>
<td>2. Grade Motivation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 8</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1. Enjoyment</td>
<td>69</td>
<td>0.254</td>
<td>0.035</td>
</tr>
<tr>
<td>2. Enjoyment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 9</td>
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<td></td>
<td></td>
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<tr>
<td>1. Problem Solving Strategies</td>
<td>69</td>
<td>0.275</td>
<td>0.022</td>
</tr>
<tr>
<td>2. Problem Solving Strategies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent Variables</td>
<td>N</td>
<td>Correlation</td>
<td>P</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----</td>
<td>-------------</td>
<td>-----</td>
</tr>
<tr>
<td>Pair 10</td>
<td>69</td>
<td>0.246</td>
<td>0.042</td>
</tr>
<tr>
<td>1. Reasoning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Reasoning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Generalized Linear Mixed Model (GLMM).** The GLMM model is an extension of the Multiple Linear Regression (MLR) model, which takes care of the independency problems in repeated data sets (non-normal distribution). The GLMM procedure assumes that all the responses are normally distributed, it also incorporates a random effect, therefore, allowing for both subject–specific (conditional) and population-averaged (marginal) inference. The GLMM is advantageous because it has higher power since all the observations are considered in the analysis at the same time. In addition, GLMM also offers more advanced options. All the random components are modeled through the RANDOM statement. The analytical procedure utilized allowed for the consideration of the contribution of each individual predictor variable included in the model in explaining the variance of the categorical dependent variable (persistent or non-persistence). Additionally, the analytical procedure produced the least squares of means for all the categorical variables included in the model, (generational status and minority status), this enabled the comparison of the categorical variables with respect to their importance in students persistence in biology. The least squares of means are equivalent to post-hoc analysis, which investigates the differences between groups.
Results

Predictors of Persistence for All Students

In order to examine the factors impacting student persistence, the binary response variable (persistence in biology or non-persistence) was modeled as a linear combination of all the predictor variables (demographic data; students final percent course grade and the scores obtained from each of the twelve scales represented on the CLASS-Bio and SMQ II survey instruments), with a one single analysis. In this study, the motivational characteristics which emerged as significant positive predictors of persistence in biology among all students were self-efficacy, $F(5.34), p = 0.0234$, and grade motivation, $F(4.15), p = 0.0436$; Table 7). The only attitudinal characteristic which emerged as significant positive predictors of student persistence was a students’ ability to apply concept-based strategies that are widely applicable to multiple problem-solving situations in biology (i.e., problem-solving strategies; $F(4.01), p = 0.0472$. Additionally, students final percent course grade also emerged as a significant predictor of student persistence in biology, $F(10.48), p = 0.0015$; Table 7). Even though students’ demographic characteristics did not emerge as significant predictors of persistence in biology in (Table 7), a post-hoc analysis (Table 8) revealed that, compared to non-first generation students’ first generation students were more likely to persist in biology ($p = 0.0339$). On the other hand, compared to minority students, the non-minority students were more likely to persist in biology (non-URMs ($p = 0.0287$; Table 9). On other hand, the same post-hoc analysis indicated that, compared to non-first-generation students, the first generation student were more likely to persist in biology (FGs ($p = 0.0339$; Table 8).
Table 7

Predictors of Persistence Among All Students: Type III Tests of Fixed Effects on Generalized Linear Mixed Model (GLMM)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Numerical df</th>
<th>Denominator df</th>
<th>F Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Final Grade</td>
<td>1</td>
<td>132</td>
<td>10.48</td>
<td>0.0015</td>
</tr>
<tr>
<td>Problem Solving Strategies</td>
<td>1</td>
<td>132</td>
<td>4.01</td>
<td>0.0472</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>1</td>
<td>132</td>
<td>5.34</td>
<td>0.0234</td>
</tr>
<tr>
<td>Grade Motivation</td>
<td>1</td>
<td>132</td>
<td>4.15</td>
<td>0.0436</td>
</tr>
<tr>
<td>URM</td>
<td>1</td>
<td>132</td>
<td>0.17</td>
<td>0.6769</td>
</tr>
<tr>
<td>FGS</td>
<td>1</td>
<td>132</td>
<td>0.34</td>
<td>0.5583</td>
</tr>
<tr>
<td>Index score</td>
<td>1</td>
<td>132</td>
<td>0.34</td>
<td>0.5585</td>
</tr>
<tr>
<td>Problem solving Difficulty</td>
<td>1</td>
<td>132</td>
<td>1.23</td>
<td>0.2698</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>1</td>
<td>132</td>
<td>0.31</td>
<td>0.5759</td>
</tr>
<tr>
<td>Self-determination</td>
<td>1</td>
<td>132</td>
<td>1.24</td>
<td>0.2669</td>
</tr>
<tr>
<td>Reasoning</td>
<td>1</td>
<td>132</td>
<td>0.17</td>
<td>0.6781</td>
</tr>
<tr>
<td>Conceptual Connections</td>
<td>1</td>
<td>132</td>
<td>0.36</td>
<td>0.5499</td>
</tr>
<tr>
<td>Real-World Connections</td>
<td>1</td>
<td>132</td>
<td>0.04</td>
<td>0.8426</td>
</tr>
<tr>
<td>First generation</td>
<td>1</td>
<td>132</td>
<td>0.34</td>
<td>0.5583</td>
</tr>
<tr>
<td>Minority</td>
<td>1</td>
<td>132</td>
<td>0.17</td>
<td>0.6769</td>
</tr>
</tbody>
</table>
Table 8

First Generation Least Squares Means

<table>
<thead>
<tr>
<th>Generation Status</th>
<th>Estimate</th>
<th>Standard d Error</th>
<th>df</th>
<th>t-Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Non-FGs)</td>
<td>0.7582</td>
<td>0.4800</td>
<td>132</td>
<td>1.58</td>
<td>0.1166</td>
</tr>
<tr>
<td>(FGs)</td>
<td>1.0221</td>
<td>0.4769</td>
<td>132</td>
<td>2.14</td>
<td>0.0339</td>
</tr>
</tbody>
</table>

**Note.** Non-FG = Non-First Generation Students, FG = First Generation Students

Table 9

Ethnicity Status: Least Squares Means

<table>
<thead>
<tr>
<th>Generation Status</th>
<th>Estimate</th>
<th>Standard d Error</th>
<th>df</th>
<th>t-Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(URMs)</td>
<td>0.7939</td>
<td>0.5137</td>
<td>132</td>
<td>1.55</td>
<td>0.1246</td>
</tr>
<tr>
<td>(Non-RUMs)</td>
<td>0.9863</td>
<td>0.4460</td>
<td>132</td>
<td>2.21</td>
<td>0.0287</td>
</tr>
</tbody>
</table>

**Note.** URM = Underrepresented Minority Students, Non-URM = Non-Underrepresented Minority Students

Predictors of Persistence Among First Generation students

The binary response variable was modeled as a linear combination of all the predictor variables among the FGs. Among the FGs, the important predictors of persistence in biology were: numerical final grade, $F(6.35), p = 0.0163$, and grade motivation, $F(4.68), p = 0.0371$; Table 10). None of demographic and attitudinal characteristics were important predictors of persistence among this group of students.
Table 10

**Predictors of Persistence Among the First Generation Students (FGs): Type III Tests of Fixed Effects**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Numerical df</th>
<th>Denominator df</th>
<th>F Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Final Grade</td>
<td>1</td>
<td>36</td>
<td>6.35</td>
<td>0.0163</td>
</tr>
<tr>
<td>Grade Motivation</td>
<td>1</td>
<td>36</td>
<td>4.68</td>
<td>0.0371</td>
</tr>
<tr>
<td>URMs</td>
<td>1</td>
<td>36</td>
<td>0.05</td>
<td>0.8272</td>
</tr>
<tr>
<td>Index score</td>
<td>1</td>
<td>36</td>
<td>2.17</td>
<td>0.1491</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>1</td>
<td>36</td>
<td>0.90</td>
<td>0.3478</td>
</tr>
<tr>
<td>Self-determination</td>
<td>1</td>
<td>36</td>
<td>0.14</td>
<td>0.7075</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>1</td>
<td>36</td>
<td>3.07</td>
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</tr>
<tr>
<td>Reasoning</td>
<td>1</td>
<td>36</td>
<td>2.20</td>
<td>0.1466</td>
</tr>
<tr>
<td>Problem-solving strategies</td>
<td>1</td>
<td>36</td>
<td>0.10</td>
<td>0.7571</td>
</tr>
<tr>
<td>Conceptual Connections</td>
<td>1</td>
<td>36</td>
<td>0.70</td>
<td>0.4068</td>
</tr>
<tr>
<td>Problem solving difficulty</td>
<td>1</td>
<td>36</td>
<td>1.46</td>
<td>0.2344</td>
</tr>
<tr>
<td>Career motivation</td>
<td>1</td>
<td>36</td>
<td>0.36</td>
<td>0.5504</td>
</tr>
<tr>
<td>Real-World Connections</td>
<td>1</td>
<td>36</td>
<td>2.33</td>
<td>0.1356</td>
</tr>
</tbody>
</table>

*Note. URMs = Underrepresented Minority Students*

**Predictors of Persistence Among the Underrepresented Minority Students’**

Among the study participants about one-third (30.4%) identified as URMs. The binary response variable was modeled as a linear combination of all the predictor variables among the URMs. Among the URMs, similar to FGs, the important predictors of persistence in biology were: numerical final grade, $F(8.51), p = 0.0064$, and grade
motivation, $F(5.62), p = 0.0240$, as a motivational variable (Table 11). None of
demographic and attitudinal characteristics were important predictors of persistence
among the URMs.

Table 11

Predictors of Persistence Among the Underrepresented Minority (URM) Students:
Type III Tests of Fixed Effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>Num DF</th>
<th>Den DF</th>
<th>$F$ value</th>
<th>Pr &gt; $F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Final Grade</td>
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<td>32</td>
<td>8.51</td>
<td>0.0064</td>
</tr>
<tr>
<td>Grade Motivation</td>
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<td>32</td>
<td>5.62</td>
<td>0.0240</td>
</tr>
<tr>
<td>Reasoning</td>
<td>1</td>
<td>32</td>
<td>0.13</td>
<td>0.7241</td>
</tr>
<tr>
<td>Index score</td>
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<td>0.7132</td>
</tr>
<tr>
<td>Self-determination</td>
<td>1</td>
<td>32</td>
<td>0.62</td>
<td>0.4364</td>
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<tr>
<td>Self-efficacy</td>
<td>1</td>
<td>32</td>
<td>2.47</td>
<td>0.1259</td>
</tr>
<tr>
<td>Problem-solving strategies</td>
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<td>32</td>
<td>0.71</td>
<td>0.4046</td>
</tr>
<tr>
<td>Conceptual Connections</td>
<td>1</td>
<td>32</td>
<td>0.00</td>
<td>0.9840</td>
</tr>
<tr>
<td>Problem solving efforts</td>
<td>1</td>
<td>32</td>
<td>0.32</td>
<td>0.5764</td>
</tr>
<tr>
<td>Career motivation</td>
<td>1</td>
<td>32</td>
<td>2.72</td>
<td>0.1086</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>1</td>
<td>32</td>
<td>0.10</td>
<td>0.7482</td>
</tr>
</tbody>
</table>

**Discussion and Recommendations**

Although over one-third of college freshmen elect to pursue a degree in a STEM
discipline each year, less than half ultimately persist in their STEM majors, instead
switching to a non-STEM domain or leaving college altogether at some point during their
academic career (Chen, 2013; Rask, 2010). Several factors have been posited to
contribute to the high rates of departure from sciences, including highly competitive
STEM classroom environments and students’ lack of success in introductory science coursework (Ost, 2010; Rask, 2010). In this study, I sought to expound upon this latter factor by examining the impact of demographic, attitudinal, success in two introductory biology courses (Principles of Biology and Organismal Biology) and motivational variables on student persistence in biology. Furthermore, I investigated to what extent these factors differentially predict persistence among underrepresented minority and first generation students. My results indicate that students’ success in introductory biology courses (grade) and the motivation for obtaining a good grade (grade motivation) in biology were important predictors of persistence among all student types including both underrepresented minority and first generation students.

Self-efficacy was an important contributor to students’ persistence in biology (Table 7). In the current study, self-efficacy was the second highest contributor of student persistence in biology among the factors examined, $F(5.34), p(0.0234); $ Table 7). Self-efficacy is a widely researched cognitive factor in both career development and academic literature (Byars-Winston et al., 2016). The concept of self-efficacy was first introduced by Bandura (1997) as a characteristic of social cognitive theory, which operates within a wide network of sociocultural influences. A majority of previous studies regarding the impact of self-efficacy in academics (e.g., Byars-Winston et al., 2016; Hurtado et al., 2010) have focused on the independent contribution of self-efficacy variables to career outcomes among undergraduates in both biology and biomedical sciences. The results of these studies have shown support for student self-efficacy as an important factor in student subsequent commitment to a major career. In agreement with my results, in their examination of the impact of self-efficacy on academic performance and perceived career
options, Lent, Brown, and Larkin (1984) found that the construct of self-efficacy was highly correlated with undergraduate persistence in science or engineering majors. Similarly, empirical studies have documented self-efficacy as an important predictor of persistence in different academic disciplines (Bandura, 1997; Eccles & Wigfield, 2002). Moreover, Wright, Jenkins-Guarnieri, & Murdock (2013) in their study on career development among the undergraduate freshmen found that college self-efficacy was an important cognitive variable in freshmen persistence decisions and academic success. Other studies (e.g., Brown et al., 2008) document self-efficacy to be associated with the broader concept of student persistence in college in general. Finally, consistent with my findings and those of Wigfield and Eccles (2002) the expectancy-value theory of achievement model, students’ confidence of their ability to successfully execute a specific task in the context of learning biology was positively associated with their success in biology.

According to the current study results, students are more likely to persist in biology when they view themselves as competent (having self-efficacy) in solving biology tasks. It is interesting to note that, self-efficacy was also a strong predictor of success in biology (Chapter II), it follows that, because performance achievements have previously been hypothesized as crucial for influencing self-efficacy (Bandura, 1997), it is likely that students’ success in biology may have partly contributed to their increased self-efficacy, leading to persistence in biology in the current study. The broader notions of self-efficacy have been shown to predict various behavior outcomes (Lent et al., 1984), which may suggest that self-efficacy is a relatively strong construct that can help to explain multifaceted behavior outcomes. Student persistence in STEM fields is a national
concern; therefore, capitalizing on developing student self-efficacy in introductory science courses might be important in students’ success and persistence in STEM fields. In light of the current results, educators might influence students’ success and persistence in STEM fields by investing in ways that help to promote students self-efficacy.

Consistent with previous research (Rask & Tiefenthaler, 2008), students’ success in introductory science courses was the highest contributor of students’ persistence in biology, $F(10.48), p(0.0015)$; Table 7). In a concurrent study on examination of predictors of success in biology, performance in introductory biology course was found to be an important predictor of student success (Chapter II). These findings suggest that, efforts towards promoting students’ performance in introductory biology courses may be important for both student success and persistence in biology. Additionally, a recent study (Byars-Winston et al., 2016) shows that an individuals’ subsequent performance provide valuable feedback that can strengthen self-efficacy and outcome expectations which ultimately reinforces persistence choices. However, it should be noted that my data reflected students’ enrollment into biology coursework into the sophomore year based on my definition of persistence in biology. As such, I recommend that, future research should examine the enrolment up to the completion of a biology degree along with withdrawal patterns (a longitudinal study following students’ registration into biology courses, examination of withdrawal patterns from biology major up to graduation with a biology degree). Such studies will paint a bigger picture of the actual role of success in introductory biology coursework on students’ persistence in biology.

Grade motivation was found to uniquely explain persistence in biology among all student types including both the FGs and URMs (Tables 7, 10, and 11). Student
motivation to obtain a good grade in introductory biology courses seems to be an important factor in persistence among all the study participants, $F(4.15), p(0.0436)$, (Table 7). The importance of grade motivation from these results is demonstrated by the significance of student percent final course grade in predicting persistence in biology in the current study (Table 7). Interestingly both grade motivation and students’ percent final course grade in introductory courses were important predictors of students success in biology (Chapter II). These results suggest that grades have significant motivational influence on students and that further studies focusing on investigating the role of grades in motivating students to learn are needed. Stan (2012) concluded that initial and continuing training of teachers should focus more on the differences between intrinsic and extrinsic motivation and the correlation of these types of motivation with the assessment. Additionally, another explanation to my results could be that, students who were more committed to the major (persistence), might be more concerned about their grades in biology.

The current study shows that, the ability to apply concept- based strategies that are widely applicable to multiple problem-solving situations in solving biology problems (i.e., problem-solving strategies), is a strong predictor of students’ persistence in biology. The construct of problem-solving strategies reflects the conceptual problem solving approaches which students’ employ when solving biology problems as opposed to simply memorizing the ways in which concepts are presented during instruction. In connection to these findings, Bernold et al. (2007) analyzed the relationship between student learning styles, GPA, persistence in engineering major, gaining an entry into an engineering major and success in the first year courses. Their results showed that, students who possessed a
learning style oriented towards conceptual understanding and real world applications had higher grades and exhibited low attrition rates from the program compared to students who exhibited surface learning styles as characterized by rote memorization of facts (Bernold et al., 2007). Together with my results, these results indicate that use of inquiry based instruction approaches that promote critical thinking, may be important in promoting student persistence in STEM fields (Momsen et al., 2010). In addition, institutions can provide students with opportunities such as structured undergraduate research projects in a professors’ research laboratory, which can help in engaging students meaningfully in their chosen major as they navigate through their STEM majors. I posit that such initiatives might positively impact persistence rates in a variety of STEM majors (e.g., Bilgin et al., 2015).

The comprehensive model on predictors of students persistence in biology indicated that, generational or minority status were not predictive of student persistence in biology (Table 7). However, further analysis regarding the coefficients of means of persistence for both first generation students and minority students (least squares of means) indicated that, first the means of the non-minority students was more that zero, where as that of the minority students was significantly different from zero. Based on my study, persistence was coded as 1, while non-persistence was coded as 0, and, therefore, even though the probability of persistence among the minority and non-minority students was not statistically different in the full model (Table 7), this meant that there were differences between the minority and non-minority students whereby the non-minority students were more likely to persist in biology compared to minority students. Similarly, Smith’s (2000) study on STEM retention showed that, minority students had higher
attrition rates compared to majority students’. Other studies (e.g., Crisp et al., 2009) found that factors such as family and community support, provision of undergraduate research opportunities and family influence and support were important in influencing URM persistence in STEM majors. Even though such factors were beyond the scope of the current study, I recommend that future research should examine these factors among different URM groups with an aim of understanding to what extent are such factors/aspects important among different URM groups. On the other hand, studies show that biological science degree aspirations are popular among the URMs (e.g., Chang et al., 2014), so I would have expected URMs to have higher persistence rates in the current study. There are several explanations for this; first aspiration does not parallel actual persistence. Second, it could be that biological careers tend to be competitive, since such professions are broadly viewed as socially prestigious and financially rewarding and therefore, they may attract and screen out more talent among all students (Chang et al., 2014). Another potential justification could be based on previous studies (e.g., Lang, 2008; Seymour & Hewitt 1997), which found that a majority of undergraduates who left the sciences for non-sciences were not well informed or did not have a detailed understanding of what STEM fields entailed. Therefore, it could be that URMs interested in obtaining a career in biological sciences in the current study had a superficial understanding of the related biological professions as a result of general familiarity with the subject and that such ambitions indicate a weak interest and weak commitment to biology degree completion (Chang et al., 2014). However, further analysis regarding the coefficients of means of persistence for minority students (least squares of means) indicated that, the means of the non-minority students was more than zero, where as that
of the minority students was not significantly different from zero. Based on my study, persistence was coded as 1 while non-persistence was coded as 0, and, therefore, even though the probability of persistence among the minority and non-minority students was not statistically different in the full model (Table 7), this means that there were differences between the minority and non-minority students, whereby the non-minority students were more likely to persist in biology compared to minority students.

On the other hand, the coefficients of means of persistence for first generation students (least squares of means) indicated that, the means of first generation students was more that zero, where as that of the continuing students was zero or not significantly different from zero. Based on my study, persistence was coded as “1” while non-persistence was coded as “0,” and, therefore, even though the probability of persistence among the first generation and continuing students was not statistically different (Table 7), this meant that there were differences between the first generation students and continuing students where by the first generation students were more likely to persist in biology compared to continuing students. The current study reports unique findings regarding FGs, contrary to previous research which has widely documented that being a FGs is an impediment to degree achievement (e.g., Choy, 2001, Soria & Stebleton, 2012).

Previous studies have reported academic advising as a strong predictor of persistence among FGs (Swecker, Fifolt, & Searby, 2013). It is important to note that, the institution in which the current study was conducted at, one third of undergraduates are FGs and the institution has different support systems for this group of students such as tutoring services and the Learning through Engaging and Authentic Practices (LEAP-program). Specifically, the LEAP-program provides support to FGs in the form of academic
advising and a collaborative network which involves parents or guardians, in this program, guardians and FGs are able to reach out to the program whenever necessary. To the best of my knowledge, this is the first study to document high persistence rates among FGs in comparison to the continuing students and I posit that further studies should be conducted to investigate the effect of academic advising and institutional social support on FG persistence in STEM fields within the study institution.

Grade motivation was also an important predictor of persistence among FGs, $F(4.68), p(0.0371)$ (Table 10) which made up one third of the study population. In light of these findings, it appears that cultural and contextual factors embedded among FGs might have mediated the predictive relationship in this study. Harackiewicz et al. (2014) reported that FG undergraduate biology students place significantly more value on select interdependent factors, such as assisting their family once they have completed college and showing others that people with their (the students’) background can do well, than a similar cohort of continuing generation students. While the authors did not explicitly measure students’ grade motivation, they note that it is especially critical that FG students have a positive experience in introductory biology, as a grade of “C” may indicate to them that they cannot make it in the field whereas a grade of “B” signals that they can. In this regard, an implicit desire to perform well in science courses, influenced by cultural and contextual factors in the individual’s environment, are likely to exert a cumulative effect on FGs likelihood of persistence in STEM disciplines. With respect to the first generation-URM students, Harackiewicz et al. (2014) research regarding the social class achievement gap in undergraduate biology revealed that URMs, whether first generation or continuing generation, performed more poorly in introductory biology than students
who were majority continuing generation. It is important to note that although a similar
effect was observed for majority FGs, individuals within this cohort were shown to obtain
significantly higher semester GPAs and persist in their programs of study at higher rates
than their URM peers following a targeted, values affirmation-based intervention (Steele
& Liu 1983). These results suggest that it is imperative both from a theoretical and
practical perspective to be mindful of the independent contributions of students’
generational and minority statuses when constructing social-psychological interventions
as well as educational interventions aimed at reforming classroom learning environments.
Indeed, previous research shows that increased course structure, frequency of active
learning, and focus on crosscutting concepts in STEM disciplines can differentially
impact the achievement and persistence gap observed among students belonging to the
aforementioned populations (e.g., Haak et al., 2011; Harackiewicz et al., 2014; Momsen
et al., 2010).

Similarly, grade motivation was a significant predictor of persistence among the
URMs, $F(5.62), p(0.024)$; (Table 10), consistent with the comprehensive and FGs models
(Tables 7 and 9). Previous research (e.g., Allen, 1999), has shown that among URMs the,
motivation to finish college was the top predictor of persistence. It is important to
indicate that Allen did not disintegrate different motivational variables, as was the case
for the current study. Nevertheless, in this study, the URM grade motivation could be
linked to their desire to graduate from college and, therefore, persist in their major until
school completion. The research by Allen (1999) and the current results suggest some
relationship between the theory of motivation and student retention in STEM majors
applicable to all student types, including FGs and various ethnic student groups.
Lastly, in this study there are still unanswered questions with respect to why some factors initially thought to have been important in students’ persistence in biology were not (e.g., index score). Index score is a broad variable, which has been found to be a strong predictor of both success and persistence among all students, including minority students (e.g., Allen 1999). Similarly, index score was a strong predictor of success in biology among all students’ types including the URMs in other results by author (Chapter II). Concurrent with results from predictors of success in biology (Chapter II), attitudinal factors were not important in URMs persistence in biology. This calls for further research to qualitatively investigate the role of such factors among URMs, especially using a multi-institution sample. Accordingly, Braxton and Mundy (2001) stated that the phenomenon of students’ departure from sciences is an ill-structured problem necessitating multiple approaches to solution. Therefore, even though my research has focused on the effect of the unique factors associated with attrition from biology, it is clear that further research is warranted to focus on broad factors, which might have special effects on persistence in STEM especially among FGs and URMs.

For comparison purposes, Chapter II (success study) and Chapter III (persistence study). The results indicated that there were more predictors of success in Chapter II (index score, minority status, generational status, freshmen status, problem solving difficulty, enjoyment of biology, self-efficacy, self-determination, grade motivation, career motivation and supplemental instruction) compared to Chapter II (final course grade, problem solving- strategies, enjoyment of biology, self-efficacy and grade motivation). These results indicate that there were few predictors of students’ persistence in biology than there were predictors of students’ success in biology. A possible
explanation to this observation could be that, since Chapter III was dealing with biology majors it is possible that biology majors had already decided that, they were going to do biology and, therefore, they did not require a lot of motivations and attitudes to remain in biology. On the other hand, success study was dealing with a variety of majors in addition to biology majors and, therefore, students who were non-biology majors required more motivations and attitudes to be successful in biology.

**Implications for Learning and Teaching**

My results regarding the impact of attitudinal and motivational factors on student persistence in biology, when considered in tandem with demographic and secondary achievement variables provide immediate implications for teaching and learning at the post-secondary level. Providing students with opportunities to develop positive attitudes in solving biology related problems (such as problem solving-strategies as found in this study) while nurturing students’ self-efficacy in biology appears to be an essential task of educators leading first-semester biology experiences. In this study students ability to engage a variety of strategies to solve biology problems (problem solving-strategies) was associated with persistence in biology. For several decades, various active learning pedagogies have been utilized to address this concern (e.g., Allen & Tanner, 2005; Armbruster et al., 2009; Jensen, Kummner, & Godoy, 2015). However, as S. Freeman et al. (2014) stated:
It may be more productive to focus on second-generation research: using advances in educational psychology and cognitive science to inspire changes in course design, then testing hypotheses about which type of active learning is most appropriate and efficient for certain topics or student populations. (p. 8413)

Therefore, I argue that a more nuanced evaluation of teaching strategies, including a range of pedagogies represented across the traditional-constructivist continuum, is necessary to better understand which methods are ideal for specific student populations and in specific learning environments (Eddy & Hogan, 2014). Furthermore, in order for such active learning pedagogies to be implemented effectively and efficiently, I contend that continued professional development is essential for faculty and graduate teaching assistants seeking to make use of these methods as part of their instructional repertoire. On the other hand, minority students and first generation students looked similar based on the predictors on the similar predictors of persistence in both groups. This might mean that, similar intervention strategies for success and persistence among both minority and first generation students might be necessary. Such factors may include institutional-student services as suggested by Ehrenberg (2010) and aspects of balancing academic and social life among this group of students. My current qualitative research (Chapter IV) shows that student experiences during college in STEM departments (Biology) coupled with obtaining higher grades in STEM courses during the first year, can have an important impact on their decision to continue in a STEM major. I posit that, further research is needed to examine these factors among URMs, and how the characteristics of different STEM departments within the field may have different impacts on student decisions to persist. Post-secondary institutions interested in increasing student persistence in STEM fields should focus on the institutional environment with respect to undergraduate student experiences.
Limitations

There were several limitations associated with the current study. First, the study sample included only students who were enrolled into sophomore biology coursework within the study period. This means that some students might have withdrawn even after being counted as having persisted in biology. Second, the extent to which my results are generalizable to a larger group of students may be limited because over one third of the participants were either FGs or URMs, therefore, my study population was not a typical undergraduate population. Furthermore, due to the difficulties associated with a single institution sample to situate the present findings within the larger context of students’ persistence in biology, I recommend that future research should be conducted using a representative sample from multiple institutions. Such large data sets would allow examination of the effects of student and institutional factors on persistence in biology. Lastly, the CLASS-Bio instrument which was used in this dissertation to assess students’ attitudes towards biology was developed, validated and tested on individuals with Ph.D.’s within biology fields as experts in the field in order to provide a baseline for assessing the undergraduate responses. However the instrument does not provide information about the demographics of the experts in the biology field. Since one third of participants in the current study were either URMs or FGs, the expert responses may not perfectly align with those of the two students groups with respect to their motivations and attitudes towards biology.

Conclusion

In this study, the significant predictors of student persistence in biology with respect to motivational characteristics were self-efficacy and grade motivation. Students’
ability to apply concept-based strategies that are widely applicable to multiple problem-solving situations in solving biology problems was the only attitudinal factor important in persistence. Additionally, students’ final percent course grade was a significant predictor of persistence in biology. Interestingly, FGs were more likely to persist in biology compared to the non-FGs, while URMs were less likely to persist in biology compared to majority students. A majority of factors highlighted in the literature with respect to student persistence such as self-efficacy and grade motivation were found to be important in this study. I acknowledge that my findings are not the final word with respect to student persistence in biology. The future of the STEM workforce and advancements in science and innovations in the U.S. depend on the supply of graduates in STEM fields. Many undergraduates interested in pursuing a STEM career do not earn a degree in one of these fields. Currently, this is an important area of research within the STEM pipeline that is receiving increased attention. The results from my study suggest that to increase the production of STEM graduates we need to focus on ways of increasing student success in science introductory courses, invest in fostering positive attitudes in classrooms and engage students in multiple ways of solving science problems. There is also a need to focus different ways of increasing persistence rates among URMs, since they are clearly different from the rest of the student population. Whereas my study contributes to the understanding of factors related to students’ persistence in biology, more research focused on why undergraduates choose to eschew from STEM majors is still required. Longitudinal studies, which follow individual students within a specific STEM field, will be able to provide a deeper understanding in the area.
CHAPTER IV
QUALITATIVE EXAMINATION OF PERSISTENCE IN BIOLOGY AMONG AVERAGE AND BELOW AVERAGE PERFORMING STUDENTS

In the biology program it was just a lot of work and it was more of a lot of very hard classes all at once, you know they get you into Math’s and then you have Chemistry and you have Biology and then you have two labs and may be an English class, you know what I mean? Just a lot of work.

Agnes, A student who switched from Biology to Earth Sciences

Researcher Stance

Similar to other qualitative studies, researcher bias may be present through various aspects of the current study. Based on the principles of qualitative research, there is rarely a clear distinction between the research and the researcher (Merriam 2009). Various studies (e.g., Gall et al., 2005, Merriam 2009; Patton, 2002) indicated that researchers should make efforts to explain any possible biases that might exist in their study and clearly reveal any personal influences, rather than trying to eliminate them. Researchers should also identify and monitor their biases as to how they might shape the processes of data collection and interpretation. This way, readers can determine if researcher biases might have influenced data collection and its interpretation. The interpretations in qualitative research are not atypical, similarly Shonkoff and Bales (2011) indicate that science does not speak for itself but a researcher does through interpretation.
As the sole researcher in this multiple case study, I feel that my own educational background is relevant to understanding this study, as it helped to form the lens through which the data were filtered. My study participants involved average and below average performing students as they narrated their experiences as biology majors. Even though personally I have never been described or classified as an average or below average performer in all my schooling, I see myself through the eyes of my participants in many different ways. When I first entered college I became the first in my family to pursue higher education; my parents did not have a college degree making me a first generation student. Being the first in my family to attend college was frightening and at times challenging because family and friends were not always supportive as far as college matters were concerned. Perhaps because they never understood college life, what goes on in college, or what it meant to be in college. Additionally, I had no positive role models in my family or anyone else in my community to motivate me to pursue a higher education degree or to help me in navigating through the challenges of higher education.

My current status in education stems from my mother (Beatrice) whom, despite having no education, encouraged and motivated me to work hard in school. My Mother believed in the transforming power of education, and wanted all her children to attain college level education necessary for economic empowerment. Growing up as a child, my mother did not receive any form of education because her parents did not believe in girl’s being educated. At age 20 my mother realized education was essential for all children regardless of their gender, and she vowed to transcend her cultural norms by giving her children education. Today this is a dream come true, almost all of my siblings have a college degree. As a result of growing up in my family, persistence and success in school
in general were important aspects emphasized either directly or indirectly. There existed an unspoken expectation for success in school and there was no excuse for not living up to that expectation. I still remember at the end of every term, everyone in school in my family was expected to show their transcript, and more importantly, their class rank; this provided some advantage into the inquiry process for the current study in general.

Growing up in Africa- Kenya, where I did most of my schooling, the concept of being a minority student was unknown to me because I was a majority student back home. I first encountered the term minority student in the year 2009 when I was at the University of California San Francisco for my Masters exchange program. With my current graduate program I now understand that the concept of minority students in education is used mainly to refer to the underrepresented minority students in sciences. I have experienced personal challenges, which are directly related to being a minority student. For example, if I have a social issue which I need to discuss with someone who is not a minority I have always found myself having to think twice on whether or not to even talk to them. This is because I am usually concerned about how they will think of me or that they might think that the subject is not worth discussion. My participants were all undergraduates and I can only imagine the weight of the issues which I have had to confront as a graduate student must be more significant to them. Similarly as described above, like many of my participants, as a first generation college student and an underrepresented minority student, I had a variety of issues to confront during my undergraduate schooling. For example, I had challenges approaching a professor either in class or during their office hours for questions or clarifications. I was basically afraid that
the professors would think of me probably as being dumb and, therefore, I was highly dependent on my own personal study skills.

Like some of my study participants, being raised in a rural home in Kenya, Africa, enabled me to have early encounters with the natural world and enhanced my understanding of biology, which shaped my worldview. The simple childhood awe I felt walking along a stream or exhilaration of passing through the thick forests within our homestead, fostered my fascination with what I would later learn was complex ecosystems. These experience engendered an appreciation for the remarkable tapestry created by interactions and adaptations of ecosystem components. With such a high level of appreciation for nature, I wanted to be successful in college regardless of any challenges. My mother always reminded us that we could become whatever we wanted to in this life as long as we believed in it and worked hard enough towards it.

My story helps to explain my interest in success and persistence in college, and specifically in biology, it also illuminates my understanding of some of challenges that under-prepared students who are often classified either as average or below average performing minority or first generation students face in the process of pursuing a college education. My experiences also provided me with an in-depth understanding of what average and below average performing students may go through while pursuing their dreams of obtaining a college degree, how they seek help and how they perceive the assistance of supportive individuals, systems, mechanisms, and community organizations in achieving their career goals. To some extent, my story also explains the influence of student’s interpersonal relationships and how those might influence the choices of persisting and being successful in college.
Due to my awareness of the aforementioned biases, I have filtered the data through my own lens and, therefore, I cannot completely eliminate any personal interpretation in this study. Through the whole process I have systematically reflected on who I am as it related to this study. I have been sensitive to my personal biography as previously described, and how it might have shaped the data. As the sole researcher, I am confident that I have succeeded in “Bracketing” my own personal experiences related to the current study in order to understand the experiences of my participants (Creswell 2003). Moreover, as a qualitative study, the current study takes into consideration of the interpersonal relationships, personal experiences and both internal and external influential factors in the college major decision-making process. Not all the findings and conclusions are generalizable to all the average and below average performing students in institutions of higher learning. The findings should be viewed as specific to the study participants at the point of data collection, given the circumstances they have experienced. If any generalization is made, it should be done with caution so as not to impose the findings and circumstances of the study at hand on another party that might not be experiencing the same circumstances.

**Abstract**

Using qualitative inquiry and thematic data analysis techniques, this study explored the persistence of both the average and below average performing students in biology by examining their experiences in a college biology program. The study focused on a cohort of junior and senior undergraduates who were in a biology program and whose sophomore GPA was 3.0 or less. Specific emphasis in this study was to understand the participants’ experiences in biology and how those experiences shaped their decision
to persist in biology or switch to other majors. The study was conducted at a mid-sized teaching and research University in the Rocky Mountains. The study’s sample size composed of 12 participants, among these, 10 had persisted in biology while two had switched from biology to other majors. Among the participants, 41.6% \((n = 5)\) were first generation students, 33.3% \((n = 4)\) were the underrepresented minority students in science, while 16.7% \((n = 2)\) were both first generation students and members of the underrepresented minorities. A majority of the participants were female (58.3%). The study findings supported by the participants’ narratives revealed that all the participants were more similar than they were different based on their experiences in biology. The four most important factors highlighted by the participants were: (a) difficulties associated with transitioning from high school to college; (b) instructional aspects of introductory biology courses; (c) effects of participants’ social interactions; and (d) aspects of competition and weeding out in biology introductory courses. The narratives of the participants experiences in biology helps in conceptualizing what it is like to be an average or below average performing student and navigate through the academic challenges to earn a biology degree or switch from the biology program to a different major. The study findings suggest that students’ success and persistence in biology may be increased with sufficient streamlining of high school preparation to meet college level expectations with respect to the necessary training for entering college. Additionally, faculty members involved in undergraduate advising should streamline their advising’s to incorporate students’ future career aspirations. Instructors leading introductory biology courses should strive to make clear connections between their research and the class learning materials and also engage students in their own research; this is likely to reduce
the students perceptions of the instructors as being more interested in their own research than teaching. On the other hand, based on comparison the remarkable difference between biology persisters and switchers was that, whether by calculated effort or by sheer desperation, persisters did not “see” themselves outside biology and they had to work it out for themselves, and switchers, for the most part, did not. Finally, instructors leading biology introductory courses should acknowledge and address the fact that weed-out in science classrooms exist and it only acts to intensify feelings of alienation among some students.

Introduction

Average and Below Average Performing Students in Sciences

Tobias (1990) in her study on college science teaching was the first to define the two tiers of incoming undergraduate college students. The first tier being composed of freshmen college students who go to college mainly interested in earning a science degree and continue on to earn a science degree. The second tier is composed of freshmen students who go to college with an initial intention and the ability to do science but instead switch to nonscientific fields. The current study focused on two categories of average and below average performing students: the first being those who started college initially interested and were academically prepared to handle biology and, therefore, are in the pipeline of obtaining a biology degree, and the second was composed students who started college initially interested in biology and were academically prepared for biology but switched from biology to other majors at the end of the sophomore year. This study sought to understand the experiences of these two categories of students in biology and their ultimate decisions to either persist in biology or switch from biology to a different
major. While my study participants do not perfectly fit in Tobias’ (1990) framework of the two tiers categorization, by focusing on average and below average performing students they represent a group of students who are at risk of ending up in Tobias second tier category. My study examined the experiences of both students who persist and students who leave a biology program, and all were likely to leave biology based on their sophomore GPA.

The major findings by Tobias (1990) suggested that science introductory courses are responsible for driving many students into the second tier. Additionally, this might indicate that improvements in the instruction of introductory science courses could be key to scaling up the number of science college majors who persist (Tobias, 1990). Some of setbacks encountered by students in science introductory courses include: failure to promote student interest by not establishing course relevancy to students’ lives, non-interactive classes dominated by student passivity, a focus on grade competition as opposed to collaborative learning, and an emphasis on mastery of problem solving procedures as opposed to conceptual understanding (Seymour & Hewitt, 1997; Tobias 1990). Such findings indicate the loss of students in science belonging to the second tier could be minimized if instructors in science introductory courses enhance their instructional approaches to cultivate motivation and interest in science among all students. According to Felder (1993), students in the second tier might be enough to close the gap of the required STEM workers in the United States (U.S.) economy.

Focus on Average and Below Average Performing Students

There is paucity in the literature with respect to the average and below average performing students’ retention in sciences with specific focus on their experiences in
sciences. Previous research on retention in the sciences has tended to focus more on high achieving students (Seymour & Hewitt 1997). Therefore, literature regarding retention of average and below average performing students is limited. Average and below average performing students are at a risk of ending up in the second tier based on Tobias (1990) classification. For example, most of the average and below average performing students become discouraged after encountering science introductory sciences during their first year (Seymour & Hewitt, 1997; Tobias, 1990). A majority of average and below average performing students are likely to be first generation and/or minority students who come from low socioeconomic backgrounds that might have impacts on their college success and persistence (Middlecamp, 2015). Additionally, research shows that, these students are smart, determined to succeed and very expressive (Middlecamp, 2015). The experiences of average and below average performing students send a strong message to educators that there is a disharmony in the larger system in which they are learning science. This disharmony is characterized by some aspects such as students’ lack of basic skills necessary for science coursework, lack of prior science content knowledge, use of the “weed out” method to get rid of the seemingly underprepared students in science, and creation of competitive learning environments (Seymour & Hewitt, 1997; Tobias, 1990). Failure to include the human element in the curriculum (with respect to ways in which the curriculum is related to students’ lives), and an emphasis of curriculum coverage as opposed to conceptual understanding are additional concerns (Mahaffy, 2011). All of these factors have the potential to contribute to a conflict in the undergraduate science introductory courses. This in turn implicates the need for educators to address the conflict
that exists between average and below average performing students’ interest in sciences and how the introductory science courses are actually taught.

Previous studies (Seymour & Hewitt, 1997) indicate that students who leave sciences are as interested in sciences as those who persist, and that introductory science courses play a larger part in driving a majority of students into the second tier (Tobias, 1990). This is because those who leave the sciences included bright students whose talent could have contributed to the STEM workforce. This is why Tobias (1990) stated that “If the sciences are to attract any new group of students to science, either to meet the projected shortfall of STEM graduates or to solve the science illiteracy problem, the effort must begin by getting to know some of ‘them,’ and well” (p.18). One way of attracting a new group of students is the need for educators to acquaint themselves with the average and below average performing students with aims of attracting and retaining them in sciences. Such efforts may include understanding the external pressures average and below average performing students might be facing, understanding what matters for them in college and more importantly capitalizing on their opinions on what educators can do to improve their success and persistence especially in sciences.

Cultivating Average and Below Average Performing Students into Science

The ethnographic study by Seymour and Hewitt (1997) provides strong evidence suggesting able and interested students could have been retained in sciences had attention been paid to their poor learning experiences in introductory science courses. In order to ensure harmony between these students and introductory science courses, it is important to understand that a blend of several factors play a role in students’ success and persistence as opposed to just one single factor (Middlecamp, 2015). This means that
educators need to explore the different factors which have the potential to increase
students’ success and persistence in the sciences. Such factors may include aspects
related to the: curriculum, faculty, introductory science instruction, home and campus
environments, students’ interactions within and outside the campus, and the students
themselves. Tobias (1990) points out that the first steps in addressing student
shortages in sciences should involve getting to know students, especially average and
below average performing students. Ways of getting to know these kinds of students can
involve understanding their experiences in sciences which led them to persist in sciences
or switch from sciences, understanding their environmental influences surrounding their
decisions, and their interactions with the faculty, peers, teaching assistants, family
members, significant others, including other interactions within and outside the campus
(Tobias, 1990). Students spend more time outside classrooms and laboratories than in
them, and even when inside these facilities, they might also be connected and
communicating to the outside world (Middlecamp, 2015). Therefore, the interaction
between students’ learning environments and outside environments might influence their
decision to leave or persist in sciences.

The design and instruction of science courses might also contribute to students’
choices to stay in sciences. A recent report through the National Science Council noted
that “a single course with poorly designed instruction or curriculum can stop a student
who was considering a science major in his/her tracks” (Kober, 2015, p. xi). Another line
of research has focused on the success and persistence of African American students
from high school through senior college year in a biology program. In the study by
Russell and Atwater (2005), the important factors of success and persistence among
African-American students included high school precollege preparation by participating in advanced high school science coursework, family support, support from teachers, perseverance, and students’ inherent intrinsic motivation. Even though the current study is not based on predominantly African American students, Russell and Atwater’s (2005) findings bears many similarities with average and below average performing students in biology, since some the average and below average performing students being examined are underrepresented in sciences.

**Research Questions**

The current study focused on some of the previously documented aspects that are viewed as crucial to facilitate retention in STEM fields by examining the experiences of the average and below average performing students in biology. An important perspective in this study was to examine how average and below average performing students’ experiences and social interactions factored into their navigation through the biology major or caused them to switch from biology to a different major. In this study a substantial proportion of participants described the influences of social interactions, how introductory science courses were taught, and aspects of transitioning from high school or home to college, as influential factors in their decisions to persist in biology or switch to other majors. In an effort to explore the reasons why average and below average-preforming students persisted in biology or switched to a different major, the following research questions guided the study.

- **Q5** How do average and below average performing students (with sophomore GPA of 3.0 and below) describe their experiences in biology?
- **Q6** How do social interactions among average and below average performing students influence their decision to persist or switch from biology?
Q7 What are the reasons that make average and below average performing students’ persist in biology regardless of their performance?

Q8 What are the reasons that make average and below average performing students’ switch from biology for other majors?

The research questions were designed to provide a deeper understanding with respect to how the average and below average performing students describe their experiences in biology. In addition the study sought to understand what reasons made average performing students’ persist in biology regardless of their performance, what reasons made the average performing students’ switch from biology, and finally, the role of interpersonal social interactions within the social institutions in their decisions to persist in or switch from biology.

**Methods**

In this study, the experiences of the average and below average performing students in biology were examined through the lens of a multiple comparative case study approach (Strauss & Corbin, 1990). The socio-cultural theoretical framework was utilized in understanding participants’ experiences in biology and how those experiences shaped their persistence decisions. According to this theory, students’ decisions to either persist in or switch from biology are viewed as participation within a larger system that works collectively to influence their practices and their individual actions (Engeström, 1987; Lemke, 2001). Furthermore, based sociocultural theory, social human activity is only possible because we all grow up and live within larger-scale social organizations or institutions depicted by interpersonal interactions. This approach was assumed in order to provide insights into the complex nature of a social phenomenon. Another important reason for using the socio-cultural framework was to understand the effect of social
interpersonal relationships (close associations between and among participants) on participants and their persistence decisions in biology. This research approach was appropriate for examining the factors that impact students’ persistence in a single science program (biology) through the participants’ spoken words. The purpose of this study was to provide in-depth insights into how 12 average and below average performing students described their experiences in a biology program and how those experiences ultimately shaped their persistence in biology. The multiple comparative case study approach was utilized in order to gain an understanding of how participants who had initially started in biology and persisted compared to the participants who had started in biology and switched from it at the end of their sophomore year. This research study received the University of Northern Colorado Institutional Review Board Approval (Appendix D). Data were collected from participants who voluntarily consented to participate.

General Study Perspective

The general perspective of this study was based on the understanding of the reasons as to why undergraduates persist in a biology major or leave biology. This reasoning was based on Tinto’s (2012) study where he noted that it is important to understand both the reasons that make students persist or switch out of a major. Tinto (2012) postulated that knowing why some students leave a major does not translate into knowing why other students persist in a major, and that the process of leaving was not a mirror image of the process of persisting and, therefore, both perspectives are important. The current study focused on both students who persisted in a biology major and those who had switched from biology to other majors.
Participants

For the purpose of this study, average and below average performing students were defined as junior and senior students whose sophomore GPA was 3.0 or less at the end of sophomore year. A total of 12 participants took part in this study. The participants’ were purposively sampled into the study from a cohort of junior and senior students who were biology majors at the end of their sophomore year and who met the study inclusion criteria based on GPA. Purposive sampling (selecting participants that will provide ‘‘information-rich’’ cases, in order to learn the most about the issues important to the purpose of the research (Patton 1990) was utilized in order to select individuals who could provide rich-information crucial to the purpose of the research. For example, participants needed to have been biology majors at the end of the first year; they had to be juniors or senior students, their sophomore GPA needed to be 3.0 or less. Although these participants are not representative of all the average and below average performing students in the general population, they represent a cross-section of undergraduate participants in terms of age, race/ethnicity and generational statuses. Among the 12 participants in the current study, 10 had persisted in the biology major while two had switched from biology to other majors (Table 12). Due to the nature of the research topic, it was challenging to recruit participants, especially those who had switched from biology. This led to a large disparity in the number of participants who had persisted and those who had switched from biology. The low number of participants among the switchers could be associated with their reluctance to discuss their experiences in biology, which could be related to the reason they had switched from the major (Lang, 2008). Seven of the participants were female, the age of the participants ranged between
20-28 years, almost half (5) of the participants were first generation students (students’ who’s parent(s) did not attain a four year college degree). The majority of participants (8) were White while rest four of the participants were Underrepresented Minority students’ (URMs) identified as African American, South East Asian-Vietnamese and Mexicana American/Chicano. Participation in the study was voluntary as specified by the guidelines for research with human subjects (Appendix E).

**Participants’ Recruitment and Data Collection**

The study participants were contacted and recruited through an email during the first 2 weeks of the spring semester, 2016 (Appendix F). Due to the sensitivity of the study, the recruiting study email was sent out to participants the by University of Northern Colorado Information Technology (IT) personnel on behalf of the researcher. This approach was utilized because all the potential participants’ personal contact information also contained information regarding their GPAs and since not all the potential participants agreed to participate in the study, it was important to protect the researcher from viewing such information. The IT personnel set up the study email in such a way that responses from students who were interested in participating in the study were send directly to the researcher, the whole process of participants’ recruitment took about three weeks. After a participant indicated their willingness to participate in the study, a link to an online pre-survey was sent to them by the researcher depending on whether they were biology majors or not (Appendix G). Once a participant completed the online pre-survey, an interview time slot was arranged based on participants schedule and availability. All the interviews were conducted in a room located within the study.
institutions library. Participants did not receive extra credit for their participation in the study.

**Questionnaire and Interview**

The current study utilized a semi-structured interview protocol qualitative method of inquiry that combines a pre-determined set of open questions with the opportunity for the interviewer to explore particular themes or responses further, as the primary method of data collection. Participants also completed an online pre-survey before the face to face interview. The pre-survey was intended to capture participants’ demographic information and provide the interviewee with orientation to the interview prior to the face to face interview. Prior to the study, the interview questions were pilot-tested with two biology education graduate students who were not part of the study. The purpose of piloting the questionnaire was to ensure clarity of the questions. The focus of the semi-structured interview questions was to explore the participants’ experiences in biology that might have led to their decision to either choose to persist in biology or switch to other majors (Appendix G). In an effort to eliminate the presumption of their experiences in biology, participants were asked broad questions with respect to experiences in the biology program. Each of the interview session began with a variety of open-ended questions, which generally asked the participant to talk about their experiences in the biology program, development of interest in biology, influential factors in biology and educational learning experiences in biology. The use of the semi-structured interviewing approach allowed a conversation between the researcher and the interviewee to flow freely but also to maintain a focus on the issues that needed to be explored.
### Table 12

**Participants’ Descriptive Information**

<table>
<thead>
<tr>
<th>Student</th>
<th>FGs</th>
<th>URM/Ethnicity/Race</th>
<th>Age</th>
<th>Gender</th>
<th>Persister</th>
<th>Leaver</th>
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</thead>
<tbody>
<tr>
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<td>F</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Clare</td>
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<td>White</td>
<td>22</td>
<td>F</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Marie</td>
<td>No</td>
<td>White</td>
<td>21</td>
<td>F</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Billy</td>
<td>No</td>
<td>White</td>
<td>24</td>
<td>M</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Mary</td>
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<td>White</td>
<td>21</td>
<td>F</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sophie</td>
<td>No</td>
<td>White</td>
<td>20</td>
<td>F</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sebastian</td>
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<td>White</td>
<td>28</td>
<td>M</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Aron Green</td>
<td>Yes</td>
<td>White</td>
<td>22</td>
<td>M</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Amy</td>
<td>Yes</td>
<td>Southeast Asian-Vietnamese</td>
<td>23</td>
<td>F</td>
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<td>X</td>
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<tr>
<td>May</td>
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<tr>
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<td>Latino</td>
<td>20</td>
<td>M</td>
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</tr>
<tr>
<td>Sten Woodward</td>
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<td>Mexicana</td>
<td>22</td>
<td>M</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Note. FGs = First General Students, URM = Underrepresented Minority Students*
It is important to indicate that questions which directly addressed study participants perspectives on influential factors (e.g., people, opportunities or other factors) that impacted their interest in biology or lack of it, were asked after the interviewee had been given ample time to discuss or describe their experiences which had influenced their interest in biology. This was appropriate in order to prevent the researcher from leading the participant into only talking about interpersonal relationships while disregarding other elements that might have influenced their experiences in biology. An example of questions that were asked include: (a) What are some of your home environmental experiences that influenced your decision to stay in biology or switch out of biology? (b) What are some of your educational experiences that influenced your decision to stay in biology or switch from biology? (c) What are some of the ways in which your social interactions both inside and outside the classroom influence your choice to stay in biology major? The interviews were audio recorded and transcribed verbatim. All the study participants were asked to select pseudonyms, which were used throughout the interviews and also during transcription, data analysis and interpretation. After the interviews had been transcribed, in an effort to ensure triangulation, transcripts were sent back to each individual participant as part of member check. This was to confirm what was transcribed was exactly what the participants had said or meant. At the end of the member check process (participants’ confirmation of their transcripts) all the participants agreed with the transcription without adding or deleting any information. Participants’ instances of laughter or significant pauses were included to enhance context to the spoken words.
Relevance of the Study Protocol

Although there are questionnaires focused on examining students’ major and career interests and choices, currently there are no documented surveys designed to understand why students choose specific majors and persist in those majors, or why they initially chose a major and decided to switch to other majors later on. Since it was important to obtain a bigger picture than what existing questionnaires could provide, it was appropriate for the researcher to develop a questionnaire specifically for this study. The semi-structured questions were designed to uncover the influential precollege and college experiences, social interactions and influential people or events that had helped to shape their major decisions in biology. The reasoning behind asking these types questions was to clarify the evidence participants used in their decision to either persist in or switch from biology, and whether a perceived reason or a specific experience had led them to their decision. The other category of questions were aimed at specifically exploring the reasons as to whypersisters had decided to continue in biology and why switchers had switched from biology. Another category of the questions was aimed at examining participants’ personal opinions about biology and their feelings of belongingness; under this category of question participants were asked to discuss different aspects of the biology major including the teaching, courses, classroom environment, one on one with instructors and general advising, and how those aspects impacted their opinion about biology. The participants were asked to check out the items which were of particular importance to them from the list. The rationale for asking these types of questions was to determine which aspects were of greater and which aspects were of less importance to their both positive and negative experiences in biology. To ensure trustworthiness of the
study protocol, the researcher had several meetings with one of the research co-advisers to deliberate about the items included in the protocol. During these meetings, items which were deemed unnecessary were removed from the protocol and new ones were added.

**Data Analysis**

Thematic data analysis was utilized in this study. The process allowed development of categories and themes to better understand the participants’ experiences in biology through their narratives. In short, thematic analysis entails manual color-coding (Marshall & Rossman, 2014). The process involved pinpointing, examining and recording patterns or themes in the form of marking in color the words, nuances, or ideas, which appeared to be relevant to the study’s research questions. This approach allows for the identification of patterns, categories, or themes within the data that adequately reflects the participants’ experiences (Boyatzis, 1998). In addition, the interview data were analyzed with an aim of identifying the basic categories and themes. Based on Strauss and Corbin (1990), data groupings or categories are identified as units of information comprised of various occurrences or events. All the study themes were organized according to their commonalities identified within participants narratives of experiences in biology. Generally the findings from these type of studies are considered valid based on the evidence provided in the participants textual statements and also the extent to which the findings bring new knowledge based on participants experiences (Davis et al., 2004). Although the participants’ narratives are not fully shared in their entirety, the study provides a cross-section of the experiences of average and below average performing students and their persistence status in a biology major. Furthermore, participant quotes provide depth and richness of participants feelings and experiences
(Watson, 2002). Even though the terms reliability, generalizability and validity are considered misleading in the realm of qualitative research, the current study addresses these constructs through extensive member check and peer review. In general generalization of study findings is not applicable in qualitative research, especially where a purposeful sample of participants is utilized. Additionally, the current study findings are specific to the group of participants interviewed. However, it is important to indicate that, the researcher was more interested in each participant's perspective or opinion and whether there was a correlation between the participants' experiences rather than generalizability. The comparative method of analysis is discussed below.

Stage 1 involved reading all the transcripts over and over followed by formulation of categories, which at this point were tentative themes. The next step was to compare the incidents (students' narratives) within each transcript applicable to each category (theme). Under this stage, each transcript was read and re-read comprehensively, to ensure that potentially interesting elements in the transcript were noted down as provisional categories within the matrix. Matrix formatting was employed to organize data such that a single row represented one participant, while a column represented an individual tentative/provisional category and the category incidents. Once all the possible provisional/ tentative categories were documented in the matrix, each interview transcript was read one more time in order to qualify support for the respective category.

Stage 2 involved integration of categories and their properties of students narratives, which supported the categories. The constant comparison of instances allowed generation of theoretical properties of a particular category as coding continued. In the process of revising the categories, two or more tentative categories were combined into
one integrated category if they were deemed similar. The final combined category was more conceptually meaningful in terms of making contrasts among participants.

Stage 3 was the final stage in the analysis and it involved development of assertions with appropriate evidence from the category properties structured around the assertions. Under this stage, examination of whether any differential patterns existed between the two groups of participants, those who had persisted in biology and those who had switched to other majors, were made through constant comparisons.

The themes and patterns that emerged from the data were identified through transcripts analysis following the tradition of (Strauss & Corbin, 1990). Open data coding (analyzing textual data- labeling concepts, defining and developing categories) was also utilized in order to break down, compare, conceptualize examine and categorize data (Strauss & Corbin, 1990). Additionally, both axial (disaggregation of core themes during analysis) and selective data coding (choosing one category to be the core category) were also employed (Creswell, 2005). The study themes were grounded on participants narratives (Creswell, 2005), the use of constant comparative analysis of the data allowed the development and refining of themes from the codes (Creswell, 2005).

The findings from this study related to the nature of the participants’ experiences in biology. Therefore, the focus of the results are related to participants’ experiences in biology, interpersonal relationships which facilitated or hindered their decisions regarding the biology major and the reasons why they either chose to persist in biology or switch to other majors. Several important themes emerged from the data, which reflect their overall experiences of participants in the biology program. Most of the themes aligned with previous theoretical perspectives on scholarly knowledge about students’
persistence in sciences in general as depicted in the discussion section (e.g., Seymour & Hewitt, 1997; Strenta et al., 1994). Most importantly, it was clearly evident that all the participants had some common views and perspectives with respect to their experiences in biology.

It is impossible using quantitative approaches to understand how the participants’ experiences can inform retention measures in biology especially at the study institution without the qualitative inquiry. Furthermore, quantitative data indicate that many students entering institutions of higher learning are interested in sciences but leave science majors for non-science majors by the end of sophomore year (Chen, 2013). The quantitative data, even though informative, does not answer the question of why this is the case. The researcher utilized a qualitative approach in an effort to answer the “why” question and also to gain a deeper understanding of the perceptions and beliefs held by the about how average and below average performing students’ related to their experiences in specifically in biology major.

**Results/Themes**

Seven themes emerged from this study based on the interpretation and analysis of the interview transcripts and data from the study’s research questions. Additionally, the study research questions were utilized to define themes. The themes were categorized based on the research questions that guided the study and, therefore, themes were discussed under the respective research questions.

The seven themes are:

1. Difficulties transitioning from high school/home to college
2. Ways in which biology courses were taught
3. Competition and weeding out in the biology major
4. Effect of social interactions and interaction challenges of FG and URM students with instructors
5. Intrinsic motivation in Biology
6. Wanting to do a challenging major
7. Performance in Biology introductory classes

In the next paragraphs I will be presenting the results based on the research questions followed by the subsequent themes which emerged from each specific research question.

Q5 How do average and below average performing students (with sophomore GPA of 3.0 and below) describe their experiences in biology?

Three themes emerged from the data related to this research question. The themes were: Theme 1--*difficulties in transitioning from high school/home to college*, Theme 2--*ways in which the biology courses were taught*, and Theme 3--*competition and weeding out in biology major*. The researcher did not impose any of the themes to the participants, instead each participant was asked to talk generally about his/her experiences in biology. The researchers’ goal was to obtain a broad understanding from the participants’ perspective pertaining to their main issues, which shaped their experiences in the biology major.

**Theme 1: Difficulties transitioning from high school/home to college.**

Participants expressed the challenges they experienced regarding either transition from high school to college or from home to college. The challenges discussed by the participants point to the differences in high school coursework expectation to those at the college level. Through students’ own descriptions, it was clear that they all had parallel experiences related to the difficulties in grounding themselves in college, especially with
respect to college expectations and how it impacted their performance in biology introductory courses. The following selected quotes by two participants’ (one who had switched from a biology major to other majors and one who had persisted in biology) illustrate the theme. Out of the 12 interviews three participants expressed this them.

Amy: In freshmen year I was declared as a biology pre-med major and in sophomore year I wanted to change to something else because I failed all my science classes in my freshmen year because they were really very hard, so I guess from high school they never prepare you for college and then in college there was no help like guidance services like all on your own so the transition from high school to college was really hard because in high school they held your hand like they were on top of you so but in college its just you and I had never really learned that until I took a year off sciences in my sophomore year and then decided hey I don’t know if I wanted to change majors because there was really nothing interesting outside biology. I didn’t know how to study and in high school I didn’t have to study and I passed all my classes I guess it’s not that easy but I didn’t really need to study so I passed all my classes in high school with A’s so and then coming here failing all my science classes I really didn’t know what to do.

Amy (persister in biology), indicated her difficulties in transitioning from high school learning to that of college learning. She explains how she failed all her introductory science courses. Her performance at the high school level did not parallel that at the college level, her experiences in freshmen college science classes is that “they were really hard.” She explains that her poor performance in college science introductory courses was the main reason she thought of changing majors, and indeed a reason why she took a year off sciences after her first year in college. She seemed to have had confidence going into the sciences at the college level based on her excellent performance in sciences in high school; this seems to have been a complete turnaround. Regardless of her poor performance in biology coursework, Amy decided to persist in the biology major as she explained to the researcher “I never saw myself elsewhere outside
Biology.” Bearing in mind that Amy was both a first generation and a minority student, the perceptions of not getting help at the college level might reflect the wide range of challenges encountered by students like her in seeking academic assistance. The next quote below is from a second participant who also discussed aspects related to the transition to college learning expectations, similar to those of Amy discussed above.

Clare: I did very well in high school but all my grades were based on homework and our tests were a lot easier than in college and so when I came in as a freshmen taking the Biology classes and the labs, chemistry and the calculus class it was so hard so I think that was very overwhelming. So I guess I wasn’t prepared for that workload coming in and I didn’t realize that and I wish someone had warned me about that joining into this major regarding the workload. I didn’t realize how much we were required to read the textbook I guess the professors told us read the textbooks and I was like “oh really we have to read the text book now!” I was like I will just read the PowerPoint’s but it requires a lot of hours. So I think I learned that after the freshmen year it was a learning experience I think because in high school we didn’t have to read that much so it was such a big leap. I guess I wasn’t aware of how much the time I would put into it. The dorm life transition as I was in freshmen going into those difficult classes and away from home was really a big stress because I had never moved away from home in my entire life. So I had never had that experience I don’t like change very well so going into the dorms and then having new roommates on top of those hard classes so I think it was a big stress factor.

In addition to challenges of transitioning from high school to college, Clare (switcher from biology to Dietetics) also talked about her other challenges of transitioning from home life to college life. She had started off as a biology major but ended up switching to a Dietetics major as a result of the challenges associated with the science introductory courses offered in the biology program coupled with the high course load. Clare’s comments are similar to Amy’s quote; like Amy she did well science coursework until she started college, when she realized that she was not well prepared for the college level course load. It appears that both of these students’ had to learn college
expectations with respect to course load on their own through their experiences of failing
the introductory biology courses (cellular and molecular biology and organismal
biology).

**Theme 2: Ways in which biology courses were taught.** This theme was
prominent in participants’ discussions about their learning experiences in biology
classrooms, either based on the teaching style or the general “feel” of the class as they
experienced it. This theme was expressed by majority of the participants, nine out of the
12 participants’ discussed both the positive and negative aspects regarding their
experiences in introductory biology courses with specific reference to how the courses
were taught. The following selected out of the nine participants’ quotes illuminate how
the theme was portrayed with respect to how biology courses were taught.

Sophie: I am in an advanced biology course right now and some of the concepts
are being blown over very quickly and that makes it very hard when its super very fast when going through the proteins in one day. In another class I took with Dr._______________the professor uses case studies being able to work through those problems and think critically and then having not giving us the answers, not having an answer for us and making us think through it I think that has helped me develop as a biologist more than anything else.

Sophie describes a situation of both positive and negative experiences she had in
two different biology courses. In the case of the advanced biology course, she describes a
situation where she portrays a teaching style that was fast- paced with minimal learning
gains as the professor was more focused on covering the curriculum content as opposed
to students understanding. On the other hand, in another biology course she describes a
learning experience where she felt challenged to think critically where the instruction
approach utilized case studies.
The next participants’ quotes are similar to the ones above and help to illustrate various aspects of participant experiences in learning biology, especially through biology course instruction.

Mary: The worst part of it is when a professor is more interested in their own research than teaching well. So in an advanced biology class, which I took it last year in the first semester and the professor would blow into the topic so fast It was too fast and a lot of like …”I know this why don’t you know this, you guys are in biology you should be knowing this.” I didn’t understand glycolysis after he explained it because I was like I don’t know what you are talking about he would not explain the parts he will be like this is an ADH and bla bla bla and am like I don’t know what you are talking about I had not taken other biology courses before, the only biology class I had so far was (Principles of Biology-Bio 110) and at that point I was like I have no background information and I don’t care what you are talking about, and he would not slow down and he would not answer a question, if you ask a question he will just find a way to just get around it “you know!!” and he would always talk about his research like oh and in my research we are looking at this specific protein and am like ok I am not doing your research am just trying to pass this class and so that’s how it happened and the whole entire semester I had a D.” But for my other advanced biology class Dr.___________does group work so she will do a little lecture a short one because she expects us to read the book outside the class that way we get our foundation by ourselves if you have any questions you can see her in her office or you put it up in the blackboard and then she will address that and then we have worksheet and we will have to get into groups when we do that and I think that really works really really well.

Mary’s first experiences in one of the advanced biology course resembled that of Sophie with regard to a fast-paced method of instruction. Mary’s comments indicated that part of the challenges she experienced in that class might be related to not having enough biology background, as she indicates that the only class she had prior to taking the advanced biology course was an introductory biology class (BIO 110). Mary also indicates her frustration regarding the professors’ interest in his own research more than teaching well; it appears as though Mary did not see the relevance of the Professors research with what she was learning or at least the connection was not made explicit. In
addition to the course being fast-paced, there is an aspect whereby the teacher had an assumption that students had prior knowledge essential to the course in question or at least the teacher had an expectation that students should have had some background information necessary for the course. On the other hand Mary describes a positive learning experience which is more student-centered involving different ways of engaging students in the process of learning which involves aspects of short-lecture, flipped learning, worksheets and group activities informed by the tenets of constructivists teaching.

Theme 3: Competition and weeding out in the biology major. This theme was based on the participants’ description of their overall sense of belonging in the biology major as part of their experiences in biology. This theme was only expressed by the two participants who had switched from biology. Participants’ comparison with peers with respect to performance and perceptions of biology as a difficult major designed to weed-out the underprepared students were some of factors that impacted their decision to switch from biology. The two switchers discussed about their personal perceptions of being weeded out of biology major by being required to take challenging classes all at once. . The two quotes from the switchers are illustrated below.

Agnes: I think there is that kind of intimidation when you think that there is this one person who is getting As in all the tests, so it’s never been a bad atmosphere but it’s just been that it was so intimidating sort of competition for grades. I think there are certain classes in the biology program as you move on that are made to weed out people out a little bit and especially in the nursing program they just have you know you are either doing it or not. Mostly, it was the whole idea that my GPA was not that great and that made me feel out of place, it wasn’t necessarily people in there or anything it was just kind of well, I am being weeded out of this and I need to leave, you know!!
The other student also discussed the perception of the weeding out in biology program as narrated below.

Clare: I have always heard of biology as a weed out class because for the students who can really do very well and those classes are made for those students but for the students who cannot, it’s like this is the class that will help determine if you can do it and I think it would be better to have a transition course realizing hey you do really need to read the book this much and you do need to study this much in order to pass the course at this level because like I guess I wasn’t aware of how much the time I would put into it.

In both participants’ narratives above, there is an aspect of students comparing themselves with the rest of their peers in terms of performance and the feeling of not belonging based on their performance. From the narratives, it is clear that the participants did not have bad experiences with respect to the people in the biology program nor did they consider the atmosphere unwelcoming, rather it was their perception of being weeded out of the biology major, e.g., Agnes indicated that, “It wasn’t necessarily people in there or anything it was just kind of well am being weeded out of this and I need to leave you know.” Additionally, based on the narratives of both Agnes and Clare, there seems to be a feeling that some elitism exists and this has potential to reduce these students self-efficacy.

Q6 How do social interactions among average and below average performing students influence their decision to persist or switch from biology?

The researchers’ goal under this research question was to explore the participants’ interpersonal social relationships, either positive or negative, which may have some bearing on participants’ decision to persist in or switch from biology. In exploring the question, the researcher asked each participant to discuss in general terms the significant social relationships which shaped their decision to persist in or switch from biology for
other majors. Under this research question one theme emerged: Effect of social interactions and interaction challenges of FG and URM students with instructors. The participants’ quotes and interpretations are discussed.

**Theme 4: Effect of student social interactions and interaction challenges of first generation students and underrepresented minority students with instructors.**

Under the specific research question discussed above, the direct interview questions which asked the participants’ about the influential people on their decision to persist in or switch from biology were asked once the interviewee had been given an opportunity to describe any experiences or opportunities in relation to their interpersonal social relationships that had affected their decision regarding the biology major. This was important in order to avoid leading the participants into discussing interpersonal social relationships while ignoring other important influences that might have impacted their decision about biology major. Several participants’ quotes have been included to help illustrate the theme. All the 12 participants described different types of social relationships and their perceptions of how they impacted their decisions in persisting in or switching from biology.

Jonzo: I had the group advising stuff they talked about what it takes to be in a biology major and then I was fine with that it did not seem like it was that hard and then the experience that demotivated me was that going to an advisor and him telling me that I needed to look for other options because my grades were not looking so good and so that really woke me up and I knew I needed to focus and if I have to get this done I have to turn myself around because biology is all I wanted to do in my life.

The next comment by Marie is similar to that of Jonzo, emphasizing their disappointments during their advising session with their advisors.
Marie: I struggled in a lot of classes and I didn’t do very well and I ended up having to retake them and when I went to see my advisor to see what other classes I would take he basically told me “you should consider switching your major because this is not going to get any easier and I was like “well NO, I am going to keep doing it till I do well!!” Because I wanted to succeed in biology career so I decided I was just going to keep trying and it’s like I got it.

The two cases above bear similarities as explained by Jonzo and Marie. They both had interactions with different advisors as they sought academic assistance. The kind of advice they received was demotivating, they were both asked to consider switching from biology to other majors. Contrary to the advice, they both decided to continue with biology regardless of their performance. One common feature among the two participants is that biology is all they wanted to do in life. Based on their perspectives, the negative advice did not seem to deter them from pursuing their career dream, it seems like the advice worked as a wakeup call to work hard in order to improve their grades and be able to continue in the biology program. On the other hand, Sten Woodward was a student who was having challenges in one of his biology classes and approached the class instructor’ after he failed the first exam. Initially he thought of dropping the class, but the instructor’s advice changed his perspective. The instructor offered to work with the student one on one to help the student navigate successfully through his class. The quote below helps to illustrate the scenario.

Sten Woodward: I have had Professor_________________ it was my first class with him on an advanced biology course and I did very badly on his first test and I came to him and I asked should I drop this class you know, can I still pass this class and he said work with me, come after class every Wednesday we shall be doing a refresher on what we covered in class we will try to do one on one and it was surprising to have like a professor go that far just for one student so I really enjoyed that and at the end of the semester I had a grade of B in that class.
Sten Woodward illustrates a positive interaction with a professor in a class he took with him. He was at the verge of dropping the class as a result of poor performance based on the first exam. The type of interaction with his professor seems to be the exact opposite of the other student-instructor interactions described previously by Jonzo and Marie. These student cases help to illustrate the dynamics of student-instructor interactions which might have a profound effect on a student’s eventual continuation in a particular class or program, together these also have the potential to affect the overall student learning outcomes and persistence choices.

The next two quotes from Sten Woodward and Agnes both illustrate the effect of participants peer interactions and the effect on their learning or switching decisions.

Sten Woodward: In my first year everybody lives in the dormitory and they had me in a community section or something depending on what your major is so they group all the biology majors together and stuff like that so my roommates were all biology majors and we were all taking the same classes we were helping each other’s with the classes. That was really helpful and two of them are my best friends so we have been friends for four years.

For Sten Woodward, the influence of his peers as a result of living in the same dormitory had a positive academic effect. The close proximity with colleagues made it easier for them to share ideas and assist each other with learning the materials. This was an important aspect in his progression through the biology program. This reflects a positive initiative on the part of the study institution with respect to fostering students’ success and persistence in their majors by facilitating students to build strong ties through closely interacting with each other in dormitory environments.
Agnes: I really really wanted to graduate in the biology program but I just wasn’t sure if such a thing was going to happen to me. So my friends were having an easier time enjoying themselves in their majors, were able to understand better, and did not have lots of anxiety with their majors. I just felt like when they took their exams and they do their things they do understand much more than I. I was always shaky and nervous but to get better than C in an exam you know what I mean? And that’s when I was like well is this what I want to be doing for the next 4 years? I had a lot of stress crying over my major all the time and thinking that it would affect my performance in other classes, because I took so much time trying to kill myself over this course that I kind of lazed in other classes. Also my Housemate had an influence in my decision about biology major, so she would go over my papers when we study, so she is the one who encouraged me to talk to my parents and go to my advisors and she kind of gave me the steps to figure out what exactly I wanted to do so she was really helpful.

Agnes’ comments indicate the influence she had from her peers and friends, and the effect it had on her final decision to switch from biology. She talked to the people she trusted for advice concerning her biology major. Agnes thought her peers were having an easy time with their majors compared to her. For her, the question of whether or not she wanted to always be crying over her major and being nervous and shaky for the next 4 years was a major factor in her decision to switch from biology. Participants who were either first generation, members of the underrepresented minority groups, or both, expressed concerns related to their challenges relating to their interaction with faculty. Two students’ quotes demonstrate the theme; one of the students (Amy) was both a FG and URM student, while the other (Mary) was a FG student.

Amy: So the professors just lecture and, so basically if you don’t understand in class it’s on your own and then when you go to the office hours they are intimidating and some of them look down on you they don’t really wanna help even though not all of them. And the way they try to explain it to you I don’t know I get that vibe that they are frustrated that I don’t get it so I kind of stopped going to their office hours.
The comments above by Amy indicated her frustrations with some of interactions she has had with some professors. She expresses the interactions as impersonal, both in class and during the professor’s office hours. Amy felt intimidated to visit the instructors during office hours. Amy has five siblings, she is the only child in her family who has attempted to obtain a college degree. It appears that Amy resolved to figure things out on her own since she indicates that she had to stop going to professors’ office hours. Even though Amy does not seem to have had a fruitful interactive experience with the professors’, this interaction doesn’t seem to have had any effect in her decision to persist in biology major. Amy persisted in biology regardless of her struggles and academic challenges she faced in biology major.

Mary: If I had a professor more than once I definitely feel more comfortable around them so sometimes I feel like ok you are way above me and am below you and this is how it’s supposed to be, but I am getting into my biology classes and I have had these professors more than once and so am like Ok you are Dr so and so and I can talk to you about this and that and it will just be like a normal conversation I don’t call professors by their first name even though they tell me to I just can’t I don’t know.

Mary is a first generation student whose comments reflect the dynamics of student-instructor relationship, especially among the first generation students and minority students. When I asked Mary to explain why she did not call professors by their first name she said “well based on the way my Mother brought me up, calling a professor by his/her first name indicates a lack of respect to the professor.” It seems to be very critical for Mary to first establish familiarity with the instructors before feeling comfortable to approach them for a conversation. Her difficulty of calling instructors by their first name might reflect deep cultural orientations previously documented (Richardson & Skinner, 1992), especially among students bearing first generation status.
or belonging to the members of the underrepresented groups. She also explained to the researcher that part of her upbringing was the emphasis of respect for older people and not to call them by their first names.

Q7 What are the reasons that make average and below average performing students’ persist in biology regardless of their performance?

For this research question, the researcher was interested in understanding the reasons which make the average and below average performing students persist in biology regardless of their performance. In exploring the question, the researcher asked each participant to discuss the reasons, opportunities or circumstances that led them to persist in biology. The researcher did not have a list of items for the participants to check with respect to this theme, rather participants’ were allowed to have a free open-ended talk about reasons, circumstances or opportunities they ascribed for their persistence in biology. The researcher also did not mention the aspect of performance when exploring the question. Two themes were gleaned from this research question: Theme 5—*intrinsic motivation in Biology*, and Theme 6—*wanting to do a challenging major*. The participants’ quotes that illustrate the respective themes are discussed.

**Theme 5: Intrinsic motivation in Biology.** All the participants interviewed (n = 12), including both those who had chosen to persist in biology (n = 10) and those who had switched from it (n = 2), indicated that their interest in biology developed either before or during early elementary or high school years. None of the participants mentioned that their interest in biology developed during college years. An inherent interest in biology was a common feature across all the participants. A desire to have a career in biology among the study participants was the main drive in persisting in biology as illustrated below.
Billy: *I go hiking a lot, but being raised in ________ in kind of a more rural area especially you know 20 years ago _________ was like half the size of this campus and I think just growing up and like going out in a bike out in the field and exploring you know you just want to know about the nature. It seems like we all have life and this is something I have been trying to save since I was young because the thing with me is that if you are going to school to study something life is the most important thing you can learn about because it’s the most wonderful thing that we got here like I never wanted to go to school for business or something like that because it’s such an artificial thing like you can actually study life itself and how we got here like evolution is the most amazing thing.*

For Billy the inspiration of nature played a big role in his inherent interest in biology, and the childhood experience of encountering nature was crucial in shaping his career path in biology. He talked of being raised in the local community, as he watched it evolve from a small remote rural town to its current state. To him life is an important aspect, which deserves to be studied; he expressed his childhood love for biology at a young age. Since life is a common denominator of all living things, he seems to be fascinated in aspects of how life evolved. He categorizes other careers such as business as artificial. When asked to elaborate the term artificial, Billy explained, they were artificial in the sense that they do not offer an opportunity to interact with people and helping them in tangible ways. These sentiments might reflect the concept of students wanting service careers, which are oriented towards giving back to the community. When I asked Billy what he meant by helping people, he described working in the health professions or teaching as a means of directly interacting with people and helping them.
Amy: I wanted to be a doctor since when I was in high school and mostly because of the money in the health career fields, the title associated with the careers in biology, my parents tell everyone that am becoming a doctor but I guess I didn’t make them proud because I really didn’t know what I was getting into if I knew I was going to take this long to get my degree I would not do something like that I should have changed my major long time.

Ever since high school Amy was interested in getting into a career in a health field, specifically becoming a medical doctor. The good paying jobs in health fields, the prestigious titles associated with health careers, and the pressure from her parents seems to have been major drives. Even though Amy persisted in biology with the hope of a career in the health field, this hope was slowly diminishing since her GPA was still below medical school GPA requirements. She felt like she had not made her parents proud. Through her struggles in the biology major, she ended up retaking several biology classes which she barely passed, and this is why she has ended up taking longer in the biology program than she expected. Amy being a first generation and a minority student, her comments might also reflect the effect of the pressure and expectations placed on students from their parents. Such pressure might have varying effects on the overall student career path.

**Theme 6: Wanting to do a challenging major.** This theme was expressed by two participants who had decided to persist in biology regardless of academic challenges which they had experienced in biology major. The narratives helps demonstrates the power of student intrinsic motivation and perseverance over academic challenges. The quotes from the two participants are shown below.
Sebastian: My strengths are in literature or history or psychology majors and social stuff like that and so biology and anything in that line is my weakness. I didn’t want to come to school and get an easy degree because I felt like even if I got that degree generally you know if it’s like psychology or something like that, the psychologists don’t have jobs anyway so I would waste my life to become a psychologists and I would not do anything with that degree. So I just really wanted to I guess trying to prove to myself I can make my weaknesses strengths and you know being able to take that knowledge with me for the rest of my life and know that I can do anything I want to it just takes a lot of time and persistence. The strong fields now are in technology or any sorts of engineering, communication and stuff like that so I wanted to do something valuable career wise and also for my self-motivation.

Marie: I did not want to look like a joker to my peers and so I wanted to take a tough major so that was really a major thing. I have a few friends that are just like, like one of them started as a biology major and then he switched to communication and he was just like “oh this is so easy” and am like well yea it is easy that’s why you tried to leave biology because it’s not that easy and for me I wanted something challenging but I also wanted to proof to myself and others that I could do it.

The comments by Sebastian and Marie underscore the point that a biology major and other associated science majors are challenging majors. It is interesting how both wanted to do a challenging major like biology and most importantly prove to themselves and their peers that they could do it. Sebastian acknowledges that STEM fields are more marketable and, therefore, it was important for him to orient himself with a major with future prospects for employment. It seems to make sense if he had chosen a social science major since that is where his strength are, but interestingly he chose a science major to prove that with persistence and hard work one can overcome challenges. For Marie taking a tough major like biology was an important aspect she valued, especially with respect to her peers. She describes the case of a peer who had switched from biology to social science major, and to her that was proof that biology was not an easy major, which made her proud. The comments by these two participants give glimpses of how students
can have interesting reasons for their persistence in biology or in other sciences. These students’ perspectives have important implications to instructors of higher education. This might call upon the faculty members to be respective of the different reasons which different students might ascribe to persisting in certain majors and find way of supporting them to successfully navigate through their majors.

Q8 What are the reasons that make average and below average performing students’ switch from biology for other majors?

Under this research question, the researcher was interested in exploring the reasons which made the average and below average performing students leave biology. In line with the semi-structured interview approach, the researcher asked each participant who had left biology to talk about the reasons or circumstances, which prompted them to leave. One theme related to academic ability emerged from this research question: poor performance in biology introductory courses.

Theme 7: Poor performance in Biology introductory classes. This theme did not come as a surprise to the researcher because the two participants who had switched from biology to other majors throughout their interviews underscored the factor of having a low GPA as a result of performing poorly in biology classes during their first year in college. A total of four participants expressed this theme; two of these had switched from biology while the rest were persisters. All the four quotes are indicated below, starting with those of the switchers.

Agnes: I always wanted to do biology and I had a great professor in high school, so I always wanted to be a biologist. So I switched from biology just because I was not getting GPA, which I needed to move on in my program and for two semesters my GPA stalled and so I moved to Earth sciences. One of the advanced biology course killed me I failed it and then I took it again and I failed it again and I was done with it and that’s one of the deciding factor when I thought I didn’t have to be in the
biology program any more. My GPA has improved quite a bit since leaving the biology program. In the biology program it was just a lot of work and it was more of a lot of very hard classes all at once, you know they get you into Math’s and then you have Chemistry and you have Biology and then you have two labs and maybe an English class you know what I mean!!? Just a lot of work.

Agnes described how she wanted to be a biologist just like other participants who persisted in biology. Her passion for biology was partly influenced by her high school biology teacher and even though she always wanted a career in biology she switched from biology to major in Earth sciences. The poor academic performance in biology courses was the main reason in her decision to switch from biology major. Agnes portrays biology course load as heavy and that she was overwhelmed by the combination of many science introductory courses all at once: “you know they get you into Math’s and then you have Chemistry and you have Biology and then you have two labs and maybe an English class you know what I mean.” Agnes’ commentary might indicate that even though some students have interest in biology at an early age, they switch from biology as a result of factors related to course load in science introductory programs.

Such comments raise pertinent issues regarding how students with an interest in biology can be supported academically to continue in the biology program. Clare, the second participant who had switched from biology echoed similar sentiments. Similarly, Clare underscored performance as the main reason for her switch from a biology major and that her GPA has improved after switching from biology major.

Clare: So in my sophomore year after my freshmen year my grades had suffered a lot after taking all the biology courses. I wanted to be a geneticists at first so I didn’t realize what I was getting my hands into I was always interested from high school but then I realized that since my grades had suffered a lot I was not interested in what I was learning. I decided to switch to dietetics because I still love science I just didn’t want to be a geneticists anymore, so after taking nutrition class I ended
up loving it and excelling in those classes as opposed to in my freshman year with my biology courses. I guess I couldn’t apply what I was learning in biology to the genetics part so now that I can apply the nutritional aspect in science together and I love it so it’s just kind of helped click that in me.

It appears from Clare’s comments that she was interested in biology in high school, so when attending college she wanted to pursue a biology major with the hope of becoming a geneticist. Like other participants, early interest in biology was a common denominator. Clare became uninterested in biology after failing all her biology courses within the first year, like Agnes, and this was the main reason she decided to switch from biology to a Dietetics major. She also discusses lack of real world connection between learning biology materials and a geneticist career; alternatively, she indicates that she was able to make a connection between dietetics and the nutritional aspects of science. Clare indicates that when she got into the biology major, she was not well informed regarding the requirements as she had explained to the researcher elsewhere, “So I guess I wasn’t prepared for that workload coming in and I didn’t realize that and I wish someone had warned me about that joining into this major regarding the workload. I didn’t realize how much we were required to read the textbook.” Her comments also indicate that some students might not have enough information regarding a certain majors demands and expectations at the point of starting college and rather have superficial knowledge about science majors. This might have important implications to college instructors and administrators.

In addition to the quotes by the switchers, the following exempts represents quotes from two students who had persisted in biology. The two quotes imply that, even
if these students had persisted in biology they had experienced academic difficulties especially in biology introductory classes.

Amy: I didn’t know how to study and in high school I didn’t have to study and I passed all my classes I guess it’s not that easy but I didn’t really need to study so I passes all my classes with As so and then coming here failing all my science classes I really didn’t know what to do.

Furthermore, Amy introduces an aspect of lack of study skills at college level, which presumably led to her failure in all the science introductory courses. She seemed to make comparison between her performance in sciences at high school level and that at college level, which did not seem to match. The other quote from May a persister is indicated below.

May: Sometimes I struggle and really feel out of place because all my peers are really smart and they don’t have to study and they ace tests so I have had ups and downs with my college career. So if I fail in class I really feel intimidated an example is in cell biology one of my friends and I in every test we got like Ds and Fs and everyone whom we were seated next by were getting Bs and As and we felt so intimidated we were like are we not studying what’s going on?

May talked about her academic struggles and frustrations as portrayed by failing most of her classes, she also seemed to compare her performance with those of her peers in the same class.

Comparison ofPersisters and Non-Persisters

While I would like to contend that the only difference between participants who switched from biology and those who persisted was that switchers failed in biology courses compared to their peers who persisted. The fact that some of the persisters also failed biology courses and often had to retake some of biology course makes this assessment at least partially false. Though this study was not designed to find the answer
to this question, I find myself compelled to try to answer the following: All things being held constant, among the study participants what led switchers to switch from biology and what led persisters to persist in biology? Based on the findings, it appears that if a student likes biology or the associated careers in biological sciences enough to compensate for the challenges he or she experienced in the major, then he or she is likely to persist. Thus, based on this assessment, it seems that an apparent difference between biology persisters and switchers is that the persisters were willing to tolerate difficulties associated with the major and switchers were not. For example, Marie, who had persisted in biology explained to the researcher that she struggled in many biology classes, failed and had to retake them, and she was advised to switch from biology due to her poor GPA, but she decided to continue in biology simply because biology is all she wanted to do in her life. Instead, Agnes, who switched from biology, explained that she had struggled in biology classes just like Marie, but she wasn’t prepared to continue with the challenges in biology for the next 4 years. This assessment implicates persisters as really wanting to be biology the biology major bad enough. As evident in a few persisters’ refusal to leave the major regardless of their poor performance and bad experiences with their advisors, this is, at least partly true. However, I do not believe that simply “wanting it badly enough” promotes persistence; rather it is wanting it badly enough to make the behavioral changes necessary for persistence. Therefore, based upon the findings of this study, I found that a remarkable difference between biology persisters and switchers was that, whether by calculated effort or by sheer desperation, persisters did not “see” themselves outside biology and they had to work it out for themselves, and switchers, for the most part, did not. Some of the mechanisms employed by persisters include creation of networks
including consulting peers (having a study buddy) and experiences that helped make their biology education more worthwhile and relevant to them. Creation of this network required a lot of effort on the part of persisters and less often involved assistance from biology faculty, as one persister expounded a common phrase repeated by persisters, “learning on your own.”

Amy: I just worked on other classes to see if I was interested in something else but I ended going back to biology because that’s where I see myself so I struggled a lot and then I had to repeat a couple classes that I failed in freshmen year and then they got easier because I learned how to study on what am focusing on and I learned that on my own, because I did not have like my advisor didn’t really help me I only met him to give me my pin to register so they never told me hey I don’t think this is a good pathway that you want to do and as a student I never wanted to go and see the teacher if I have a problem so I guess that’s my fault too but I mean my advisor did not give me advice. So I guess the professors more so they just lecture and if you don’t understand in class its on your own I figured it on my own by studying alone and I no longer walk into their offices. A lot of my peers are in the same boat as I am retaking classes so we clicked on that part so we help each other getting through it and then having multiple classes with each other just meeting like hey go to class I will be there or study together and stuff like that made it better at least I have a study buddy because if you didn’t get something at least the other person got something.

**Relationship Between Quantitative Data and Qualitative Findings**

The quantitative results indicated that success in introductory biology courses was a predictive of persistence in biology. On the other hand, qualitative findings showed that lack of success in introductory biology courses was a big factor, which led students to leave biology major. This means that promoting students success in biology introductory courses might promote students persistence in biology as well especially among the average and below average performing students.
The implications for institutions are two-fold: if we want students to persist in STEM majors, including biology, we need to create experiences that promote persistence and train students how to persist. This meant: (a) providing and requiring students to use the tools and the resources they will need to make reasonable and well-informed decisions and (b) providing experiences that will help make their efforts relevant and worthwhile.

**Discussion and Recommendations**

This study investigated the patterns of persistence of average and below average performing undergraduate students in biology by examining their experiences. Several national reports highlight the growing concern about the attrition of undergraduates from STEM in the U.S. (e.g., Frehil et al., 2008). For example, the report on “Rising Above the Gathering Storm” (NAS, 2005) specifically emphasizes the social and economic impact this decline may have on individuals intending to compete for high-quality jobs in STEM fields and the negative effect with respect to the U.S. ability to compete in a global scientific environment. This focus on science fields has resulted in a call for institutions of higher learning as well as national organizations to address challenges related to persistence among undergraduate students who, on admission to their institutions, had aspired to pursue careers in STEM fields. Equally important is the need to understand the experiences of undergraduates who are currently enrolled in STEM fields (Fries-Britt et al., 2010). In an effort to contribute to the national call for addressing undergraduate attrition from STEM fields, the current study examined the experiences of 12 average and below average performing students in a biology program with an aim of understanding how those experiences had shaped their decisions to persist in biology or switch majors.
The findings from this study illuminated several themes based on participants’ experiences in a biology program. It is important to point out that even though this was a comparative case study between participants who had persisted in Biology and those who had switched from it, the findings revealed that all the study participants were more similar than they were different in relation to their experiences in biology. Specifically, most of the participants indicated their struggles in biology classes in having to retake most of the introductory classes, they also had parallel social relationships. Some of the important factors highlighted by the participants include: difficulties associated with transitioning from high school to college, instructional aspects of the introductory biology courses, aspects of competition and weeding out in the biology major, and the effects of participants’ social interactions. The narratives of the participant’s experiences in biology help to conceptualize what it is like to be an average and below average performing student navigating through the academic challenges to earn a biology degree. In the next paragraph each paragraph will represent a specific theme under discussion and how the theme relates with the broad literature.

**Theme 1: Difficulties Transitioning from High School/home to College**

Challenges associated with difficulties transitioning from high school to college was an important factor voiced by one student who had persisted in biology and two students who had switched from it. These results are in agreement with Daempfle (2004), who indicated that there existed a lack of consensus between secondary biology teachers and college biology instructors with respect to what introductory biology courses should entail. This has the potential to contribute to students’ challenges in transitioning from high school to college level learning expectations with respect to workload and study
skills. For example they expressed that in high school they were not expected or required to read the textbook, as was the case in college as expressed by one of the participants, “I didn’t realize how much we were required to read the textbook I guess the professors told us read the textbooks and I was like “oh really we have to read the textbook now!” I was like I will just read the PowerPoint’s.” This clearly delineates the differing expectations and an existence of disharmony between secondary and post-secondary instructors with respect to aspects related to preparation for collegiate success in biology. Overall, these differences might explain students’ difficulty in adjusting to college level learning expectations. Similarly, Russell and Atwater (2005) noted that students’ transition to college was often difficult, especially among the African American students.

**Theme 2: Ways in which Biology Courses were Taught**

Instructional aspects of biology introductory courses were an important factor with respect to participants’ persistence or lack of it in biology. A majority of the participants (75%) expressed this theme. The participants’ vignettes resonate with numerous studies (e.g., Derting & Ebert-May, 2010), which call for reform in teaching science introductory courses. Participants discussed their experiences in biology classes in which the instructors used either inquiry-based, non-traditional collaborative approaches or the didactic lecture based instruction methods, indicating higher enjoyment where the former two methods were used. Glick (1994) noted that college instructors are often scientists who are untrained in instructional theory and practice. Consequently, most instructors rely on instruction methods by which they were taught in developing a conceptual framework that guides their teaching (Glick, 1994), this framework is often a traditional instruction method as characterized by a high adherence to content
transmission as opposed to the development of students reasoning skills. Introductory post-secondary biology courses are often characterized by large lecture classes that reinforce passive roles for learners and, therefore, there it is a challenge to promote student reasoning skills (Derting & Ebert-May, 2010). The current study findings, as evident through students narratives where they expressed enjoyment of the learning process when active-learning teaching methods were used in non-traditional classrooms is likely to contribute to higher learning gains as it has been shown by a variety of studies (Daempfle, 2002; Derting & Ebert-May, 2010; S. Freeman et al., 2007).

When asked to describe the teaching within the biology introductory courses, participants used words such as high paced, competitive, dull, and lack of support. The large class sizes of biology introductory courses was mentioned by several participants as a barrier to efficient learning, with students associating the large class sizes with their inability to have personal (one on one) contact with the instructor during class time. On the other hand, participants described some of their biology classroom experiences where the instructor used inquiry-based teaching approach as interesting. Similarly, these results are partly in agreement with previous studies which document the effect of the “chilly hypothesis” in introductory science courses dominated by poor instruction (Seymour & Hewitt, 1997). Consistent with previous research (Seymour & Hewitt, 1997), results revealed participants disappointment with some instructors’ interest in their own research above teaching. One participant who persisted in biology felt that one of her biology instructors was more interested in his research than teaching. In line with these findings, Daempfle (2004) found that students’ attitudes about faculty preoccupation with their own research changed when students were allowed to participate in the instructors’
research. In addition to the student perception of the course being fast-paced by the instructor, there was an aspect whereby the teacher had an assumption that students had prior knowledge essential to the course in question or at least the teacher had an expectation that students should have had some background information necessary for the course. On the other hand, the two participants who had switched from biology to other majors (Agnes and Clare), described to the researcher of their enjoyment of teaching in their new majors, indicating that the teaching was slow paced compared to that in biology (Agnes), and that they were able to make connection between the material learned in class and they desired future career (Clare). Lastly, with respect to poor instruction in biology classrooms, in agreement with Seymour and Hewitt (1997), part of participants’ criticism focused on the lack of collaborative learning dominated by one-way instruction.

Remarkably, in agreement with studies by Seymour and Hewitt (1994) and Strenta et al. (1994), all the study participants valued their high school biology learning experiences, which they described as more interesting, explorative, collaborative and offering more experiential opportunities to learn biology, aspects which helped to nurture their interest in biology. These aspects are well captured in the AAAS (2010) Vision and Change document, which emphasizes the importance of students understanding science, being competent in communication and collaboration, and having some experiences with modeling and simulation. This contrasts with the common explanations by college science faculty for the high attrition rates within undergraduate science introductory courses as associated with poor high school preparation (Seymour & Hewitt, 1997). Although this does not refute the faculty’s opinion, it helps to emphasize the effect of differential expectations of college faculty and high school instructors for their students,
with study participants favoring of their high school learning experiences. In this study, an examination into the reasons for preference for high school learning experiences over college, participants expressed disappointment with aspects of the chilly climate in some college biology courses as opposed to the enriched high school learning experiences. The study participants also indicated to the researcher that, the workload at high school was less compared to that at college, and that they didn’t have to work as hard at high school.

**Theme 3: Competition and Weeding out in the Biology Major**

From the study findings, the two students who switched from biology to other majors mentioned the competitive nature within biology courses and their personal perceptions of being weeded out of biology (as a result of being required to take challenging classes all at the same time), as one of their reasons that contributed to their decision to switch out of biology. These findings are in agreement with previous research (e.g., Seymour & Hewitt, 1997), which have described the nature of the first two years of undergraduate study in STEM fields as overly competitive. Additionally, according to Fries-Britt et al. (2010) in their study on high performing students of color, a majority of participants perceived that during their freshman and sophomore years, there was an attempt to weed them out of STEM majors by requiring them to take extraordinarily difficult classes. Interestingly, both persisters and switchers complained about students’ competition for grades in biology classrooms. This trend was previously demonstrated by Strenta et al. (1994), who found that biology students rated their courses as more competitive than students in other disciplines, including engineering and physics. As gleaned from interview responses, the likely source of this competition was due to premedical students who tend to compete for grades as a result of the competitive nature
in the health professions, as similarly found by Seymour and Hewitt (1997). Additionally, in this study, competitive learning environments seemed to be more of a complaint among female participants than male participants, a finding supported by Seymour and Hewitt (1997). While this does not imply that male students are less bothered by competition, the differential effect of competition between women and men may be one explanation for the generally lower persistence rates of female students in STEM majors (Seymour & Hewitt, 1997). In general, students’ perception of unsupportive learning environments and the heightened competition for grades within STEM courses has potential to contribute to students’ leaving the sciences.

Conversely, students’ perceptions of competitive learning environments can be intensified by poor performance in a course. Based on this, it is, therefore, likely to cast doubt on the chilly climate hypothesis (which is characterized by competitive learning environments), this is because attainment of a poor grade in science courses could contribute to a students lower self-efficacy in sciences and, therefore, lead to negative student opinions of classroom environments and course instruction. On the other hand, students’ who switched from biology to other sciences indicated that, they never experienced competition in their new majors and this might suggest that the chilly climate could have been a common feature within introductory biology courses. Based on the current findings, it appears that the popularly misconceived notions in explaining attrition in science majors such as language problems with foreign teaching assistants and poor high school preparation (Daempfle, 2003) were not supported. Instead, consistent with other studies (Seymour & Hewitt, 1997; Strenta et al., 1994), student perceptions of poor quality of undergraduate biology instruction dominated by competitive classrooms
and a general perception of being weeded out of biology major were mentioned by majority of the participants.

**Theme 4: Effect of Social Interactions and Interaction Challenges of First Generation and Underrepresented Minority students with Instructors**

The study participants described various social interactions that had impacts on them, ranging from effects on how they viewed themselves with respect to a biology career or their ultimate decision to either to persist in biology or switch from it, to effects on their learning gains. Participants described multiple positive student-faculty interactions (one-on-one), which participants associated with their success and persistence in biology. Similarly, Astin (1993) documented positive effects of instructor-student interactions, indicating that mentoring experiences in undergraduate science introductory courses are strong predictors of student success and persistence in the respective science courses. In addition, according to Strenta et al. (1994), regular student personal contact with a specific faculty member who took interest in them was among the factors significantly associated with students’ retention in sciences. Seymour and Hewitt (1997) found that poor student-faculty interaction was among the factors that turned students away from science majors, and they further documented that poor interactions were associated with instructor unavailability to students during faculty’s office hours. On the other hand, negative student-faculty interactions were reported by two participants who persisted in biology. They described some demotivating experiences where they were encouraged to switch from biology to other majors either because their performance was not on par with expectations for the programs continuation with a biology degree and
that the learning materials in biology were not going to get any easier. The two participants despised their advisors advice and continued in the program primarily due to the fact that all they wanted to do was biology; they wanted a career in biology and the negative advice they received did not deter them from pursuing their goals in biology. Furthermore, positive participants’ interaction with peers and friends, either within the classroom settings or outside was described as important for students’ persistence in biology. Participant’s interactions inform of support networks, especially within students taking the same course. These findings concur with previous research by Astin (1993), which found that the amount of interaction among peers had far-reaching effects on nearly all areas of student learning and development. Astin (1993) emphasized the role of social support in student persistence in college, noting that, “The students peer group is the single most potent source of influence on growth and development during the undergraduate years” (p. 398). Astin’s work underscores the role of friendship circles above that of faculty-student support and also points to ways in which such relationships may strengthen the connection between the student and the institution. These results act to emphasize the power of student intrinsic motivation and perseverance over their challenges (Russell & Atwater, 2005).

This study documents challenges that were unique among first generation and underrepresented minority students with respect to their interaction with instructors. Specifically, the FGs and URM participants were the only participants who consistently expressed feelings of intimidation when approaching an instructor during office hours or the discomfort they experienced when instructors asked them to refer them by their first name. In connection to this, one of the participant who was both a FGs and a URM
described to the researcher that she had resolved to no longer visit a professors office hours due to discomfort coupled with her perceptions that some professors are not willing to help, this is her quote:

   Amy: So the professors just lecture and, so basically if you don’t understand in class it’s on your own and then when you go to the office hours they are intimidating and some of them look down on you they don’t really want to help even though not all of them. And the way they try to explain it to you I don’t know I get that vibe that they are frustrated that I don’t get it so I kind of stopped going to their office hours.

The current findings help to reinforce the previously documented cultural shifts especially associated with first generation students when they enter college (Hsiao, 1992). As FGs begin college and advance in their educational careers, they lie on the margins of different cultures, becoming less sensitive to their customary place within the family setting, and at the same time not quite fitting into the institutional lifestyle (London, 1992). One participant, who was a FG explained that part of her upbringing was the emphasis of respecting older people and that she found calling instructors by their first name to be disrespectful. Consistent with other findings, this might indicate some aspect of substantial social, academic and cultural transitions, especially among FGs (Terenzini et al., 1994). These findings may indicate the limited power of negotiating the rigor of the college classroom by FGs as a result of the cultural shift they experience. Furthermore, the findings reveal some similarities between FGs and URMs with respect to establishment of their interactions with the faculty and to some extent with their peers, which might adversely affect their overall persistence in a biology program.
Theme 5: Intrinsic Motivation in Biology

All the 12 participants described that they were intrinsically motivated in biology either from childhood or during high school years. Each of the participant described specific teachers, individuals or experiences that impacted their interest, success and persistence in biology during their high school schooling. Though the roots of this interest began in childhood, for many of the participants, this interest was not developed intellectually until high school. This makes sense considering students are not introduced to the more complex life science curricula, such as cell and molecular biology, until they are in high school. This finding is in agreement with previous research (Ogbu, 1990; Russell & Atwater, 2005), which documented positive effects of high school instructors on impacting students’ persistence in high school sciences, especially among African American students. The findings from this study are in agreement with previous studies that document the power of intrinsic motivation and perseverance as a key driver in persisting in sciences (e.g., Russell & Atwater, 2005). Among the 12 participants, regardless of whether they persisted in biology or switched out of it, all were intrinsically interested in biology since childhood or high school. Aspects of early exposure to the natural world included adventures like hiking, interacting with aquatic animals in places like SeaWorld, watching medical shows on television, high school experiences with biology through dissecting animals and collecting and analyzing biological samples. All the study participants overwhelmingly described their high school biology experiences as the most important aspect in developing their interest in biology, often adding that these experiences played a role in their decision to major in biology. Furthermore, switchers and persisters were very similar in terms of the other experiences that helped develop
their interest in biology. Many of the participants’ narratives about enjoying high school biology centered on hands-on experiences, especially dissection. Whether these dissections occurred as part of their AP biology course or a senior anatomy and physiology course, all the participants described dissection as important in helping them learn biology as one persister described:

Mary: We dissected the cat and so we squeezed a bean through the digestive system and that was awesome and so my best friend was also in that class too and she was the one who was writing everything down, and she doesn’t like cats and she was like this is horrible I don’t want to touch it and I was like this is so cool. So I liked dissecting things and so in my biology classes in my anatomy classes we could dissected everything and those were the classes I actually had fun doing stuff in class so it was more fun than math’s, and I liked dissecting rats and I liked dissecting an eyeball and grasshoppers and all that stuff to see what is inside it.

The findings of the current study help to illustrate the importance of nurturing the intrinsic motivation of students who already have it, in addition to efforts to develop the interest of those students who lack it. This is because if students are intrinsically interested in biology they can endure the challenges associated with the difficulty of a biology major and the challenges related to course instruction. Additionally, if students are intrinsically motivated in biology, then they are likely to have high self-efficacy in biology. Self-efficacy has been shown to be a strong predictor of both success and persistence in a variety of disciplines (Wigfield & Eccles 2002).

Theme 6: Wanting to do a Challenging Major

An interesting theme from the current study was a desire by some study participants to “do” a challenging major. This was a theme voiced by the two participants who had decided to persist in biology regardless of their academic challenges. In their
vignettes, there were strong elements of recognition of biology as a “tough” STEM major compared to other non-STEM majors, perseverance or persistence through a tough major, a need to self-prove and also prove to peers that they could handle a tough major like biology, and a recognition that biology like other STEM majors hold good prospects for future careers. These findings are in agreement with previous research, which describes STEM careers as prestigious and competitive, and broadly viewed as socially prestigious and financially rewarding (Chang et al., 2014). There seems to be an awareness of the benefits of STEM careers to both self and larger economic realms among the two study participants who expressed this theme. This awareness is in line with the predictions by economic analyses which indicate that by 2018, many science and engineering occupations’ growth rates will be faster than average, and that many jobs will require post-secondary training (NSB, 2012). Consistent with Davis et al. (2004), the current findings portrays the need by average and below average performing students, which is comparable to African American students desire to “prove their academic worthiness,” to overcome the traditional perceived misconceptions and stereotypes regarding their academic success and persistence in sciences (Russell & Atwater, 2005).

**Theme 7: Performance in Introductory Biology Courses**

Performance was a big factor among the participants who had switched from biology. It is important to indicate that the two students in this study who had switched from biology underscored their inherent desire to pursue a career in biology. However, failure in biology introductory courses was the major reason that turned them away from biology. Their poor performance in biology courses was associated with difficulties with the workload offered within biology major during the first year, as they described to the
researcher. Other studies with similar results show (Strenta et al., 1994; Chapter III), performance in introductory science courses as a strong predictor of persistence in biology within the first two years of college. These findings warranted the instructors leading introductory biology courses to focus on ways of promoting students success in introductory biology courses. Such efforts are deemed to promote students persistence in biology, and this had a broader impact on reducing attrition rates in STEM majors nationally. According to Seymour and Hewitt (1997), performance was not a major factor among students who switched from sciences to non-sciences rather they found that other factors such as poor teaching in science introductory courses and unavailability of professors during advising as the major reasons which turned students away from sciences. Considering that Seymour and Hewitt utilized participants’ self-report, which may work to conceal embarrassment at poor performance. Furthermore, Seymour and Hewitt (1997) and Strenta et al. (1997) drew their study participants from a population of high-performing students as evidenced by math’s SAT scores above 650, meaning that, even among the high ability students, poor performance within the first two years of college science predicted students’ attrition from sciences.

In the current study, both students who persisted in biology and those who switched from biology had comparable GPA at the end of their sophomore year. One participant who switched to Earth sciences (Agnes) described the heavy course load in biology program, competition for grades, and poor teaching compared to that in Earth sciences as important for her decision in switching from biology. The other student who switched to Dietetics (Clare) explained that in addition to failing the introductory biology courses, she was unable to make connections with what she was learning in biology to the
biology career (geneticist) she wanted to pursue. As previously stated, this trend was previously demonstrated by Strenta et al. (1994), who found that biology students rated their courses as more competitive than students in other STEM disciplines, including engineering and physics.

**Recommendations for Teaching and Learning**

The current study findings highlighted important themes from the study participants. A majority of the themes contribute to our understanding of the reasons as to why undergraduates initially interested in Biology major do not graduate with a biology degree. In an effort to stem students’ attrition, specifically from biology, several measures needs to be put in place. First, there is a need to have sufficient streamlining of high school preparation to meet college level expectations with respect to the necessary training for high school graduates entering college. This is likely to enable high school graduates joining college to have a smooth transition to college and ultimately reduce anxiety over college course load for some of the students. Second, there is a need to completely transform the structure of all post-secondary biology classrooms to incorporate activities that actively engage students in learning. This is because the findings showed that some of biology classrooms are in the initial stages of the transformation process to incorporate inquiry-based teaching approaches as indicated by one of the participant Clare:

But for my other advanced biology class Dr.____ does group work so she will do a little lecture a short one because she expects us to read the book outside the class that way we get our foundation by ourselves if you have any questions you can see her in her office or you put it up in the blackboard and then she will address that and then we have worksheet and we will have to get into groups when we do that and I think that really works really really well.
Reforming introductory biology classrooms might have potential to reduce students’ perceptions of being weeded-out, and reduce the perceptions of competitive learning atmosphere. Thirdly, the study findings indicate the need for college biology instructors to try and make clear connections between their research and classroom teaching materials or alternatively, engage students in their own research (Daempfles, 2004). Such efforts have the potential to reduce students’ perceptions of instructors as being more interested in their research above teaching and also help students to see the relevance of the instructors’ research and the learning material at hand. Fourthly, the findings revealed student-instructor interaction challenges unique among the FGs and URMs. There is a need for college instructors to be aware of and understand their social and cultural contexts which might impact their overall college survival, success and persistence especially for the ones who are at risk of failing, changing majors or dropping out of college and device ways of helping them. Fifthly, trainers of college biology instructors should focus on the ways of nurturing and strengthening student-instructor interactions, because positive interactions was a strong predictor for students’ persistence in biology as indicated by participants narratives. Finally, because this study provides some evidence of unique experiences common among FGs and URMs, with respect to their resource use during college, a worthwhile extension would be to analyze which and to what degree students such students utilize the resources connected to the biology major (i.e., instructors, research opportunities, study groups, organizations, etc.) and the institution (i.e., career counseling, academic assistance such as tutoring, cohort programs, among others).
Conclusions

The current study highlights the salient characteristics of the structure and culture of introductory biology courses at the study institution. The interaction of these characteristics was associated with students’ dissatisfaction with the biology major and eventual persistence or attrition from the biology program. The interaction of the differing high school and college expectations with respect to what undergraduates aspiring in biology and instructional factors, could contribute to a higher dissatisfaction found among undergraduate science courses and the associated attrition from those sciences. Faculty members involved in undergraduate advising should streamline their advising’s to incorporate students’ future career aspirations.
CHAPTER V

SUMMARY

Critical to the United States (U.S.) ability to maintain its position as an economic global leader is its potency in Science, Technology, Engineering, and Mathematics (STEM). Several reports have documented the growing concern about the attrition of undergraduates from STEM fields, (e.g., Frehil et al., 2008; Lacey & Wright, 2009; NAS, 2005; President’s Council of Advisors in Science and Technology [PCAST], 2010; 2012). For example, the report on “Rising Above the Gathering Storm” (NAS, 2005) specifically emphasizes the social and economic impact the attrition of undergraduates from STEM majors may have on individuals intending to compete for high-quality jobs in STEM fields and the negative effect with respect to the U.S. ability to compete in a global scientific environment. This has resulted in a call for institutions of higher learning, as well as national organizations, to address challenges related to success and persistence among undergraduate students who, on admission to their institutions, had aspired to pursue careers in STEM fields. Student success and persistence in STEM fields is paramount to the overall national agenda of combating the paucity of individuals graduating with science degrees (PCAST, 2012). Furthermore, identification of predictors of success and persistence in science introductory courses, and examination of average and below average performing students’ experiences in introductory science has the potential to contribute to the nationwide need for more graduates in STEM sciences.
The overarching purpose of this study was to examine the predictors of success and persistence in biology among students enrolled in introductory biology courses (Cellular and Molecular Biology and Organismal Biology) with a focus on average and below average performing students in biology as categorized by student GPA at the end of the sophomore year. The predictors of success and persistence were based on motivational and attitudinal educational experiences examined in tandem with demographic factors. Furthermore, this research investigated to what extent such factors or predictors differentially predicted success and persistence among the underrepresented minority and first generation students. Additionally, a second part of this study was to examine the predictors of persistence among the average and below average performing students in biology, through qualitative methods. Qualitative inquiry involved exploration of the experiences of the average and below average performing students whether they had persisted in biology or not.

Quasi-experimental design was utilized for the quantitative part of this study. In order to determine the predictors of success and persistence two validated instruments, the Colorado Learning Attitudes about Science Survey- CLASS-BIO (Semsar et al., 2011) and the Science Motivation Questionnaire-SMQ (Glynn et al., 2011), were administered to students in an introductory biology course (Principles of Biology and Organismal Biology), over several semesters. Qualitative inquiry was utilized as an exploratory tool to provide deeper insights into the quantitative results with respect to why average and below average performing students either chose to persist in biology or opted out of biology for other majors.
Results from this study suggest that motivational factors (self-efficacy, self-determination, career motivation and grade motivation), were equally important predictors of success among all student types including both underrepresented minority and first generation students (Chapter II). Participants’ index score, minority and generational statuses were among the top demographic predictors of success. The attitudinal factors, which significantly predicted student success were ability to apply knowledge to solve biology-specific tasks and enjoyment of biology. Dual enrollment in a biology supplemental instruction course was an important factor for success in biology among the minority students. First generation (FG) students who were non-minority were more likely to succeed in biology compared to the FG minority students.

The motivational factors, which emerged as predictors of persistence in biology, were self-efficacy and grade motivation, the only attitudinal predictor of persistence was application of different strategies to solve biology problems (Chapter III). Additionally, students’ final percent course grade was a significant predictor of both success and persistence in biology. Interestingly, FGs were more likely to persist in biology compared to the non-FGs, while the underrepresented minorities (URMs) were less likely to persist in biology compared to majority students. The study results confirms the importance of students’ index score, ethnic background, and generational status in predicting success and persistence in undergraduate biology, a finding replete in the literature (e.g., Crisp et al., 2009; Harrell & Forney, 2003; Singh & West, 2014).

The current study findings suggest that, each of the predictors of student success and persistence in biology is important in its own right and educators in post-secondary institutions should strive to develop, enhance and focus on such variables among their
students. If students are to excel in biology as a STEM field, then they need proper motivations and positive attitudes to encourage them to prepare for class and participate in class activities. By enhancing students’ motivations and attitudes, and taking into consideration the specific motivational and attitudinal factors important for URM and FG success may be a step forward in addressing the critical problem of success and in STEM fields. Providing students with opportunities to develop positive attitudes in solving biology related problems while nurturing students’ self-efficacy in biology appears to be an essential task of educators leading first-semester biology experiences.

The qualitative findings highlighted four important factors as emphasized by study participants with respect to their experiences in biology, such as: difficulties associated with transitioning from high school to college, instructional aspects in introductory biology courses, effects of participants’ social interactions and perceptions of competition, and weeding out in biology classrooms (Chapter IV). The findings emphasize the need to have sufficient streamlining of high school preparation to meet college level expectations with respect to the necessary training for high school graduates entering college. Such initiatives might include establishing collaborative programs between colleges and high schools, which specifies key areas which high school graduates should be prepared for necessary for college success. Alternatively, colleges can commit to do more preparatory work among first year students within the first semester. This is likely to enable high school graduates joining college to have a smooth transition to college and ultimately reduce the difficulties associated with transitioning from high school to college among some students. Additionally, college biology instructors should to try to make clear connections between their research and classroom
teaching materials or alternatively, engage students in their own research (Daempfles, 2004). Such efforts have the potential to reduce students’ perceptions of instructors as being more interested in their research above teaching and also help students to see the relevance of the instructors’ research and the learning material at hand. With respect to FGs and URMs challenges of interaction with the faculty, the findings point to the need for college instructors understanding and taking into consideration the cultural and social circumstances of URMs and FGs which might have effects in their overall college survival, success and persistence. Finally, since this study provides some evidence of unique experiences common among FGs and URMs, with respect to their resource use during college, a worthwhile extension would be to analyze which and to what degree students such students utilize the resources connected to the biology major (i.e., instructors, research opportunities, study groups, organizations, etc.) and the institution (i.e., career counseling, academic assistance such as tutoring, cohort programs, among others). Whereas my study contributes to the understanding of factors related to students’ success and persistence in biology, more research focused on why undergraduates choose to eschew from STEM majors is still required. Longitudinal studies that follow individual students within a specific STEM field, will be able to provide a deeper understanding in the area.

There are several aspects highlighted from the three studies all of which are important for students’ success, persistence and retention of the average and below average performing students in biology. First, quantitative results (Chapters II and III), showed that, motivational factors were important predictors of success and persistence among all the student types including both underrepresented minority and first generation
students. Qualitative findings indicated that, students poor performance in biology introductory courses was a major factor for leaving biology, on the other hand success in introductory courses was a predictor of students persistence in biology (Chapter III), this shows that, promoting students success in introductory biology courses is crucial for promoting persistence in biology among all students types including the average and below average performing students. Higher order thinking skills (expert-like attitudes about biology) such as students’ ability to apply knowledge to solve biology-specific tasks and their ability to solve difficult problems in Biology were important for both students’ success and persistence (Chapters II and III). Such aspects are related to the findings from the qualitative study (Chapter IV), where by students described enjoyment of the overall class instruction where instructors employed inquiry based instructional approaches. Additionally, restructuring all the Biology introductory instruction might be important for both promoting students’ inquiry skills and their enjoyment of the biology discipline as well as reducing some students perceptions of being weeded out of the biology major.

**Recommendations for Teaching and Learning**

Providing students with opportunities to develop positive attitudes in solving biology related problems while nurturing students’ various motivational factors such as self-efficacy in biology appears to be an essential task of educators leading first-semester biology experiences. The findings from Chapter IV shows that student experiences during college in STEM departments (Biology) coupled with obtaining higher grades in STEM courses during the first year, can have an important impact on their decision to continue in a STEM major. Therefore, post-secondary instructors should strive to promote positive
students experiences in introductory science courses. Additionally, post-secondary institutions interested in increasing student success and persistence in STEM fields should focus on the institutional environment, which has potential to influence undergraduate student experiences. Transforming the structure of all post-secondary introductory biology classrooms to incorporate activities that actively engage students in learning have potential to reduce students’ perceptions of being weeded-out, reduce the perceptions of competitive learning atmosphere and increase their enjoyment of biology discipline. Such efforts have potential to promote success and persistence in biology. Supplemental instruction (SI) was important for underrepresented minority success, therefore, encouraging such students to enroll in SI sessions might promote both their success and persistence in biology.

**Future Research Directions**

There is always room for improvement in any research and the current research is no exception. There are various aspects, which can be utilized to further the current research. First, further research should disintegrate the URMs into their specific groups, this will enable how various attitudes and motivations play out among different URM groups. Second, there should be examine the enrolment up to the completion of a biology degree along with withdrawal patterns, this will be able to paint a complete picture of persistence rates in biology. Finally, further research should analyze to what extent does the FGs and URMs utilize the resources connected to the biology department (instructors, research opportunities) & the institution (career counseling, tutoring). This is because these two groups perceived lack of support within the biology department.
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APPENDIX A

CONSENT FOR--QUANTITATIVE STUDY
CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO
(Quantitative Study)

Project Title: Expectations and Persistence in the Introductory Biology Series
Researchers: Dr. Susan Keenan, Dr. Sue Ellen DeChenne, Jeffrey Olimpo and Biscah Munyaka (PhD student). School of Biological Sciences
Phone: (970) 351-2510
E-mail: susan.keenan@unco.edu; sueellen.dechenne@unco.edu; jeffrey.olimpo@unco.edu; muny0732@bears.unco.edu

Purpose:
We are inviting you to participate in this research project because you are (a) an undergraduate student currently or previously enrolled in introductory biology; or (b) a graduate teaching assistant for either BIO 110 or 111 at the University of Northern Colorado. This research is not intended to help you specifically, but the information gathered from this study will help us to develop better methods for promoting student success in introductory biology courses at our campus.

Procedures:
You will be asked to complete several short, Likert-item surveys (CLASS/SMQ, SPARST, and a Biology concept inventory-knowledge views diagnostic) designed to capture your attitudes and beliefs regarding expectations for success in introductory biology courses at your college or university. It is expected that these surveys will each take you no more than 15 minutes to complete. If you are an undergraduate student currently enrolled in either BIO 110 or BIO 111 at University of Northern Colorado, you will be asked to complete these surveys twice – once at the beginning of the semester and once at the end. If you are a student at another college or university you will be asked to complete the survey once.

If you are a student at University of Northern Colorado, you will also be asked to participate in a one-on-one or focus group interview, the intent of which is to allow you to elaborate upon the responses you provide in the surveys. These interviews are not expected to exceed 60 minutes in duration. Graduate teaching assistants, with their consent, will also have their classroom sessions videotaped in an effort to generate a representation of student-student and student-faculty interaction in the laboratory.
Your introductory biology course grades, enrollment in biology coursework, and information recorded by the registrar (such as high school GPA, SAT/ACT scores, and basic demographic information) will be compiled from university and course records.

You will not be compensated for your participation in this study.

**Potential Risks and Discomforts:**
There is minimal risk associated with participation in this study. However, you may become self-conscious while being videotaped. It is your prerogative to cease collection of videodata at any point throughout the duration of the study with no repercussion or penalty. Because the study does involve the use of videotaped observations, you should be aware that giving consent to the public and private display of your recorded image may also increase the risk of you being identified as a participant in the study. To minimize these risks, we will only show the videotaped data in settings for professional educators and scientists, and, in all cases, you will only be referred to by a pseudonym. There are no perceived risks associated with loss of confidentiality in these settings.

**Potential Benefits:**
There are no direct benefits to you. However, this research aims to provide valuable insight into factors influencing student retention and attrition in the biological sciences. It is anticipated that this study will, therefore, be of interest to biology educators and administrators.

**Confidentiality:**
To protect your confidentiality, you will be identified by a pseudonym in all datasets. There will be no record that relates your personal identity with the assigned pseudonym. We wish to remind you, however, that stating your real name at any time during the interview phase of the study will preserve your identity on videotape; thus, we recommend that you should make every effort not to do so. You may also elect to participate in the study without being videotaped. The videotapes that are generated from this study will not be published in any form, and the data shall be used exclusively for educational research only in the following professional settings: closed research meetings, seminars, and professional conferences.

All data will be stored in a locked cabinet in the office of PI, Dr. Sue Ellen DeChenne, 2570 Ross Hall at the University of Northern Colorado when not in use by approved research personnel. Because these data will be used to guide future curriculum development and professional development opportunities in the department, your data will be stored for a period of no more than 10 years following the date of collection. At that time, or when the data are no longer of use (whichever is earlier), the data will be destroyed by the PI, Dr. Sue Ellen DeChenne.
Please note that your information may be shared with representatives of the University of Northern Colorado or government authorities if you or someone else in danger or if we are required to do so by law.

Please check one:

_______ I agree to be videotaped during my participation in this study.

_______ I do not agree to be videotaped in this study.

Medical Treatment:
The University of Northern Colorado (UNCO) does not provide any medical, hospitalization, or other insurance for participants in this research study, nor will UNCO provide medical treatment or compensation for any injury sustained as a result of participation in this research study, except as required by law.

Right to Withdraw & Questions:
Your participation in this research project is completely voluntary. You may elect not to participate, and if you begin participation, it is your right to stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report any injury related to this research study, please contact Dr. Sue Ellen DeChenne at 2570 Ross Building, (970) 351-2004, or by e-mail: SueEllen.DeChenne@unco.edu.

Participant Rights:
If you have questions about your rights as a research participant or wish to report a research-related injury, please contact:

Office of Sponsored Programs
Sherry May, IRB Administrator
Office of Sponsored Programs
Suite #25, Kepner Hall
University of Northern Colorado
Greeley, CO 80639
E-mail: osp@unco.edu
Telephone: (970) 351-1910
**Statement of Consent:**
Your signature below indicates that you are at least 18 years of age, you have read this consent form in its entirety or have had it read to you, your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study. You may receive a copy of this signed consent form upon your request.

If you agree to participate, please sign your name below.

________________________________________
Subject’s Printed Name

________________________________________  ____________
Subject’s Signature                     Date

________________________________________  ____________
Researcher’s Signature                  Date
APPENDIX B

INSTITUTIONAL REVIEW BOARD APPROVAL
--QUANTITATIVE STUDY
DATE: January 23, 2015

TO: Jeffrey Olimpo

FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [494383-9] Expectations and Persistence in the Introductory Biology Series

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVAL/VERIFICATION OF EXEMPT STATUS

DECISION DATE: January 22, 2015

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Hello Dr. DeChenne,

Thank you for your explanations and modifications. You are approved and good luck with your project.

Sincerely,

Nancy White, PhD, IRB Co-Chair

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.
This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.

- 1 - Generated on IRBNet
APPENDIX C

COLORADO LEARNING ATTITUDES SCIENCE SURVEY FOR BIOLOGY (CLASS-BIO) AND SCIENCE MOTIVATION QUESTIONNAIRE II (SMQII) QUESTIONNAIRES--QUANTITATIVE STUDY
COLORADO LEARNING ATTITUDES SCIENCE SURVEY FOR BIOLOGY (CLASS-BIO) and SCIENCE MOTIVATION QUESTIONNAIRE II (SMQII) Questionnaires--QUANTITATIVE STUDY

**Instructions:** On the Scantron sheet provided, please write and bubble in both your PDID and your name. Please do NOT write directly on this survey. All answers must be recorded on the Scantron form using a #2 pencil.

**Demographic Information**

Please complete the following items to the best of your ability:

1. What is your race/ethnicity (select the one with which you most identify)?
   a. Caucasian (white)
   b. Black/African American
   c. Hispanic
   d. Asian
   e. Multiracial/Multiethnic or Other

2. Are you a first generation college student? (i.e., are you the first individual from your family to attend college?)
   a. Yes
   b. No

3. If you answered YES to question #2, are you involved in the Center for Human Enrichment (CHE) program on campus?
   a. Yes
   b. No
   c. I am not a first-generation college student

4. Is English your first language?
   a. Yes
   b. No

5. What is the highest level of mathematics you completed in high school?
   a. Calculus
   b. Pre-Calculus
   c. Algebra 2

6. How many years of math did you take in high school?
   a. 2 years
   b. 3 years
   c. 4 years
7. What is the highest-level biology course you completed in high school?
   a. AP Biology
   b. Honors/General Biology
   c. I did not take any Biology courses in high school

8. Did you take any biology electives (e.g., genetics, advanced health, anatomy and physiology, ecology, etc.) while in high school?
   a. Yes
   b. No

9. What is the highest-level chemistry course you completed in high school?
   a. AP Chemistry
   b. Honors/General Chemistry
   c. I did not take any Chemistry courses in high school

10. What is the highest-level physics course you completed in high school?
    a. AP Physics
    b. Honors/General Physics
    c. I did not take any Physics courses in high school

11. Are you currently working while completing your degree?
    a. Yes, 30+ hours per week
    b. Yes, 15 - 29 hours per week
    c. Yes, 1 - 14 hours per week
    d. No, I am not working at the present time

12. Are you currently involved in extracurricular activities on campus?
    a. Yes, and I spend 20+ hours a week participating in these activities
    b. Yes, and I spend 10 – 19 hours per week participating in these activities
    c. Yes, and I spend 1 – 9 hours a week participating in these activities
    d. No, I am not involved in extracurriculars

13. Currently, what is your level of interest in biology?
    a. Very High
    b. High
    c. Moderate
    d. Low
    e. Very Low

14. Why? (Please use the blank space on your Scantron to record your answer)

15. Do you plan to switch your major?
    a. Yes
    b. No
For the following questions, please fill in the “A” bubble if your future plans DO include the following; otherwise, bubble in “B.”

16. Biology related grad school
17. Medical school
18. Teaching biology
19. Other professional program (e.g., pharmacy school, dental school, etc.)
20. Working in government or industry (e.g., working for a pharmaceutical company)

INTRODUCTION

Here are a number of statements that may or may not describe your beliefs about learning biology. You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the five choices that best expresses your feelings about the statement. If you don’t understand a statement, leave it blank. On the Scantron, 1 = A, 2 = B, etc.

We are asking that you express your own beliefs. Your answers will not affect your grade in any way. Your instructor will never know who filled out what survey, so please be honest! The information you provide will help us design more effective biology courses here at UNC.

SURVEY ITEMS

21. My curiosity about the living world led me to study biology.

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<td>Strongly Agree</td>
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22. I think about the biology I experience in everyday life.

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23. After I study a topic in biology and feel that I understand it, I have difficulty applying that information to answer questions on the same topic.

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24. Knowledge in biology consists of many disconnected topics.

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25. When I am answering a biology question, I find it difficult to put what I know into my own words.

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26. I do not expect the rules of biological principles to help my understanding of the ideas.

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27. To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed.

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28. If I get stuck on answering a biology question on my first try, I usually try to figure out a different way that works.

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29. I want to study biology because I want to make a contribution to society.

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30. If I don’t remember a particular approach needed for a question on an exam, there’s nothing much I can do (legally!) to come up with it.

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31. If I want to apply a method or idea used for understanding one biological problem to another problem, the problems must involve very similar situations.

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32. I enjoy figuring out answers to biology questions.

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33. It is important for the government to approve new scientific ideas before they can be widely accepted.

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34. Learning biology changes my ideas about how the natural world works.

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35. To learn biology, I only need to memorize facts and definitions.

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36. Reasoning skills used to understand biology can be helpful to my everyday life.

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37. It is a valuable use of my time to study the fundamental experiments behind biological ideas.

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38. If I had plenty of time, I would take a biology class outside of my major requirements just for fun.

(Strongly Disagree) 1 2 3 4 5 (Strongly Agree)

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39. There are times I think about or solve a biology question in more than one way to help my understanding.

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40. If I get stuck on a biology question, there is no chance I’ll figure it out on my own.

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41. When studying biology, I relate the important information to what I already know rather than just memorizing it the way it is presented.

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42. There is usually only one correct approach to solving a biology problem.

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43. When I am not pressed for time, I will continue to work on a biology problem until I understand why something works the way it does.

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44. Learning biology that is not directly relevant to or applicable to human health is not worth my time.

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45. Mathematical skills are important for understanding biology.

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46. I enjoy explaining biological ideas that I learn about to my friends.

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47. The general public misunderstands many biological ideas.

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48. I do not spend more than a few minutes stuck on a biology question before giving up or seeking help from someone else.

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49. Biological principles are just to be memorized.

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50. For me, biology is primarily about learning known facts as opposed to investigating the unknown.

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51. We use this statement to discard the survey of people who are not reading the questions. Please select 4 to preserve your answers.

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52. When I am in a college biology course, the biology I learn is relevant to my everyday life.

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53. I like to do better than other students on biology tests.

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54. Learning biology is interesting.

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55. Getting a good grade in biology is important to me.

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56. I put enough effort into learning biology.

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57. I use strategies to learn biology well.

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58. Learning biology will help me get a good job.

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59. It is important that I get an “A” in biology.

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60. I am confident that I will do well on biology tests.

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61. Knowing biology will give me a career advantage.

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62. I spend a lot of time learning about or studying biology.

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63. Learning biology makes my life more meaningful.

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64. Understanding biology will benefit me in my career.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |

65. I am confident I will do well on biology labs and projects.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |

66. I believe I can master biology knowledge and skills.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |

67. I prepare well for biology tests and labs.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |

68. I am curious about discoveries in biology.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |

69. I believe I can earn a grade of “A” in biology.

   | Strongly Disagree | Strongly Agree |
   | 1 | 2 | 3 | 4 | 5 |
70. I enjoy learning biology.

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71. I think about the grade I will get in biology.

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72. I am sure I can understand biology.

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73. I study hard to learn biology.

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74. My career will involve biology.

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75. Scoring high on biology tests and labs matters to me.

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76. I will use biology problem-solving skills in my career.

| Strongly Disagree | 1 | 2 | 3 | 4 | Strongly Agree | 5 |

Thank you for taking the time to fill out this survey. Your participation is really helpful because knowing more about students’ beliefs about biology helps improve our teaching practices.
APPENDIX D

INSTITUTIONAL REVIEW BOARD APPROVAL
QUALITATIVE STUDY
DATE: December 7, 2015

TO: Biscah Munyaka, Ms

FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [788825-4] Examination of Persistence in Biology Among Average Performing Students

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVAL/VERIFICATION OF EXEMPT STATUS

DECISION DATE: December 7, 2015

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

We will retain a copy of this correspondence within our records for a duration of 4 years. If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB’s records.
APPENDIX E

CONSENT FORM--QUALITATIVE STUDY
CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO
(Qualitative Study)

Project Title: Examination of Persistence in Biology

Researchers: Biscah Munyaka (PI, Doctoral student), Sue Ellen DeChenne,
School of Biological Sciences
Phone: (970) 351-2122 (PI Munyaka)
E-mail: Biscah.Munyaka@unco.edu, SueEllen.DeChenne@unco.edu

Purpose:
I am inviting you to participate in this research project because you are (a) an
undergraduate student classified as either junior or senior and you are currently a biology
major or you were previously a biology major but switched to other fields at some point.
This research project is not specifically intended to help you directly but the information
obtained from this study will help us (biology department) develop strategies which
enhance persistence in biology major at the University of Northern Colorado and possibly
beyond.

Procedures:
You will be contacted individually through an email to sign up for an interview slot
depending on your availability. Through semi structured interview procedures you will be
asked to share your experiences in biology with respect to having stayed in biology or
having switched from biology to other majors. Confidentiality of the information you will
share during the interview will be maintained, and you will be only referred by synonym
throughout the processes involved in data handling and report writing. The interview is
designed to take between 1-2hours, you will be audio recorded during the interview.
Potential Risks and Discomforts:
There is minimal risk associated with participation in this study. Some individuals may become self-conscious while being audio recorded. It is their prerogative to cease from participating in the study at any point throughout the duration of the study with no repercussion or penalty. Other participants might experience psychological discomfort and stress associated with recalling their “bad experiences in biology” which made them leave biology for other majors. To this effect the interview might be slightly modified in response to any prevailing emotional atmosphere. Only the researchers involved in the study will have access to the interviews and confidentiality will be maintained during transcription and, in all cases, participants will only be referred to by a pseudonym. There are no perceived risks associated with loss of confidentiality in these settings.

Potential Benefits:
There are no guaranteed benefits to you and you will not be compensated for your participation in this study.

Confidentiality:
To protect confidentiality, all participants will be identified by pseudonyms in the dataset. There will be no record that relates your personal identity with the assigned pseudonym I wish to remind you, however, that stating your real name at any time during interview phases of the study will preserve your identity on audio records; thus, we recommend that you should make every effort not to do so. The audio records that are generated from this study will not be published in any form, rather it will be transcribed to text using a pseudonym, and the data shall be used exclusively for educational research only in the following professional settings: closed research meetings, seminars, and professional conferences.

All data will be stored in a locked cabinet in the office of PI, (Biscah Munyaka), in 1533 Ross Hall at the University of Northern Colorado when not in use. These data are majorly being used for dissertation purposes; therefore, I am requesting to store the data for 5 years following the date of collection. At that time, or when the data are no longer of use (whichever is earlier), the identifiable data such as; voice recordings and signed consent forms will be destroyed by the PI, Biscah Munyaka. If a report or article about this research is written, your identity will be protected.

Your information may be shared with representatives of the University of Northern Colorado or government authorities if you are in danger or if I am required to do so by law.

Please note that your information may be shared with representatives of the University of Northern Colorado or government authorities if you are in danger or if I am required to do so by law.
Medical Treatment:
The University of Northern Colorado (UNC) does not provide any medical, hospitalization, or other insurance for participants in this research study, nor will UNC provide medical treatment or compensation for any injury sustained as a result of participation in this research study, except as required by law.

Right to Withdraw & Questions:
Your participation in this research project is completely voluntary. You may elect not to participate, and if you begin participation, it is your right to stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report any injury related to this research study, please contact Biscah Munyaka at 2556 Ross Hall, (970) 351-2122, or by e-mail: Biscah.Munyaka@unco.edu.

Participant Rights:
If you have questions about your rights as a research participant or wish to report a research-related injury, please contact:

Office of Sponsored Programs
Suite #25, Kepner Hall
University of Northern Colorado
Greeley, CO 80639
E-mail: osp@unco.edu
Telephone: (970) 351-2161

Statement of Consent:
Your signature below indicates that you are at least 18 years of age; you have read this consent form in its entirety or have had it read to you, your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study. You may receive a copy of this signed consent form upon your request.

If you agree to participate, please sign your name below.

Please be aware also that your signature below indicates that you are at least 18 years of age, you have read this consent form in its entirety or have had it read to you, your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study.
If you agree to participate, please sign your name below.

________________________________________
Subject’s Printed Name

_____________________________    ____________
Subject’s Signature            Date

________________________________________
Researcher’s Signature          Date
APPENDIX F

RECRUITMENT EMAIL--QUANTITATIVE STUDY
Study title: Examination of persistence in biology

Email communication for recruitment

Dear _____________________. (Name of the student)

I am contacting you on behalf of a doctoral student, Biscah Munyaka, who is currently conducting a study entitled; “Examination of persistence in biology,” as part of her dissertation.

I am excited to inform you that you have been selected to participate in this study, because you were a biology major at the end of your sophomore year.

She would like to personally interview you about your experiences in biology (whether or not you are currently a biology major). Your interview will be anonymous and no faculty or staff member in biology will know you have been interviewed or know the contents of the interview. The interview will be conducted in an anonymous room within the Michener library. To maintain confidentiality, the specific room where the interview will take place will be communicated to you upon acceptance to participate in the study. The interview will be arranged depending on your availability within the course of the semester. Your participation in this study will play a very important role in contributing towards strategies to increase persistence in biology.

You can reply to this e-mail and it will be sent to Biscah Munyaka. Kindly reply at your earliest convenience indicating whether or not you wish to participate in this study.

Thank you in advance,

Derek Herbert and Biscah Munyaka
APPENDIX G

INTERVIEW QUESTIONS/PROTOCOL--
QUALITATIVE STUDY
Project Title: Examination of Persistence in Biology

Researchers: Biscah Munyaka (Doctoral Candidate (PI), SueEllen DeChenne,

Phone: (970) 351-2122 (PI Munyaka)

E-mail: Biscah.Munyaka@unco.edu

Interview Questions/ Protocol

Interview questions are designed to understand students’ experiences as average performers and how that affected their decision to persist in or switch out of biology. The main data collection method will be open-ended interviews which will be video recorded (Brenner, 2006). Video recording will be used in place of audio recording in order to facilitate ability to confirm specific participants’ responses during data analysis. Follow-up questions will be asked depending on the participants’ response. Each individual interview will be expected to last one to two hours.
Overview of the Interview

Gender
Ethnicity
Age
1st generation status
English second language?
Years of HS biology
Biology grades
Original major

Types of social interactions
Influential people/ events
Reasons for staying /leaving biology

Biology major?

No
Current major
Number of semesters in biology
Reasons for leaving biology
How did the social interactions influence your decision?

Yes
Reasons for persisting in biology
How did the social interactions influence your decision?

Your opinion regarding biology major
Effect of different aspects on overall opinion on biology

All participants will be identified by pseudonyms in the dataset; participants will explicitly be reminded not to use their names at any time during the interview to avoid identity recording. Participants will have an option of participating in the study without being videotaped. The videotapes will not be published in any form, and all data will be used exclusively for educational research.
The following question clusters will guide the research.

**Demographic and Educational characteristics:** The following demographic and educational backgrounds will be collected from all the participants
- Gender
- Ethnicity
- Age
- First generation status
- English second language
- Minority status (White or Not)
- Current enrollment status (Junior, senior)
- Semesters of biology taken in high school
- Current GPA
- Biology grade,
- Initial major,
- Current major
- Semesters in biology major, etc.
- How many jobs did you do?
- Do you hold a part time or full time job? (if so how many hours per day)
- Have you been involved in any study groups?
- Tell me about your study group dimensions
- What kind of organizations are you involved in (e.g., African American organization, Asian Students organizations, Native American Student Organization, biology clubs, sorority group, etc.)
- What did you have to do this past summer
- What kind of support systems do you have (Both financial and emotional)

**Social interactions and influential factors**
1. Influential factors in biology (tell me about some influential events/people in biology, why did you major in biology).
2. Social interactions in college: classroom interactions, teachers, mentors, TAs, peers, group discussions, others)
3. Social interactions outside college (family members, friends, church, social gatherings others)
4. How did the above social interactions influence your major decision?
5. Please tell me about other precollege experiences that influenced your interest in biology?
6. Influential people in biology (family members, elementary/HS teachers etc.)
7. Thinking backwards, when did you first decided to major in or develop interest in biology?

The following categories of questions will be asked to the two different categories of students (Stayers or leavers)
Leavers
1. What is your current major?
2. Can you describe to me the reasons or circumstances that made you leave biology other than the ones you have talked about?

Stayers
1. Why did you decide to continue in biology?
2. Can you describe to me the reasons or circumstances that made you stay in biology other than the ones you have talked about?

Opinion questions about biology major (both stayers and leavers)
1. What are some of facilities or opportunities which affected your overall opinion of the biology major whether in a positive or in a negative manner?
2. How did the advising in biology major affect your overall opinion about biology whether in a positive or in a negative manner?
3. What are some of aspects of biology courses which affected your overall opinion about biology whether in a positive or in a negative manner?
   - Grading
   - Exams
   - Laboratory experiences
   - General learning experience
   - Issues with understanding biology
   - Structure of biology lectures
   - Classroom discussion groups
   - Classroom learning environments
   - Perceptions of whom you are as a learner (malleable vs fixed mindsets)
   - Belonging in a community (I care being part of biology leaning community)
   - Effect of recognition or lack of it by others, e.g., teachers, peers, etc.
   - Effect of desirable or undesirable ascribed identity

Do you have anything else to add to what you just told me?
4. What are some of aspects of your biology instructors and TAs which affected your overall opinion of the biology major whether in a positive or in a negative manner?
   - Teaching style
   - Classroom management
   - Classroom environment
   - Communication of concepts
   - Technology use
   - Content knowledge
   - Helpful
   - Availability outside class
   - Attitudes towards me/students in general.
Do you have anything else to add to what you just told me?

5. Please consider areas where in your opinion you think the biology department (either based on
   - Faculty
   - Advising
   - TAs
   - Any other aspect which needs to improve as a department to increase students’ retention in biology major.
   - What do you wish they would do differently?
   - What do you wish they would change? Please be honest and constructive in all your responses.

At the end of every question, the researcher will summarize the participant responses to ensure that what was captured is exactly what the participant meant or said; changes will be made to the participant responses accordingly.