The Impact of the Design Process on Student Self-Efficacy and Content Knowledge

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ABSTRACT

The United States of America needs STEM trained workers, STEM faculty and STEM professionals to improve its technical and professional workforce in order to maintain leadership in a global economy. However, American students are not opting to remain in a STEM course of study, and this is especially so for women and minorities. Of the students who pursue post-secondary education, the majority of movement away from STEM majors occurs in the first two years. Thus, educators are concerned with investigating factors that may influence students' persistence and success when in a STEM track of learning. To that end, this quasi-experimental mixed-method study was concerned with investigating the effects of participation in the design process on student self-efficacy and content knowledge gains in an undergraduate anatomy and physiology laboratory. Over fifty students participated in a design task that paralleled the topic being studied in a given semester and were given efficacy surveys along with lab practicums. Qualitative efficacy data, quantitative efficacy data and quantitative practicum results were analyzed and triangulated to produce a meta-inference as to the effect of participation in the design project had on student learning. Preliminary results indicate that the design process makes statistically significant impacts on both self-efficacy and content knowledge in the given context. The author follows with a discussion of the impact of design-based learning in the undergraduate biology classroom and implications for further research are considered.

DEDICATION

For Geraldine Hope Howe Harding

Consummate teacher and lifelong learner.

My mother.

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"And I thank Christ Jesus, our Lord, who has given me strength, that he considered me trustworthy, appointing me to his service." I Timothy 1:12

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CHAPTER ONE: INTRODUCTION

The Nature of the Problem

The United States of America (US) is no longer the world economics and innovation leader. This information is not new. The National Science Board (NSB), as far back as 1986, recognized the now accepted "shift to a global economy" and the subsequent need for the US to stay ahead of other countries by keeping "new ideas flowing through research; to have the best technically trained, most inventive and adaptable workforce of any nation; and to have a citizenry able to make intelligent judgments about technically-based issues" (p. 1). In response, state and national governments began to focus time and energy into both K-12 and undergraduate educational reforms (Fairweather, 2009; Kuenzi, 2008; Kuenzi, Matthews & Mangan, 2006). However, more recently, attention has turned also to the effectiveness of higher education in general and STEM education in particular (Arum & Roska, 2011). The NSB recognized "the deterioration of collegiate science, mathematics and engineering [STEM] education is a grave long-term threat to our nation's scientific and technical capacity, its industrial and economic competitiveness, and the strength of its national defense" (1986, p.1). As a result, "the last 30 years has seen a widespread consensus that America needs to do a better job at promoting and supporting STEM education. Indeed, numerous task forces, commissions and study groups have produced an array of reports and calls to action" (NSB, 1986, p. 6). Atkinson & Mayo succinctly articulate the prevailing viewpoint that "STEM is so important that we can't afford not to have every student in America given the best STEM education, with the hope that this will increase the likelihood that at least some of them will go into STEM jobs" (2011, p. 6). Experts agree that STEM literacy should be the goal of a free and public education, which works to further the collective goals of national economy, democratic freedom and national security (Bybee, 2013;

NRC, 2011; NSB, 2013). Thus, as stated by Bybee (2013), "education should contribute to a STEM literate society, a general workforce with 21st century competencies, and an advanced research and development workforce focused on innovation" (p. X).

In an effort to find a path to innovation and a STEM literate society, policymakers, educators and professionals have pointed to the need to improve collective efforts in the fields of science, technology, engineering and math education across the board (Kuenzi, 2008; Kuenzi, Matthews & Mangan, 2006; NGA, 2011; NSB, 1986; NSF, 1996; NSF, 2009; President's Council of Advisors on Science and Technology, 2012). In response to this widespread call for action, the STEM reform movement has gained considerable momentum since 2001 (Breiner, Harkness, Johnson & Koehler, 2012). According to the National Science and Engineering Indicator report "raising student achievement, reducing performance gaps and improving the international ranking of U.S. students on achievement tests from the middle to the top are high priorities for education reform across the United States" (NSB, 2014, p. 1-41).

Student learning and achievement in grades K-12 continues to be a focus of the above-referenced reform. In addition, the reform spotlight has also been turned to undergraduate education. In 2011, researchers and authors Richard Arum and Josipa Roska revealed conclusions from their study into the state of US undergraduate education. In essence, Arum and Roska reported that for undergraduates,

> Gains in critical thinking, complex reasoning and written communication are either exceedingly small or empirically nonexistent… While students may have developed subject-specific skills…in terms of general analytical competencies assessed, large number of U. S. college students can accurately described as academically adrift. They might graduate, but they are failing to develop the higher-order cognitive skills that are

widely assumed college students should master. (p. 121-125)

According to the American Association of Community Colleges, almost half of all these undergraduate students are beginning their college studies at community colleges. In addition, increasing numbers of high school students are taking advantage of the open access to college education that the community college provides before they graduate (AACC, 2014; Hoffman, Strarobin, Laanan & Rivera, 2010). This is evidenced by increasing associates degree enrollment, which accounted for 49.8% of total higher education enrollment increases from 2000 to 2011, in contrast to enrollment in baccalaureate education, which accounted for 6.8% of the total increase in enrollment (NSB, 2014). Earned Associates' degrees in STEM fields from 2010 to 2011 increased in engineering (11%), biological sciences (16.3%), agricultural science (8.7%), earth sciences (-4.2), mathematics (36.1%); computer sciences (13.7%), physical sciences (24.9%), and non-engineering technologies (9.6). Earned bachelor degrees in STEM fields increased in engineering (4.7%), biological sciences (4.3%), agricultural science (10.4%), earth science (9.4%), mathematics (6.6%), computer sciences (8.0%), physical sciences (4.1%) and non-engineering technologies (5.3%). The impact of the community college with regard to STEM study is clear when observing the amount of STEM degrees being conferred.

In order to improve STEM literacy for all students and to increase the likelihood of attracting and retaining women and under-represented minorities in STEM disciplines, increasing attention needs to be paid to the community college arena. In an effort to understand what works with regard to STEM teaching and learning, discipline based education research (DBER) has shown that actively involving undergraduate students in the learning process improves understanding more than listening to a traditional lecture (NRC, 2012). Effective instruction strategies can promote conceptual change. Such strategies include, for example, making lectures more interactive, having students work in groups, and incorporating authentic activities and open-ended problems into teaching (e.g., learning in laboratories or learning in a field setting). Students can be taught more expert-like problem-solving skills and strategies to improve their understanding of concepts by instructional practices that provide steps and prompts to guide them, use multiple ways to represent those concepts, and help them to make their own thinking visible (NRC, 2012). Interestingly, research reveals, for postsecondary study in particular, "the classroom *per se* does not dominate the locus for instruction and learning to the degree that it does in k-12 settings" (Coppola & Krajcik, 2013, p. 631). Thus, opportunities for students to extend knowledge and understandings outside of the classroom should also be the focus for college professors, who are considered subject-matter experts. Discipline-based knowledge, while necessary, is not sufficient. After all, students today come to courses armed with bits of information and portable electronic devices that provide ready access to the World Wide Web. In other words, students have no problem finding knowledge. Of growing importance is the necessity to give students opportunities to authentically analyze and apply the knowledge in appropriate and responsible ways to the variety of confounding situations and circumstances, which will confront them in the course of daily life (AAAS, 2011; Bybee, 2010; Bybee, 2013).

Within this educational forum, community college faculty should first agree on a definition of STEM that includes literacy as its focus. STEM education should therefore be concerned with the acquisition of STEM knowledge and practices and then creating the opportunity to apply said content in a variety of contexts so as to learn how to predict and explain phenomena, and assess how applications of knowledge affect society as a whole (Bybee, 2010; OECD, 2006; OECD, 2013). In order to achieve the outcome of literacy, faculty should embrace an integrative approach to learning whereby the content and practice of each STEM discipline is taught in concert while also including aspects of other disciplines to authenticate the learning cycle (Wells & Ernst, 2012). Integrative learning is the approach that capitalizes on the wealth of knowledge that learners come to the table with and gives students the opportunities and context in which to both fail and succeed. Drake & Burns (2004) describe three different approaches to designing such a curriculum. Using a standards base will lead to a presentation that is "highly rigorous, yet readily adaptable to different contexts" (p. 21) and may be multidisciplinary, interdisciplinary or transdisciplinary. From an instructional perspective, this flexibility around standards is especially appealing as it preserves academic freedom while still working within the scope of accountability set forth by the institution and accrediting body. From an academic perspective, integrative approaches will better prepare students for the "multilayered, unscripted problems" (Humphreys, 2005, p. 30) that are routine in all aspects of life.

Methods of Integration

Among the options described by Drake and Burns (2004), the transdisciplinary model is the most appealing for the STEM educator (Dugger, 2010; Wells, 2008, 2014) who desires to reach the goals of improved persistence in STEM subjects, improved knowledge transfer between academic subjects, increased presence of women and underrepresented minorities in the STEM pipeline, higher levels of achievement as measured by national and international tests, and a STEM literate society whose population is globally engaged and makes informed decisions using critical thinking and other such 21st century skills (NRC, 2011; NSB, 2007; Partnership for 21st Century Skills, 2008; Pines, 2009). When engaging in a transdisciplinary approach, the driving force behind learning becomes an authentic problem and learning is framed around discovering a solution, thus overcoming the "mismatch between knowledge production in academia and knowledge requests for solving societal problems" (Hoffmann-Riem et al., 2008, p. 4). One such transdisciplinary pedagogical approach is through engaging in design. In order to learn in this manner "design is used as a vehicle through which scientific knowledge and real-world problem solving skills can be constructed" (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004, p. 1081). Design thinking is characterized by "resolving ill-defined problems, adopting solution-focused cognitive strategies, employing the logic of conjecture and using non-verbal modeling media" (Cross, 2006, p. 38). One hallmark of design is the emergence of creativity, a way of thinking which is likely to contribute to positive social outcomes (Davis, 2011, p. 150-151). Teams of students work together to solve an ill-designed problem by applying knowledge from all STEM disciplines along with their own experiences. Ultimately, production of an artifact serves as evidence of the problem resolution (Fortus, Krajcik, Dershimer, Marx & Mamlok-Naaman, 2005; Fortus et al., 2004). Learning for STEM literacy could therefore be maximized through employment of the transdisciplinary pedagogical method of design learning, specifically using either an engineering/technological systems design or an artistic design approach. This way of teaching and learning capitalizes on the diverse backgrounds especially inherent in the community college to intentionally construct knowledge in a context extended from the classroom.

Benefits of Design-Based Learning

When engaging in the design process, learners begin by articulating their own need for a design and as they work their way through to a solution for the ill-designed problem. In order to arrive at a solution, students may find the need for generative, inquiry, analytical, synthesis and/or evaluative thinking (Mehalik, Doppelt & Schunn, 2008). The contextual base of the design model encourages subject ownership and meaningful interaction with abstract concepts for a broad range of students, including low achievers (Stone, Alfeld & Parson, 2008), therefore promoting student persistence in STEM disciplines (Froyd & Ohland, 2005). The design presentation allows students to interact and communicate amongst one another in order to solve their own identified problem with either a technical or an aesthetic solution. Problem solving and communication skills are engaged and positive knowledge transfer is a result (Mehalik et al., 2008). This pedagogical approach is consistent with research on how students learn best (NRC, 2009), has been used as the basis for successful presentations in STEM subjects as well as in some arts (Bamberger, 2003; Fortus et al., 2004; Hacker & Burghardt, 2004; Jacobson & Lehrer, 2000) and supports the development of an innovative society (Wagner, 2012).

Design-based education is of unique value to the STEM educator who embraces the need to help students "build habits of mind that prepare students to make informed judgments in the conduct of personal, professional and civic life" (Huber & Hutchings, 2004, p. 2). Within the realm of design, there are two different, yet related processes that may be chosen for problem resolution. Engineering and technology offers a design process that utilizes a purposeful method of planning practical solutions to problems. This systems design approach begins with a "needs analysis that emerges from a student's interests and world experiences" (Mehalik et al., 2008, p.75). Students are therefore more likely to become engaged in the process of working toward a solution rather than asking "Why do I need to learn this?" (Mehalik et al., 2008, p. 71). Engineering/technological systems design offers a systematic way of thinking and interpreting that is predictive and analytical and therefore a way to contextually construct knowledge in an authentic way (NRC, 2009). The resulting design artifact will be an engineering/technological solution that addresses "such factors as the desired elements and features of a product or system or the limits that are placed on the design" (ITEA, 2006, p. 20). The design-based approach, as described above, empowers students to develop both the cognitive modeling and representational abilities needed in the technology and science domains.

A second design process that is an option for the transdisciplinary educational approach is that of artistic design. As asserted by Bonser & Mossman (1923),

> Since the desire for beauty in all that we possess or produce is so fundamental, it is readily seen that the industrial arts and fine arts are closely and vitally related. Any attempt to separate them completely is artificial... In the process of their design and production, however, the two purposes [of science and art] are almost inseparably related. (p. 5)

When designing, if functioning and operation is the most important consideration, the employment of engineering/technology design is appropriate. In contrast, if the design outcome is more concerned with the aesthetic qualities of the artifact, then artistic design may be employed. Either way, "the creative process forms the pathway (or part of it) through which new insights, understandings and products come into being" (Bergdorff, 2011, p. 46). Both artists and scientists need convergent (logical, analytical and craft) skills as well as divergent (innovative and inspirational) skills" (Williamson, 2011, p. 42). Art and science may therefore be considered parallel processes in inquiry and the production of a prototype, whether a product of engineering or artistic design, will work as a satisfactory solution to the conundrum, which drives the investigation. Thus, it is the assertion of this research that artistic design can also be used as an authentic context in which to construct knowledge and achieve mastery in the STEM classroom.

Rationale for the Study

Among STEM disciplines, increased enrollments of undergraduate in the fields of engineering and biology have been noted since 2008 (Jacobs & Sax, 2014). There is also increased interest from undergraduate educators as to discovering what works in the classroom. Recognizing that "recent advances throughout the life sciences require new approaches to preparing biology majors and premedical students" and that these advances also "call out for new ways to prepare all undergraduates, regardless of their eventual career paths" many biology professionals agree that a student-centered, integrative, collaborative approach to science learning should form the foundation of undergraduate biology education (AAAS, 2011, p. viii).

Implementation of the design-based approach to learning in the undergraduate biology classroom with either an art artifact or a technology/engineering prototype as the solution will improve the opportunity for students to develop the habits of mind that a global society needs in its citizenry. A wider range of students will be reached and persistence in the STEM subjects is more likely when students engage the content in a deep and meaningful way, as in a pedagogical model, which revolves around design approaches. Knowledge transfer is improved and wisdom is cultivated to think critically and make responsible decisions in our technologically advancing world.

Purpose for the Study

It is imperative to American society to focus research efforts at the community college as an important educational arena with special regard to STEM education. There is growing evidence for the employment of the technological/engineering design-based approach to STEM learning as a means to improve student persistence, knowledge transfer, and STEM literacy (Cajas, 2001; Dunham, Wells & White, 2002; Hmelo, Holton, & Kolodner, 2000). However, there is a notable gap in the literature with regard to the use of the design-based approach that culminates in an artistic artifact within STEM disciplines. The goal of this study was to address this research need by providing evidence of improved self-efficacy and content knowledge as a result of engagement in the process of artistic design in an undergraduate, biological sciences course.

The research presented in this document was designed to reveal to what extent changes in undergraduate, community college, student learning outcomes (both affective and academic) can be demonstrated as a result of participation in a design-project during a fall semester Anatomy and Physiology I course.

Research Questions

The following research questions formed the basis for this study:

1. To what extent does the design approach to teaching and learning the content of Anatomy and Physiology in the undergraduate, community-college laboratory result in changes to students' biological science self-efficacy?
2. What is the effect of the design approach on undergraduate, community college students' content knowledge in Anatomy and Physiology?

Limitations of the Study

Study limitations included the homogeneity of the student population and limited sample size. Demographically, the students involved in this investigation are very similar (refer to Chapter 3 for specific population descriptions). The maximum enrollment at the outset of the study was 63 students; however, at the end of the study, there were only 36 who continued to participate. The attrition rate from this study was therefore approximately 43%, a statistic which aligns with the average attrition rate from the overall A&P classes for this college. Thus, study analyses include data from only the remaining 36 students, who self-enrolled in the sections being investigated. Finally, causality is not being investigated as a part of study design. The findings of this study therefore have limited generalizability and readers should carefully consider study context when contemplating transferability of results to different populations (Ercikan & Roth, 2014).

Operational Definitions

Aesthetic

Anything concerned with the beauty, appearance or art (Dominiczak, M., 2013).

Anatomy, Study of

Specific study within the scope of biological sciences concerned with the structure of living things (Tortora, G. & Dickerson, B., 2013).

Art

A refined and intensified form of an experience; The most effective method of communication that exists (Dewey, J., 1934).

Biological Sciences (Biology)

Natural science concerned with the study of living organisms, their life, growth, structure, function, evolution and taxonomy. Several sub-disciplines of biology exist, such as anatomy, cell biology, botany, ecology, molecular biology, and physiology.

Design (n.)

“That actual manifestation of a product, a tangible object, an idea, a concept, a pattern, etc. – the way it looks, feels and behaves, the result of an intention” (Eder, 2012, p. 1).

Design (v.)

“The mental and other processes that occur during this activity in order to establish ‘the design’” (Eder, 2012, p. 1).

Integrative STEM education

“The application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (Wells & Ernst, 2012, para. 2).

Literacy

“An essential part of a democratic society through the study of five essential components of industrial art study: health, economic, art (aesthetic), social and recreational” (Bosner & Mossman, 1923, p. 6-14).

Physiology, Study of

Specific study within the scope of biological sciences concerned with the function of living things (Tortora & Dickerson, 2013).

Self-efficacy

An aspect of social cognitive theory which is defined as “the exercise of human agency though people’s beliefs in their capabilities to produce desired effects by their actions” (Bandura, 1997, p, vii).

STEM

An acronym that refers to interaction amongst the fields of science, technology, engineering and math (Sanders, 2009).

STEM literacy

> "A deictic means (composed of skills, abilities, factual knowledge, procedures, concepts, and metacognitive capacities) to gain further learning" (Zollman, 2012, p. 12)

Technological/Engineering (T/E) design process

> "An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems" (ITEA/ITEEA, 2000, 2002, 2006, p. 237)

CHAPTER TWO: LITERATURE REVIEW

Across the disciplines of science, technology, engineering and mathematics the call for reform is crescendoing. Experts continue to call for deeper learning experiences, characterized by integrative connections that tie together the content and practice of each content area (NAE & NRC, 2014; NRC, 2013; Wells & Ernst, 2012). Despite increased money and attention, the results of STEM reform heretofore have resulted in improvements described as mediocre at best as evidenced by both national and international test results. For example, the Program for International Student Assessment (PISA), a test that is coordinated by the Organization for Economic Cooperation and Development (OECD) and conducted in the US by the National Center for Education Statistics (NCES) is designed to assess students' literacy in science, math and reading literacy close to the time they would be exiting from high school. In other words, students' ability to apply knowledge in mathematics, science, and reading to problems within a real-life context is the focus (OECD, n.d.). In 2012, this international test focused primarily on mathematics. The US average mathematics scores were lower than the OECD averages and in science and reading, students' average scores were approximately reflective of the OECD average. In addition, "the U.S. average mathematics, science, and reading literacy scores in 2012 were not measurably different from average scores in previous PISA assessment years with which comparisons can be made (2003, 2006 and 2009 for mathematics; 2006, and 2009 for science; and 2000, 2003, and 2009 for reading)" (NCES, 2012).

The National Assessment of Educational Progress (NAEP) evaluates US student content knowledge in mathematics and reading at or about grades 4, 8, and 12. According to NCES, "the 2012 long-term trend results show 9- and 13-year-olds scoring higher in both reading and mathematics than students their age in the 1970s. At age 13, the overall average score in each subject was also higher in comparison to the last assessment in 2008. At age 17, however, the 2012 reading and mathematics average scores were not significantly different from those in the respective first assessment year" (NCES, 2013).

Thirdly, the Trends in International Mathematics and Science Study (TIMSS), similar to NAEP, measures math and science achievement for students in 4th and 8th grade, but unlike NAEP, these scores are compared to students in other countries. The results of the last assessment in 2011 revealed decreases in mathematics achievement from grade 4 (outperforming 42 education systems, internationally) to grade 8 (outperforming 32 education systems, internationally). Similar results were noted in science results: in grade 4, the US system outperformed 47 education systems and in grade 8, the US outperformed 33 education systems (NCES, 2013). "Although U.S. students have performed above the international average on the TIMSS mathematics and science tests, they have not been among the very top-achieving groups in the world" (NSB, 2014, p.1-41).

Finally, also in 2011, there was a NAEP-TIMSS linking study performed in order to compare US student performance indicators by state to international student data (NCES, 2013). In essence, average scores for eighth grade students in 51 states reached the intermediate benchmark in mathematics and science. Average scores for eighth grade students in only one state (Massachusetts) reached the high benchmark in math but in 8 states (Maine, Massachusetts, Minnesota, Montana, New Hampshire, North Dakota, Vermont and Wisconsin) for science. In other words, the majority of US eighth graders can apply basic mathematical knowledge and have basic knowledge and understanding of practical situations in the sciences. Whereas, students in education systems such as China, Singapore, Japan, the Republic of Korea and Finland (along with students from the US state of Massachusetts) whose average scores fell into the High Benchmark in both categories can *apply* their mathematical knowledge in a variety of complex situations and *apply* their scientific knowledge to explain phenomena in everyday *and* abstract contexts (NCES, 2013). If observed longitudinal trends in all four tests continue to hold true, it is reasonable to expect that these eighth graders will not improve in their ranking and neither will upcoming students.

Educational benchmarks are not the only indicators of educational success. In a 2009 study by Atkinson & Andes, the US was ranked dead last with regard to economic progress over the last decade. These researchers reported that the United States is rapidly falling behind the majority of the world, especially as other nations make significantly more private and public investments needed to grow internationally competitive economies. In a subsequent analysis (2011), the same researchers evaluated the economic progress of 44 countries and regions and, in terms of progress, they reported that the United States only surpassed Italy in the last ten years. The authors continue by noting that:

> Some of these findings reflect a simple process of catch up. Countries that are less advanced when it comes to innovation can perhaps advance more easily than countries at the leading edge. But some of the nations that have shown faster progress than the United States or the EU-15 are advanced nations, such as S. Korea, Japan, Australia, and Canada. (p.1)

When remembering the lackluster test scores, it is no surprise that the measures of innovation do not indicate improvement.

In an effort to understand and explain the downward trends noted in national innovation, researchers and analysts have looked not only to international student test scores and economic growth data. There is also a growing body of knowledge, especially within the disciplines of science and math, which addresses information that includes, but is not limited to, student persistence in STEM fields of study, student attitudes toward STEM disciplines, teacher preparation and effectiveness in STEM disciplines, STEM curricular strengths and weaknesses, effective pedagogical practices, etc. For example, we now know that persistence in STEM fields correspond to higher socioeconomic status, parent education level, academic preparation in high school, the type of institution in which the student first enrolled, and full or part-time student status (Chen & Weko, 2009). Researchers have also revealed a disparity in how many students select and persist in STEM fields. Less than one-quarter of students entering postsecondary studies select a STEM field as a major and less than 50% of these students are projected to persist in the field through graduation (Chen & Weko, 2009). Women are less likely to enter STEM fields than men (14% vs. 33%), and only 18-23% of ethnic minorities choose STEM, with the exception of Asian students, who were actually more likely to choose a STEM field (47%) (Chen & Weko, 2009). Of the students who are recipients of STEM bachelors and/or masters degrees, the women are more likely to have attended a community college than their counterparts (Tsapogas, 2004). More women and underrepresented minorities attend community college in general and these students are more likely to attend only part time (St. Rose & Hill, 2013).

Perhaps another reason that successful results of STEM education efforts continue to elude us is that the term STEM education is little more than a tagline. In a study done about faculty perceptions about STEM education, professors are described as confused at best as to what is expected of them as a STEM educator. "If STEM education is going to advance beyond a slogan, educators in the STEM community will have to clarify what the acronym actually means for educational policies, programs and practices" (Bybee, 2010). Bybee continues by asserting that, as a nation, to advance STEM education, we must:

> 1. Recognize that science has been diminished as evidenced by NCLB and reauthorization of elementary and secondary education act, 2. Increase programmatic emphasis on Technology, 3. Improve the presence of engineering in K-12, 4. Improve 21st century skills in all STEM disciplines, and 5. Use an integrated STEM approach to improve meaningful study in the "grand challenges" of our era (energy efficiency, resource use, environmental quality, hazard mitigation). (p. 31)

Of these suggestions, the one that is perhaps the most important is that of effective STEM education being integrative (Sanders, 2009; Wells & Ernst, 2012; NAE & NRC, 2014). In essence, both the content and practice of each of the STEM disciplines of should be presented together, along with the content and practice with non-STEM subjects, so as to provide the student with the context and relevance that is necessary for deep learning (Wells & Ernst, 2012). This consistency in definition and presentation should pervade throughout the K-20 educational system so as to create a STEM education track that is vertically aligned and coherent in its presentation (NSB, 2007).

The Community College

Knowing that over half of the community college population consists of students who are underrepresented in STEM fields and that over half of the students declaring STEM as a major will be lost at these institutions, it is clear that this educational arena is fertile for improvements in STEM teaching and learning so as to capture this untapped resource of human potential. Why are students, and particularly those who are women and underrepresented minorities, less likely to select and persist in STEM fields of study? Certainly, lack of preparation may be blamed. Over 50% of all entering freshman at the community college must take remedial math and/or

English in order to begin college classes. Additionally, it is less likely that women will be full time students as they have jobs and family that dominate their time (NSF, 2013). Women, in general, have also been shown to have a lack of self-efficacy in STEM disciplines, which may also contribute to their lack of persistence in the fields (NSB, 2010; Starobin & Laanan, 2008; Zelden, Britner & Pajares, 2008). Finally, women and underrepresented minorities have been shown to be more engaged and learn more in a classroom, which is geared around authentic learning and not just simple inquiry or dominated by lecture as is most often found in higher education STEM classrooms (Chinn & Malhotra, 2007).

The primary focus for community college faculty is to teach; very few of these subject matter experts are trained in pedagogy and the majority (almost three-quarters) of the teachers are adjunct (AFT, 2010). Many of these faculty members do not embrace a cohesive presentation of STEM, nor do they acknowledge relevance of STEM initiatives to their daily teaching practice (Breiner et. al, 2012). Faculty in STEM fields spend 16% more time lecturing and significantly less time engaging in pedagogical techniques that have been shown to improve student learning and self-confidence, particularly for women and minorities, regardless of discipline (Hyde & Gess-Newsome, 2000). John Savery (2006) sums the problem when he asserts that teaching discipline specific content using a "traditional" lecture approach does not prepare students to apply knowledge in alternate contexts or clinical application, which, in this age of information, is constantly changing (p. 10). These faculty members are not prepared to deal with the challenges presented by diversity of the classroom and are resistant to change (Gess-Newsome, Southerland, Johnston &Woodbury, 2003).

Design-Based Learning

In the last two years, there has been growing support for using the pedagogical approach of technology/engineering design-based learning (TE/DBL) outside of the STEM disciplines and to incorporate art as an optional authentic context in which to situate the design product. Certainly this focus is in line with the efforts being made to improve critical thinking and other 21st century skills which enable productive members of society to transcend disciplinary knowledge and creatively work between and among disciplines to construct new knowledge (Partnership for 21st Century Skills, 2008). This STEAM (STEM with A for arts) approach to learning is not a new idea. Robert Root Bernstein, a biochemist, performed a study of 150 scientists and found that almost all of these STEM innovators were also artists (Root-Bernstein, 1999). In a subsequent study (2008), this same author (along with many other co-authors) came to the conclusion that "increasing success in science is accompanied by developed ability in other fields such as the fine arts" (Root-Bernstein et al., 2008, p.56). It is therefore reasonable to assume that persistence in science disciplines may be more likely when the creative side of the brain is also being engaged (Root-Bernstein et al., 2008).

Technological/engineering design is at the heart of the TE/DBL approach. This planned, systematic course of study is not unique to technology and engineering. Bonser & Mossman (1923) distinguish the study of industrial arts from the study and creation of fine arts in that fine arts are an integral part of design, decoration and use industrial products (p 5). Indeed, works of art are the most intimate and energetic means of aiding individuals to share in the arts of living (Dewey, 1934). The design process provides the vehicle through which the student sets on "understanding the messiness of real-world practice" in authentic contexts (Barab & Squire, 2004). In design-based education, the importance of students engaging their learning outside of the context in which it is learned as a social endeavor supports the efficacy and cognitive needs of each student.

Through the creation of any design product, the effort is to create order; to use rational thought and conscious reflection to create new knowledge. Neither an engineering prototype nor an artistic expression is spontaneous. The creation of an artistic artifact gives the student another opportunity for mastery (and therefore improvement in self-efficacy) outside of the classroom context and the solution, whether in science or the arts, requires the clear definition of the problem and the view (model) of a unique, best answer as identified by the problem solver (Williamson, 2001). In her recent article, Emily Gottlieb (2014) asserts to successfully execute a STEM outcome in the context of art,

> Students must engage all learning styles (visual, audio, kinesthetic, and all combinations therein) to synthesize information about STEM topics into completed art projects. They must select and create the most effective images needed to describe the topics and to convey a message. To do this, students must learn how to visualize the problem or topic as a whole, adapt their project throughout its progress, and edit their own work. (p.1)

Blood, imagination and intellect running together" (Yeats, 1906) describes both artistic and STEM solutions.

The application of an artistic solution allows students to engage in all of the same learning opportunities as described when producing a technological model. Both approaches "encourage development of content knowledge and process skills through a creative inquiry approach" (Angle & Faster, 2011, p. 58) and, through the use of a context outside of the learning situation, can extend learning beyond the classroom. Both include iterative cycles of learning, within and outside of the learning context, applying the content and practice of all STEM disciplines and supplemented by the content and practice of the chosen artistic medium. Both engage the learner in cycles, which will guide them on the path to literacy.

Theoretical Foundation for Design-Based Learning

Current educational trends support a decisive move away from learning silos into an integrative model of teaching and learning. In specific, the technological/engineering design based learning (TE/DBL) approach is favored for teaching the content and practices in the disciplines of science, technology, engineering and mathematics (STEM). Given that the education and social needs have been clearly established, it is important to ensure that whatever we move to is sufficiently grounded in well-established learning theory. In the case of TE/DBL, this educational approach has been grounded and shaped in the learning theories of behaviorism, cognitivism, and constructivism (Dunham, Wells & White, 2002).

Behaviorism. Behaviorists subscribe to the idea that explicit behavior can be observed and measured. This belief laid the foundation for the discovery of stimulus-response behavior, which led to the assertion that the learning process is simply a response by the student to a stimulus, usually employed by the teacher (Ertmer & Newby, 2013). Thus, from a behavioral perspective, the teacher may deliberately guide student learning though purposeful manipulation of the learning environment; behaviorist theory denies "any role of consciousness or subjective experience in the learning process" (Kolb, 1984, p. 20).

Dunham, Wells & White (2002) clearly connected specific elements of TE/DBL that are supported by behaviorism. They asserted that it is in setting the educational context, stating the design problem/challenge, and establishing evaluation as the loci for crossover. Learning in the US K-20 classroom, now more than ever, is concerned with appropriate assessment of student learning using performance objectives, thus supporting the idea that behavior can be observed and measured. In the TE/DBL approach, teachers gear learning around planned sequences of instruction and these sequences are grounded in a learning framework characterized by clear, performance-based objectives that can be measured (assessed) (Dunham, Wells & White, 2002). Correct student responses are then reinforced are likely to re-occur and are evidence of learning (Ertmer & Newby, 2013).

Cognitivism. Cognitive learning theory is a second foundation for TE/DBL approach to learning. Cognitivists looked beyond overt, observable behaviors and looked to studying the deeper aspects of cognitive processes that were a part of the learning process such as thinking, problem solving, language, concept formation (including mental modeling) and processing (Snelbecker, 1983) that are the direct prelude to the learning occurrence. Thus, as the student engages with the environment in actual exploration and resolution of an authentic problem (i.e.: "learning by doing"), their cognitive structure is changed and learning occurs. However, it is important to note that in this case, new ideas are not necessarily the focus; rather, assimilation of existing learning ideas and outcomes drive the problem.

With regard to TE/DBL, the elements of cognitivism that are identifiable in the approach include, but are not limited to, introductory inquiry-type activities and the introduction of general problem solving strategies throughout the design process (Dunham, Wells, & White, 2002) that are generally situated within the learning context where the student can acquire knowledge elements necessary for learning. Some direct instruction may be used to deliver specific elements of factual content that is necessary to begin and/or perpetuate the learning process and this piece is also behaviorist in nature. In specific, the systems design approach is a way that the learner can efficiently and consistently acquire necessary knowledge to include in their solution.

Constructivism. This branch of cognitivism asserts that learners must not only assimilate but also interpret new information and incorporate it into their current knowledge foundation in an effort to construct new, deep understandings for themselves (Ertmer & Newby, 2013). Each student comes to the classroom with their own set of experiences in which they have learned. Thus, learning is a product of action and experience, a concept in stark contrast to behaviorism, where the environment is largely ignored (Knope, 2012) unless being purposefully manipulated by the instructor to affect a certain outcome. In the classroom, “knowledge is constructed through reflection during and after this experimental action on the ill-defined and messy problems of practice” (Fenwick, 2000). Thus, any one student’s experience may have a different outcome from than another. This element is one foundational difference among the theories. Vital to the construction of knowledge, therefore, is not just physical interaction; rather, through mentally confronting a perplexing problem, carefully considering all alternatives, proposing a plan of action and evaluating the outcome, the learner is not only “hands-on” but also “minds-on” (Dewey, 1916).

> Teachers who base their practice on constructivism reject the notions that meaning can be passed on to learners via symbols and transmission, that learners can incorporate exact copies of teachers’ understanding for their own use, that whole concepts can be broken into discrete sub-skills and that concepts and be taught out of context. In contrast, a constructivist view of learning suggests an approach to teaching that gives learners the opportunity for concrete, contextually meaningful experience through which they can search for patterns; raise questions; and mold, interpret, and defend their strategies and ideas. (Fosnot, 2013, p. ix)

Social constructivists focus on the learning that is taking place as social interactions occur. The focus is on the “interdependence of social and individual processes in the co-construction of knowledge” (Palinesar, 1998, p. 345). Inquiry and logic are both social endeavors and the only way to prepare for a social life, is to engage and learn in a social context

(Dewey, 1909). By making overt relevant connections of abstract material to “the place which it occupies with reference to use in social life”, the teacher will be more likely to affect improvement in learner motivation and engagement (Dewey, 1909, p. 41). In addition, situating learning within a social framework, instructors can “harness the natural verbal energy of students to promote a critical discussion of course content, so that students can actively construct and internalize their own meanings of the concepts” (Powell & Kalina, 2009, as quoted in Schrieber & Valle, 2013, p. 396).

Students may engage each other so as to glean knowledge form a shared experience. This approach takes project based and inquiry based learning to a new level by taking students’ learning out of the context of the classroom and encouraging them to work to construct new knowledge within the design context. To this end, the design product may be situated in the realm of technology and/or engineering (as in TE/DBL). Dunham, Wells and White (2002) again point us to the key elements of constructivism in the TE/DBL approach. Through assigning meaningful contexts in which to resolve problems, collaborating with team members in the shared experience of problem resolution, creation of an original solution, and employing thoughtful reflection throughout the design process.

In design based learning, resolving problems is central to the approach and proponents assert that learning “is likely when presented within the context of a design problem” (Sidawi, 2009, p. 285). Scientific meanings are dependent upon the context in which they are derived. Thus, the meanings can change and must constantly be tested in different context in order to be in everyday life (Dewey, 1909). Rossouw, Hacker & deVries (2011), after their Delphi study of experts to identify key content and contexts in which to increase the likelihood of achieving technological literacy through education, asserted that “by teaching concepts in a variety of contexts gradually the learner will start to recognize the more generic nature of the concepts and be able to apply it in new contexts" (p. 423).

How should these alternative contexts be chosen? In the early uses of the term Industrial arts, as defined by Bosner and Mossman (1923), the authors focused on the manipulation of natural materials into products, which better serve mankind and that through the process of design the products of industrial arts may result. The authentic focus of the design situation was essential for learner engagement and persistence through the problem solving process. By making overt relevant connections of abstract material to "the place which it occupies with reference to use in social life", the teacher will improve learner motivation and engagement (Dewey, 1909, p. 41).

Literacy is "an essential part of a democratic society through the study of five essential components of industrial art study: heath, economic, art (aesthetic), social and recreational" (Bosner & Mossman, 1923, p. 6-14). With the choice to live in and participate in a democracy, also comes the individual responsibility to be citizens who are well informed, capable of critical thought and analysis, and able to contribute meaningfully to society. It naturally follows that in order to develop these characteristics, learning in a constructivist environment is the most effective for advanced knowledge development (Jonassen, 1991) for *all* learners.

As a part of a problem-solving team students will interact with each other in a "community of practice "to solve a shared conundrum (Stone, et al., 2008), thereby accessing the social persuasion and vicarious learning sources of efficacy, often missed in traditional lecture classrooms. Students cooperate by sharing information and in critiquing each other's work. The diversity of backgrounds, no longer a hindrance to learning, serves to lead to more creative ideas for solving the specific TE/DBL challenge (Sawyer, 2007).

Whether overtly taught or implied throughout the learning cycle, engagement in the iterative cycles of the design process drives the student through the reflective practice that is a hallmark element of this learning theory. Engaging in design also affords the student the opportunity to construct mental models and physical models of the potential design solution (Crismond & Adams, 2012), another overt connection to constructivism, with regular and consistent opportunities for ongoing evaluative opportunities with the instructor.

Certainly, it is clear that a teacher needs to employ elements from all three learning theories to maximize the likelihood of positive learning outcomes. In addition, other pertinent elements from cognitive science research may also be used to support the use of TE/DBL as a valid instructional framework to promote 21st century skills such as critical thinking (i.e.: solving problems using both mathematics and science, focusing on problems, imagining solutions), demonstrating persistence through obstacles, using effective oral and written communication and working in either teams or alone (Pines, 2009).

Three additional learning theories may also be considered important theoretical foundations for the implementation of TE/DBL in the context of the college classroom: experiential learning theory, transformative learning theory and self-efficacy theory.

Experiential learning theory. Grounded in cognitive learning theory, experiential learning focuses on the learning process as a continuous one, not necessarily in the tracking of a specific learning outcome. Learning is seen as transactional between the learner and the environment in that it is the way the learner perceives and processes a given experience that gives meaning to "objective conditions and subjective experience" (Kolb, 1984, p. 36). Weil & McGill (1989) express experiential learning as follows:

The process whereby people individually and in association with others, engage in direct

> encounter and then purposefully reflect upon, validate, transform, give personal meaning to and seek to integrate their different ways of knowing. Experiential learning therefore enables the discovery of possibilities that may not be evident from direct experience alone. (p. 248)

In TE/DBL, learners are challenged to complete learning tasks just slightly beyond their current knowledge and skill level. Thus, through a series of successive, planned learning experiences in the learning environment, the learner can extend their knowledge from "concrete experience into abstract conceptualization" and "active experimentation to reflective observation" (Kolb, 1984, p. 31), thereby achieving many of the coveted 21st century habits of mind. However, the issue of context must be addressed. In the case of experiential learning, the context of application generally exists within the context of learning. Thus, the learner will be able to move from construct to construct, facilitated by instructor intervention and appropriate evaluative feedback. However, the "transfer of experiential learning from an educational context to the situation of its main deployment-such as the work situation- is a major issue" (Moon, 1999, p. 118). Thus, in an experiential classroom, it would be important to not only ask the learner to engage in sequential activities and deep reflection, but the learning cycle must include a final step of anticipation or imagination or speculation as to the nature of the improved practice in an authentic environment. The systematic, iterative cycles of learning embedded within a design-based unit allow learners to develop solutions to complex problems both in and out of the learning context and therefore enhance knowledge transferability.

Transformative learning theory. This learning theory is the newest of the ones discussed herein and is also the one that is situated exclusively within the realm of adult learning. Since the research study is based in the community college, addressing adult education in specific is a meaningful endeavor. As stated by Mezirow (1997), transformative learning is the "process of effecting change in a frame of reference" (p. 5). This frame of reference is reminiscent of the contextual applications discussed in TE/DBL, however, "a frame of reference encompasses cognitive, conative and emotional components and is composed of two dimensions: habits of mind and a point of view" (Mezirow, 1997, p. 5). Thus, when teaching adults, many habits of mind and subsequent points for view have already been established through a lifetime of experience. It is the job of the educator, therefore, to guide the learner to challenge these points of view through "critical reflection on the assumptions" that provide the foundation for one's habits of mind, thereby deliberately improving the autonomous and critical thought identified as essential components of a literate populace (Mezirow, 1997). Employment of a supported self-directed learning approach with opportunities for active learning opportunities in which mastery was encouraged through structured learning cycles were found to improve student engagement which, in turn, led to deeper learning and improved understandings of material (Findlater, Kristmundsdottir, Parson & Gillingwater, 2011). The pedagogical approach of TE/DBL also allows the adult educator a way to improve adult learning and communication. The situation of design problems within authentic workforce contexts encourage the acquisition of skills and abilities that employers are looking for in autonomous adults, such as effective peer collaboration in problem solving groups, self-control, self-awareness, and critical reflection.

Self-efficacy theory. Self-efficacy theory is the central point of Albert Bandura's sociocognitive theory. Bandura defines perceived self-efficacy as "beliefs in one's capabilities to organize and execute courses of action required to manage prospective situations" (Bandura, 1995, p.2). One's self-efficacy beliefs are affected by four sources of influence: mastery experiences (ME), vicarious experiences (VE), social persuasion (SP) and psychological and emotional states (A) (Bandura, 1995). For students to persist through obstacles, as encountered throughout life, a strong sense of self-efficacy is required (Bandura, 1995). In addition, the assessment of this affective construct must occur situated in a "specific domain of functioning" (Zimmerman, 2005) and thus efficacy is context driven. Indeed, an understanding of not only the cognitive components of learning but also the affective components of learning is warranted as we strive to create significant learning experiences (NRC, 2012).

Within a carefully constructed, TE/DBL learning unit, there is a clear opportunity to make purposeful impact on each source of efficacy. Opportunities for mastery experiences exist when the teacher assigns clear learning objectives and supportive classroom practice. Opportunities for vicarious experiences may occur as students work in groups to solve an authentic task and they observe peers successfully moving through the design challenge. In addition, working collaboratively in groups to negotiate the iterative design process also provides opportunities for teacher-student and student-student interaction with different types of consistent formative assessment. Finally, a TE/ DBL unit is one that is highly structured in parts and not as structured in others. Thus, the inclusion and experience moving through ill-structured problems may help to engender a "resilient sense of efficacy" (Bandura, 1995, p. 3) since each learner will move through with sustained effort to pursue the answer. Higher academic achievement has clearly been linked to higher academic self-efficacy, particularly for college students (Hackett & Betz, 1989; Pajares, 1996). It therefore stands to reason that teaching with a design-based approach will potentially improve academic self-efficacy and, subsequently, academic performance and persistence.

In theory, the use of the design process should give the undergraduate educator the most opportunity to affect learning in the classroom and to extend this learning into extra classroom contexts, where research has shown has more meaning for the adult learner (Coppola & Krajcik, 2013). In addition, the introduction of an artistic design solution to an authentic problem has the possibility of improving the persistence of a wider audience, possibly having more influence on the self-efficacy of those who traditionally do not "think scientifically" or who have a low math self-efficacy (Betz & Hackett, 1983). From the social constructivist perspective, gaining knowledge about gender is also a result of social construction (Knopke, 2012).

Evaluation

In order to better understand the specific sources of academic self-efficacy, researchers have turned to both qualitative and quantitative investigations. For quantitative evaluation, domain-specific self-efficacy inventories have been designed to measure overall efficacy as well as interpretation of information from four different sources: mastery experiences, vicarious experiences, social persuasion and psychological states. Judgments of self-efficacy are task specific and therefore measures of self-efficacy should be domain specific in order to increase the predictive value (Bandura, 1995). It is also important, when evaluating self-efficacy, to consider the age of the students being evaluated, as well as the construct validity. For example, when evaluating sources of self-efficacy for middle-schoolers, gender differences noted at higher academic levels do not appear. Girls had higher academic performance however the sources of self-efficacy are not different than boys at this age (Britner & Pajares, 2006). In a study performed on high school students, male students had higher self-efficacy scores in math and science; however there was no gender difference in efficacy scores for biology (Uitto, 2014). In addition, math, chemistry and physics efficacy scores were correlated, as were biology and geography (Uitto, 2014), whereas in younger students, these correlations did not necessarily appear. High school sources of efficacy are different from college sources of efficacy. Seymour and Hewitt's observations that women feel most comfortable in "particularly cooperative interactive and experiential learning contexts … and encourage the development of skills and attitudes that have increasing value in occupational and social context beyond academe" (1997, p. 314).

Science self-efficacy has been well established as a reliable predictor of science academic achievement in general (Jiang, Song, Lee, & Bong, 2014; Usher & Pajares, 2008) and specifically at the college level (Andrew, 1998; Klomegah, 2007). In addition, both math and science self-efficacy has been associated with persistence in STEM related majors (Gwilliam & Betz, 2001). Within these domains, mastery experiences, as reported by students, consistently predict self-efficacy (Chen & Usher, 2013). However, at the college level, Zelden & Pajares (2000) revealed that mastery experiences in science, while significant predictors of self-efficacy for men, were less important for women; rather, vicarious learning and social persuasion were more significant sources of self-efficacy. It is important to remember, though, that general science efficacy is not necessarily reflective of the efficacy in individual science domains. For example, according to Satwelle, Brewe & Kramer, vicarious learning is significant source for women in physics, but social persuasion is not (2012). Thus, deep and meaningful interactions with the material and each other help women to derive confidence in STEM fields of study. Subsequently, in 2008, Zelden, Britner and Pajares, engaged in a qualitative study of men who selected careers in science, technology, engineering or math. These researchers found that these male students who persist in STEM careers derive most of their self-efficacy from mastery experiences, thus reinforcing earlier findings. Sax, Jacobs and Riggers (2010) revealed that the persistence of gender segregation in STEM fields continues as evidenced by the fact that in 2008, the number of women bachelor's degree recipients exceeded that of men, however they comprised a significant minority of STEM degrees (p. 4). These authors point to several possible causes, one of which is a lack of STEM self-efficacy. Women have equal or superior academic performance, yet in college, they rate their abilities in STEM subjects lower than their male counterparts (Sax, 2008). In addition, women who tend not to persist in STEM subjects tend to have a stronger artistic or activist personality (Sax, Jacobs & Riggers, 2010, p. 21). It is therefore important, in this study, to especially delineate mastery, vicarious learning and social persuasion sources of efficacy and the changes that occur in each domain in response to the design process and subsequent creation of an artistic artifact. Within the discipline of Biological Sciences, and specifically anatomy and physiology, the content is more closely aligned with verbal than math skills. Therefore, it is important to utilize a self-efficacy scale that accurately measures the construct and is not general in its assessment. Efficacy instruments that are more closely aligned with Biology rather than Chemistry, Physics, or Engineering are important since the three later are all closely correlated with mathematics. Finally, an instrument that has a high internal validity and reliability must be used to lend credibility to this study.

Measurement of self-efficacy for students in mathematics has been well studied. Betz and Hackett in1983 developed the Mathematics Self-Efficacy Survey (MSES). Both the full-scale original survey and its subscales have been independently validated with coefficient alphas 16 ranging from .72 to .96 (Betz and Hackett, 1983; Betz & Hackett, 1993; Walsh, 2008). Revised versions of the MSES have also been tried and tested with coefficient alphas between .90 and .95 (Kranzler and Pajares, 1997; Lent et al., 1991; Pajares and Miller, 1995).

A large number of researchers have used the adapted versions of the Sources of Mathematics Self-efficacy Scale (Anderson & Betz, 2001; Britner & Pajares, 2006; Lopez & Lent, 1992; Smith, 2001; Usher & Pajares, 2006a, 2006b). This scale was originally designed by

Lent et al, (1991) to evaluate the sources of mathematics self-efficacy of college students and has been used in both social and academic settings (Britner & Pajares, 2006; Pajares & Miller, 1995; Usher & Pajares, 2006a, 2006b; Usher & Pajares, 2008). The Sources of Science Self-Efficacy Scale is one example of a measurement tool adapted from the Sources of Mathematics Self-Efficacy Scale as reported by Britner & Pajares (2006). Loadings for the mastery experience items ranged from .60 to .81; for the vicarious experience from .47 to .72; for the social persuasions from .55 to .85; and for the physiological index from .66 to .88. Cronbach's alpha reliability indexes were .90 for mastery, .80 for vicarious, .88 for social persuasions, and .91 for physiological states. Researchers reported alpha coefficients ranging from .69 to .85 when academic self-efficacy has been measured in a similar way. Britner and Pajares (2001) reported .86 for science self-efficacy. Usher and Pajares (2009) again validated this scale in a separate study and a 24-item four-factor confirmatory model resulted. Authors reported that the revised scale "not only reflects the four sources hypothesized by Bandura but also displays strong psychometric properties and invariance across gender, ethnicity and mathematics ability level" (p. 99). They further conclude that as self-efficacy is not generalizable and is context-specific, and, when considering the psychometric soundness, this scale may be confidently adapted for use in other domains (Usher & Pajares, 2009).

The Survey of Academic Orientations (SAO) academic self-efficacy subscale measures college students' readiness by "enhancing our understanding of how undergraduates interpret the academic environment" (Davidson, 1999, p.690). Six factorially-distinct academic orientations, of which self-efficacy was one, were evaluated and determined stable across different semesters, with test-retest coefficients ranging from 0.63 to 0.86 and validity coefficients of 0.3 to 0.69. The subscale was also determined internally consistent as evidenced by alpha coefficients of 0.59

to 0.85. In specific, for the self-efficacy subset, scores ranged from 0.49 to 0.65 with alpha coefficient of 0.7 and a test retest coefficient of 0.7 (Davidson, Beck & Silver, 1999).

The Biology Self-Efficacy Scale is an instrument designed by researchers who were a part of the NSF funded "Slice of Life" research project in order to determine undergraduate confidence in mastering biological literacy (Baldwin, Ebert-May & Burns, 1999). This inventory is subdivided into subscales that do not support the four efficacy subscales as outlined by Bandura (1995). Instead, researchers indicated three subscales: confidence in writing and critiquing biological ideas in laboratory reports, using a scientific approach to problem solving within biology, and applying biological concepts to everyday life events (validity coefficients ranging from 0.18 to 0.27) (p. 404). In the recommendations, the authors encourage further research into correlating biology efficacy with further elements with Bandura's theory. This survey was used as a template for the only Anatomy efficacy survey found in the literature: The anatomical self-efficacy instrument (as named by the creators). Investigators reported overall efficacy indicators that corresponded with different units of material covered and were looking to determine if self-efficacy was a good tool for predicting academic performance of students in medical gross anatomy, while controlling for academic ability (Burgoon, Meece & Granger, 2012).

The Chemistry Attitudes and Experiences Questionnaire was developed to measure university chemistry students' attitude toward chemistry, chemistry self-efficacy and learning experiences. From the self-efficacy portion of this instrument, average inter-correlation of 0.80 and Cronbach's alpha of 0.74 at the beginning of the year and 0.84 at the end of the year, thus indicating a high instrument validity and reliability. Concurrent and predictive validity were also confirmed using correlation evidence expressed to a significance of $p < 0.05$ (Dalgety, Coll, &

Jones, 2003).

The Sources of Self-Efficacy in Science Courses-Physics (SOSESC-P) survey was developed by Fencl and Scheel (2005) to assess each of the sources of self-efficacy as described by Bandura (2006). Internal consistency reliability coefficients range from 0.68 to 0.88 with the coefficient for total scale at 0.94. In many other cases, researchers created unique efficacy measuring instruments to provide unique insights into their particular construct (Britner, 2002; Whitt-Rose, 2003; Lawson, Banks & Logvin, 2007). However, according to Usher & Pajares (2008), "items and scales have differed considerably across studies and not all researchers have been attentive to issues related to construct validity or to theoretical guidelines related to the nature of the sources" (p. 755). Thus, the predictive power of these instruments should be treated with caution since the explanatory and predictive power diminishes when efficacy is evaluated too broadly or when they do not meaningfully correlate with the outcome they are meant to predict (Usher & Pajares, 2008).

Qualitative investigations of science student self-efficacy have been less frequent, but are present in the literature (Brand & Wilkins, 2007; Britner & Pajares, 2000; Burnham, 2011; Hutchison-Green, Follman, & Bodner, 2008; Usher, 2009), primarily with college-age students. Of these, most are semi-structured interviews that explore not only the four interpretive domains, but also allow for deep and meaningful understandings of the students' viewpoints. In order to get a more comprehensive view of the influences of self-efficacy, focus groups, interviews, end of course reflections and other qualitative interactions with students that are designed to examine student experiences and perceptions in greater detail should be considered (Baldwin, Elbert-May, & Burns, 1999; Brand & Wilkins, 2007; Painter & Bates, 2012; Usher & Pajares, 2008, 2009).

In particular, within the domain of Biology, there is very little self-efficacy data present.

Perhaps this is because Biology has historically been less aligned with mathematics. Science sub-disciplines (such as Chemistry and Physics) that are more closely aligned with mathematics predominate in the efficacy literature, especially for undergraduate learning. However, that being said, there is a plethora of research which addresses undergraduate student achievement in Biology and, in particular, Human Anatomy and Physiology (A&P). The learning of Anatomy is associated with learning the structures of the human body and the learning of Physiology entails the understanding of gross and cellular function of each structure. Thus, there is a natural connection between the two studies. When undergraduate students start to learn the necessary material, they oftentimes are overwhelmed by the sheer volume of information given and the amount of new terms utilized in the new course. Thus, educators have been particularly concerned with ways to encourage student mastery of course content. It has been well established that students who have achieved mastery in prior relevant coursework are more likely to be successful in A&P (Peterson & Tucker, 2005; Forester, McWhorter & Cole, 2002). DeHoff, Clark & Meganthan (2011) found that students performed better on both higher order and low order style content questions when exposed to modeling opportunities to learn structures and reported higher satisfaction overall with their learning experiences. In addition, the students articulated strong preferences for group interactions in order to learn the material. In a similar study situated in a large urban community college, students also reported high satisfaction ratings with the use of clay modeling techniques to learn anatomy and these opinions were supported again by improved content mastery (Haspel, Motoike, & Lenchner, 2014). In another study, Levy (2014) found greater student satisfaction and achievement in a hybrid A&P course when allowed to construct learning using a Wiki tool. Students reported more positive feelings of success since they were able to increase opportunities of collaboration using this tool in particular. Hopper (2011) reported that A&P students found greater success and higher retention in the courses with improved content mastery that was facilitated by a multifaceted classroom approach in a community atmosphere. Team-based self-directed learning approaches in A&P, as seen in Biology, have been shown to produce higher levels of academic success as well as greater satisfaction in students (Findlater, Kristmundsdottir, Parson, & Gillingwater, 2012; Hopper, 2011). In the case of these groups, opportunities for mastery within specific cycles of learning were included in the pedagogical approach to learning. Researchers reported higher than average scores on examinations, fewer students failing and of those that completed the course, their end of course score was higher (Findlater, et al, 2012). Across the board, it is interesting to note that all of the above-referenced studies cite classes with highly diverse groups of students with regard to prerequisite knowledge and academic ability.

The Anatomy and Physiology literature clearly links mastery opportunities with academic achievement in the course. Undergraduate students' perceptions of what experiences are meaningful are also revealed by researchers and point to sources of self-efficacy that are mastery and social in nature. However, that being said, there is no known study that definitively links these sources of efficacy with academic achievement in this domain of science study. Burgoon et al. (2012) reported that medical students who engaged directly in mastery experiences (such as dissection) may have higher anatomical self-efficacy, as evidenced by higher laboratory practical examination scores that correlated with higher anatomical self-efficacy. However, test scores and anatomical self-efficacy did not correlate. Of course, the learning context, in the case of practicum versus test changed, but the measure of self-efficacy did not and this could explain the source of discrepancy. These researchers did not investigate sources of self-efficacy in this study. In addition, there is no research available that specifically targets improvements in course presentation to improve self-efficacy. A need for research is thus revealed.

Summary of the Literature Review

In response to the rifts in educational literature, this study is designed to help educators understand the effect of the design process, as manifested in an artistic design artifact, on the self-efficacy and knowledge gains of undergraduate Anatomy and Physiology students. Aligning with what is known in other STEM disciplines about sources of self-efficacy and gender differences in these sources, each of the four sources of self-efficacy will be tested within the context of an A&P course order to understand specifically how student self-efficacy is impacted. It is also important for both qualitative and quantitative data to be gathered and considered together to access the full picture of Human Anatomy & Physiology efficacy and its influences on these students. In order to achieve this deep data-driven understanding, end-of-course reflections along with efficacy data from a Likert-style survey instrument will be considered in concert. There is a notable lack of efficacy instrumentation that is available to evaluate within the A&P domain. Of the surveys that are available, they are predominately aimed at finding out student "preferences and "satisfaction" rather than efficacy. Within the Biology domain, only one efficacy survey exists and it does not address Bandura's hypothesized sources of efficacy. Within the STEM domains, several valid efficacy surveys exist and, of these, the Sources of Mathematics Efficacy Scale, as used and validated by Britner & Pajares (2006) has the best internal validity and alpha coefficient consistency and will therefore be used as a foundation for efficacy evaluation in this study.

The design project will serve to fulfill an opportunity to construct new meanings and each learner's progress will be evaluated using both formative and summative evaluations. The dialogue that ensues between instructor and student and between peers about the artistic solution will be similar in that the aesthetic value will be of importance along with the rationale founded in content knowledge and personal experience which supports the solution. While this research will include individually completed artistic design projects, it will be important for the professor to consistently engage the learners one-on-one to not only discuss content but also to imagine or speculate on the interpretation which best represents the problem. Thus, students will be guided in the iterative cycles of learning, which are correlated with developing 21st century habits of mind. Social cognitive theory and self-efficacy theory remind us that mastery will not be enough in this classroom, which is dominated by women. Adding in informal peer review opportunities and perhaps a time where students are asked to brainstorm together in the class time will be important to capitalize on the possibility of constructing shared meanings and improving self-efficacy through social persuasion.

CHAPTER THREE: RESEARCH METHOD

This chapter presents the research methods used to investigate the following research questions:

1. To what extent does the design approach to teaching and learning content of Anatomy and Physiology in the undergraduate, community-college laboratory result in changes to students' biological science self-efficacy?
2. What is the effect of the design approach on undergraduate, community college students' content knowledge in Anatomy and Physiology?

The investigative methods are described in the following sections: research design, participants, instruments, data collection procedures, data analysis (quantitative, qualitative and mixed) and summary.

Research Design

This study is concerned with revealing the potential effects of engaging in the design approach to teaching and learning in the undergraduate Anatomy and Physiology (A&P) laboratory. In order to tease-out different aspects of the same research questions, a sequential, concurrent mixed method design was employed and a visual representation of the research design may be seen in Figure 1 (Creswell, 2003; Teddlie & Tashakkori, 2006, p. 20).

The experimental pool consisted of students who, prior to the beginning of the term, self-selected (registered themselves through computer or were registered by an academic advisor) into one of the available 15 lab sections of Anatomy and Physiology I published by the college they felt would best suit their academic and personal needs. Of these classes, four sections, taught by two different professors, were included in the study and neither the advisors nor the students knew before the semester started which sections or professors would be included. Approximately two weeks before the first day of classes (See Appendix D for the semester schedule), each of the participating professor's two lab sections was randomly assigned one or the other of two design projects (tissue project or bone project) to complete over a three-week period in the fall semester (See Appendices F and G for a copy of each design assignment given to students). All study participants (n = 36) were evaluated for potential gains in self-efficacy and content knowledge throughout the semester using three quantitative and one qualitative source of data. Demographic information was also gathered about all study participants at the outset of the study. Quantitative data were acquired from lab practicum scores that were gathered sequentially throughout the first half of the fall semester, individual grades on the design project, the administration of the Science Self-efficacy scale (Britner & Pajares, 2001) and the administration of an adapted form of the Sources of Mathematical Self-efficacy Scale (Usher & Pajares, 2009). Qualitative data were derived from the administration of an open-ended questionnaire developed for this study and analyzed as guided by Brand & Wilkins (2007). Since there were two research questions there were also two relatively independent strands of data in this design. The relationship between self-efficacy and academic achievement has been well established in the literature (Hackett & Betz, 1989; Jiang, Song, Lee & Bong, 2014; MacPhee, Farro & Canetto, 2013; Pajares, 1996) and, as such, inferences from each data strand were "synthesized to form meta-inferences at the end of the study" (Teddlie, & Tashakkori, 2006, p. 20).

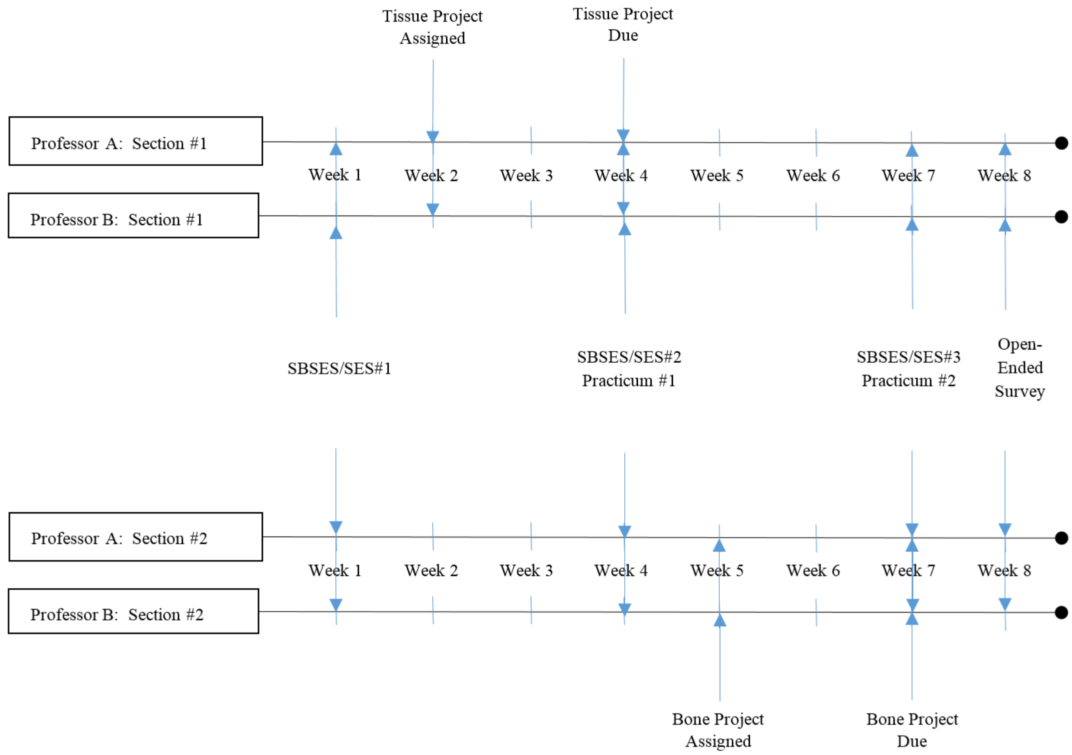


Figure 1. This graphic represents the timeline of the study and demonstrates the concurrent, sequential study design.

Participants

This study was conducted on the campus of a Mid-Atlantic community college in a small to mid-sized urban area. Of the approximately 12,000 enrolled, the student population is 54% female and 46% male with a racial makeup of 86% white, 9% African American and 5% other races. The average student age is 29 and 66% of the students attend part-time.

Study participants self-selected into available Anatomy and Physiology I courses for the Fall, 2014 semester. Four of the 15 available classes participated in the study and, prior to the first day of class, students were unaware of which sections would be involved. In specific, at the outset of the study (N = 63), participants were almost equally distributed among full (n = 30) and part-time status (n = 33). Participating students were 17% male (n = 11) and 83% female (n =

52) and the most represented age range was between 15 and 20 years old. Ethnically, the sample was 84% Caucasian (*n* = 53), 9.5% African American (*n* = 6) and 3% Asian (*n* = 2). Sixty-one percent of these students (*n* = 38) reported a "D" or better in at least one college-level science course and only 28% (*n* = 17) reported taking a college class in either visual or performing arts within the last five years (Appendix N). By the end of the study, 36 participants remained, demonstrating a study attrition rate of 41%. Of those that no longer participated in the study, all also withdrew from the course before the end of the semester. The demographics of the remaining students was similar to that of the original sample. Increases in percentage represented by female students (*n* = 31) and by full time (*n* = 22) were of note (Appendix O).

Instruments

Six instruments were administered to gather data with the purpose of informing the research questions of this study. Four instruments gathered quantitative data (Sources of Biological Science Self Efficacy scale, Science Self-Efficacy survey, design project grades and lab practicums), one instrument gathered qualitative data (open-ended sources of self-efficacy survey) and demographic data were gathered at the outset of the study (see Appendices H-K for all surveys used).

Sources of Biological Science Self-Efficacy Scale (SBSES)

In order to quantitatively evaluate the sources of self-efficacy for each student, the Sources of Mathematics self-efficacy scale was modified by rewording in order to make each questions applicable in the domain of Biological Sciences and used after obtaining written permission from Dr. E. Usher (Usher, Personal communication, August 20, 2014). This scale was originally designed to be used in a college environment (Lent et. al, 1991) and has subsequently been utilized in middle school (Britner & Pajares, 2006; Pajares & Miller, 1995;

Usher & Pajares, 2006a, 2006b; Usher & Pajares, 2008) and high school environments (Chen & Usher, 2013). Usher and Pajares (2009) re-validated this scale and reported Cronbach's alpha scores at levels above 0.80 for each source of self-efficacy. Chen and Usher (2013) again used the scale with middle and high school students and re-worded for the domain of science. These authors reported Cronbach's alpha coefficients of their modified survey as follows: .87 for mastery experiences (ME), .71 for vicarious experience (VE), .85 for social persuasion (SP) and .86 for psychological and affective states (A).

For this study, the survey items were used from the Chen & Usher model (2013) since it was already situated within the science domain and successfully used in high school. These authors used the term "science" in their revised version. However, the general term of "science" was rejected for this study since at the college level, many different domains of science are commonly recognized and a specific context of Biological Science needed to be maintained. The term "Biological Science" was used instead of "Anatomy and Physiology" so as not to confuse students who may not have completed a college science course or who may not distinguish Anatomy and Physiology from other sciences (such as Chemistry or Physics). This reworded survey was subsequently renamed Sources of Biological Science self-efficacy scale (SBSES). The SBSES scale included all 24 items as used by Chen and Usher (2013), six of which addressed each source of self-efficacy. Independent sources of self-efficacy alpha coefficients were determined for the SBSES used in this study (Appendices H-J, items #1-24). The fact that this study sample was less than 50 participants presented a concern for the stability and precision of the alpha coefficient. Knowing this fact, the coefficients under each testing condition were independently determined in the current investigation and the corresponding confidence intervals are reported, as guided by Bonett & Wright (2014)(Table 1).

Table 1

Sources of Biological Science Self-Efficacy Survey/Science Self-Efficacy Survey Reliability Statistics

	SES Total Self-efficacy (Items 25-29)	SBSES Mastery Experiences (ME) (Items 1-6)	SBSES Vicarious Experiences (VE) (Items 7-12)	SBSES Social Persuasion (SP) (Items 13-18)	SBSES Psychological States (A) (Items 19-24)	SBSES Total (Items 1 – 24)
Survey #1	.654 [.453, .797]	.802 [.689, .884]	.677 [.493, .811]	0.900 [.844, .942]	0.803 [.691, .884]	.871 [.806, .922]
Survey #2	.874 [.800, .927]	.789 [.669, .876]	.746 [.601, .851]	.854 [.771, .914]	.827 [.729, .899]	.838 [.756, .903]
Survey #3	.929 [.833, .961]	.855 [.764, .919]	.829 [.721, .904]	.940 [.902, .966]	.902 [.840, .945]	.916 [.869, .952]

Note: This table reports Cronbach's alpha coefficients and their corresponding confidence intervals (CI) for the SBSES and SES. All CI were determined at 95% and all calculations were made assuming no interaction effect, because the statistic is not estimable otherwise.

The statistics revealed stability across each measure and within each survey, therefore re-establishing the validity of the instrument to this undergraduate-level population in the Biological Science domain and in the manner chosen. In addition, the statistical stability allowed researchers to accept the changes made to the instrument to make it domain-applicable and proceed confidently in the study.

Science Self-Efficacy (SES)

Biological science self-efficacy was assessed using the science grade self-efficacy scale (Britner & Pajares, 2001, 2006). These five questions asked participants to rate how confident they were that they could earn a particular grade in their science class at the end of the semester. The authors previously reported alpha coefficients of 0.86 and 0.85, respectively, for science self-efficacy using this scale (Britner & Pajares, 2001, 2006) when used in a middle school population. Permission was received (Dr. S. Britner, personal communication, August 20, 2014) to use these five questions to measure science self-efficacy and were subsequently included as the last five questions as a part of the SBSES (See Appendices H-J, Questions 25-29). Alpha coefficients were again determined for each implementation of the instrument and the alpha coefficients and corresponding confidence intervals for each are reported in Table 1 (Bonett & Wright, 2014). The average alpha for this study was .819, consistent with prior published results, and therefore establishes the applicability of the instrument to this community college level population to measure the desired construct.

Content Knowledge

Student grades (percentages) on two lab practicums were collected to indicate effects on content knowledge. Lab practicums for each class were designed and implemented by the participating professor. In order to improve consistency and reliability of scores, each participating professor agreed to: (a) utilize the same lab objectives for teaching and testing; (b) follow accepted department guidelines for practicum design and administration; and (3) include an identical set of fill-in-the-blank common questions on each lab exam (five on the first practicum and ten on the second) that were created by a team of four separate Anatomy and Physiology professors during a previous semester (see Appendix E, Part 2 for a listing of all common questions). These common questions share the exact verbiage, have the same right or wrong answers, are presented as a part of each lab practicum and graded as such. Thus, overall practicum scores along with common question scores were separately submitted to the investigator and each were statistically analyzed to establish the reliability of the content knowledge data (see Appendix E for a list of common lab objectives and common questions).

Sources of Self-Efficacy

In order to qualitatively evaluate student sources of self-efficacy in the study, a student self-efficacy response survey consisting of five open-ended questions was employed one week after the final SBSES/SES to attempt to elucidate student perceptions of the design process and its effect on their self-confidence (Appendix K). These five questions were exploratory in nature and included requests of all participants for information about participation (i.e.: vicarious experiences and/or social persuasion), opportunities for iteration (mastery), and changes in anxiety or confidence so as to guide the researcher to deep and meaningful understandings from the participant's perspective (Corbin & Strauss, 2008). The resulting qualitative data were then analyzed alongside of the quantitative indicators (described in the data analysis section of this chapter) to provide researchers with a deep and meaningful view of treatment effects.

Project Grade

Each design project was due on the day of the practicum. Over the two weeks immediately following project submission, the two participating professors and the researcher met and graded each project according to a grading rubric developed and tested over the past two years by a separate team of Anatomy professors (Appendices F and G). The rubrics were first developed by the lead investigator in 2004 when the projects were first conceived. These rubrics were subsequently used to grade the tissue and bone projects by several different groups of professors in two different community colleges. Each time the rubric was used, the professors would discuss the clarity of the wording in the rubric itself, the alignment of the rubric with the stated project objectives, and applicability of the rubric to the given student population. If the professors agreed that changes needed to be made to improve the rubric, a consensus was reached to make the changes and the improved rubric was used in the following semester and tested again. The rubrics have been regularly used and refined over the past 6 years, in 18 separate semesters by six different teams of 2-4 anatomy and art professors (13 different professors in total: 10 anatomy and 3 art). The rubrics used in this study are in their final form after having no additional additions/corrections to them in four consecutive semesters. The resulting project scores were used as a source of data, in conjunction with practicum scores and common question scores, to provide evidence of student content knowledge.

Demographics

At the end of the first implementation of the SBSES/SES, a one-page survey supplement was designed to collect demographic data from study participants (Appendix H). Information about school status, prior coursework in sciences and in art, gender, age, and ethnicity were all included in the demographic portion of the survey in keeping with factors known to have influences on college-student self-efficacy (Zelden & Pajares, 2000). These factors were included in the data analyses and demographic data was considered individually and collectively for possible influence on efficacy.

For a concise representation of the alignment between the research questions, data sources and data analysis, refer to Table 2.

Table 2

Alignment between Research Questions, Data Sources, and Analysis Methods

Research Question	Data Collection Techniques	Data Analysis
1. To what extent does the design approach to teaching and learning in the undergraduate, community-college Anatomy and Physiology laboratory result in changes to students' biological science self-efficacy?	Quantitative: • Sources of Biological Science Self-Efficacy Scale (SBSES) • Science Self-Efficacy Scale (SES) • Demographics Qualitative: • Sources of Self-Efficacy survey	Alpha Coefficient; Descriptive Statistics; Paired *t*-test; Repeated Measures MANCOVA; Multiple Regression Content analyses
2. What is the effect of the design approach on undergraduate, community college students' content knowledge in Anatomy and Physiology?	Quantitative: • Objective-based lab practicum grades • Common question grades • Project grades	Descriptive Statistics; MANCOVA; Multiple Regression

Data Collection Procedures

Prior to beginning research, appropriate approvals from governing internal review boards (IRB) was acquired by the principal investigator (Appendices A and B). During the second week of lab for the fall semester, each participating professor introduced the research study by showing a video made by the principle investigator. The video was used in order to provide a consistent presentation of procedures to all potential participants and included an explanation of the study background, purpose, and overview. In the video, students were then asked to participate in the study and assured that their participation was completely optional and would have no part in determining their semester grade. The professor immediately distributed the consent forms (Appendix C) and students indicated on the form if they gave consent or not. For those who did consent, using a computer-generated list of random numbers, the professor assigned each an identification number and recorded each student's number. Each consenting student was immediately given the SBSES/SES + demographic questionnaire (Appendix H) to complete and included only their student identification number in lieu of their name. The instructor collected all completed consent forms and initial surveys and submitted them to the principle investigator within 48 hours for data compilation. The investigator entered each student identification number and corresponding data into an Excel spreadsheet. Hard copies of each survey were filed for reference.

Two professors (noted as A and B) participated in the research study and with each of them were two lab sections (noted as section 1 and 2). Before the beginning of the semester, sections A1 and B1 were assigned the tissue project and sections A2 and B2 were assigned the bone project, therefore resulting in one section for each being a reference population for the other (Figure 1).

During the lab period in week 2 of the course, participating professors introduced the tissue design project to selected lab sections (A1 and B1) during the regular lab period by using a pre-recorded video, created by the principle investigator. This video introduced students to the project goals, provided specific instructions and details about grading criteria and was used to minimize inconsistencies that may have occurred if individual professors presented the project. A copy of the assignment page distributed to students which includes grading rubric is provided in Appendix F. The design project is an integral component of the course and, as such, all students participated in the design project, regardless of participation in the self-efficacy portion of the study, and were given approximately three weeks to complete the project. After assignment submission, consenting students were given the SBSES/SES #2 approximately 10 minutes before participation in the class lab practicum (Appendix I). The timing of the survey administration was important so as to gather student perceptions about their self-efficacy before experiencing the actual practicum, in an effort to increase the probability of isolating the potential effects of the design project on sources of self-efficacy. Each professor graded the completed lab exams for correctness. These practicum scores (inclusive of scores on five questions common to all sections, found in Appendix E, Part II) were collected by the principle investigator within 48 hours of completion in order to use as evidence of content knowledge to address study question #2. Participating professors submitted all surveys and practicum scores to the principle investigator for data compilation and analysis being sure to identifying students only by pre-assigned number. Tissue project scores were submitted to the principle investigator after the team graded the assignments, approximately two weeks after the practicum. These data were used along with the practicum scores as evidence of content knowledge.

During week 5, the lab sections that were not assigned the tissue design project were assigned the bone design project (lab sections A2 and B2) by their professor during the regularly scheduled lab period by playing a pre-recorded video, created by the principle investigator. This video introduced students to the project goals, specific instructions, and grading criteria and, again, was used to minimize inconsistencies in presentation (Appendix G). As before, all students in these lab sections participated in the design project, regardless of participation in the self-efficacy portion of the study, and were given approximately three weeks to complete the project. After assignment submission, consenting students were given the SBSES/SES #3 approximately 10 minutes before participation in the class lab practicum (Appendix J). The timing of this survey implementation was important so as to gather student perceptions about their self-efficacy before experiencing the final lab practicum, thus increasing potential for isolation of any effect of the design project on sources of self-efficacy. Within 48 hours, participating professors submitted all surveys and practicum scores (inclusive of the 10 common questions: five on bone structure and five on bone ossification, found in Appendix E, Part 2) to the principle investigator for data compilation and analysis, again only identifying students by pre-assigned number. Bone project scores were submitted to the principle investigator after the team graded the assignments, approximately two weeks after the practicum. These data were used along with the practicum scores and tissue project scores as evidence of content knowledge.

Finally, during the week 8 lab, the professor administered the final open-ended student self-efficacy response survey at the beginning of the lab period (Appendix K). This survey included five free-response questions used to more deeply explore the student perspectives about participation in the design project and the effects (if any) on self-efficacy. Participants were allowed to work toward completion with no time restriction. In keeping with previous procedure, participating professors submitted all surveys to the principle investigator within 48 hours for data compilation and analysis, only identifying students by pre-assigned number. Hard copies of all surveys collected in this study were filed by the investigator for future reference. See Figure 1 for a graphical depiction of the above-described process.

Data Analysis

This study collected data to evaluate the possible effects of the design process on undergraduate student science self-efficacy and content knowledge. The data for each research question were evaluated separately and then merged at the end to produce study conclusions (Figure 2).

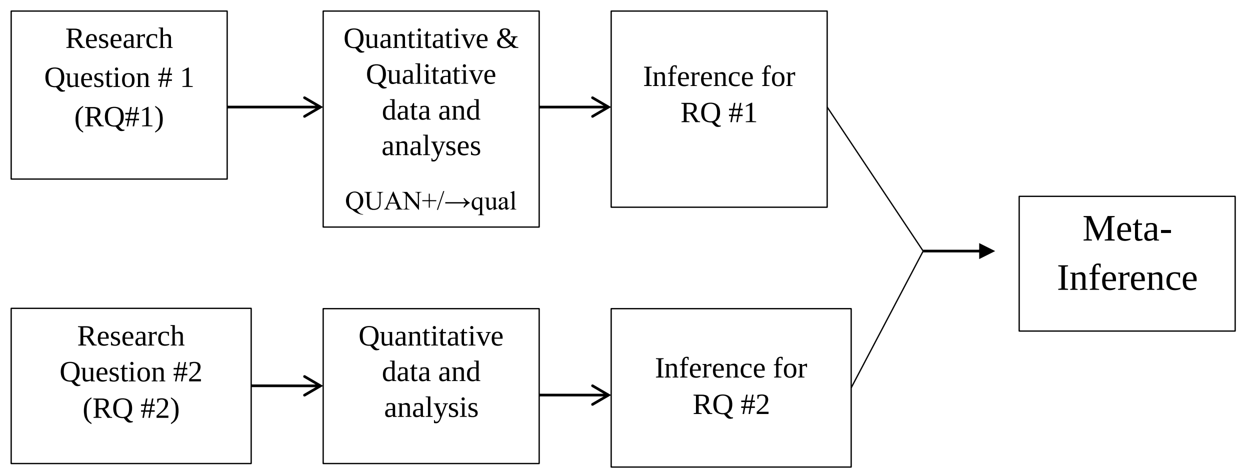


Figure 2. Data analysis process used in this study.

Research Question #1

To investigate the effects of participation in the design project on student self-efficacy, quantitative self-efficacy data were considered first and analyzed using IBM SPSS Statistics for Windows, Version 22.0. The independent sources of self-efficacy revealed in the SBSES were totaled and averaged. Science self-efficacy, as documented in the SES was also totaled and averaged. Descriptive statistics (means, paired *t*-tests and standard deviations) and correlation coefficients for all variables in the study were compiled from the three iterations of the SBSES/SES. Next, a multivariate analysis of variance with repeated measures (MANCOVA) was conducted in order to determine (a) if science self-efficacy differed as a function of each independent variable and (b) if any of the independent sources of self-efficacy differed as a function of each independent variable. Finally, multiple regression analyses were performed to determine (a) the independent contribution made by each of the four hypothesized sources of self-efficacy to the prediction of student Biological Science self-efficacy and (b) if gender, ethnicity, age, school status and prior science or art coursework can be used to predict science self-efficacy in the quasi-experimental context (see Appendix P for a complete listing of the above described analytical results).

Qualitative data were subsequently analyzed. The researcher chose to use an analytic method that involved combining categorical and holistic analysis of codes as guided by self-efficacy theory, to elucidate the perspective and experience of the learner in the setting of the Anatomy and Physiology course (Rossman & Rallis, 2012). The *a priori* decision that all coding would be subject to multiple coders was then implemented in order to improve the dependability of the resulting data (Creswell, 2014). To this end, the researcher first created a preliminary codebook that included definitions (Bandura, 2006) and descriptions of each source of self-efficacy. This codebook was modeled after a similar guide created by Brand and Wilkins (2007), after receiving permission from Dr. B. Brand to use the guide (Brand, Personal communication, April 12, 2014). In an effort to improve the trustworthiness of the study, two research assistants were asked to participate in the coding process (Lincoln & Guba, 1985). At the outset of the analytical process, the researcher conducted one three-hour training whereby two research assistants were introduced to the coding process and the preliminary codebook. First, the definitions of each source of self-efficacy were articulated and then openly discussed in the group so as to confirm a consistent understanding. Then, the text from an interview from an earlier qualitative study that this team evaluated was distributed, discussed and coded as a group, using the codes and definitions in the codebook for the purposes of training and establishing a cohesive foundation upon which to proceed. Each group member took time to upload one common excerpt from this interview into QSR International's NVivo 10 qualitative data analysis software. The length of this text was determined by its approximation of a similar length as what was expected from the actual content being analyzed in this study (Riffe, Lacy & Fico, 1998).

Then, each member defined the codes of interest in the software by designating them as individual nodes, as described in the codebook. Finally, each group member read and used the software to highlight and code according to the defined nodes. The group again came together and consolidated the coding into NVivo software for comparison. NVivo was used to calculate a percent agreement among each pair of coders by totaling the number of characters (letters) in the sample and dividing that total into the amount of characters that the coders had exactly in agreement. The percent agreement was used to give a diagnostic indication of inter-rater reliability. In an effort to improve the accuracy of the measure, percent agreement was also calculated by hand by following the example given in Brand and Wilkins (2007) whereby the number of coding agreements was divided by the total number of codes for each pair of coders and then the average pairwise agreement was calculated by adding each pair percent agreement and dividing by three. For each of the sources of self-efficacy, over 80% agreement was reached (Joyce, 2013; Neuendorf, 2002, Riffe, Lacy, & Fico, 1998) and the hand calculated percent agreements were consistently at or higher than the NVivo calculated percent. Since the length of the example approximated that of the actual data, and a high agreement was reached, the chances of achieving the same result was high and gave researchers confidence to proceed (Riffe, Lacy & Fico, 1998). Despite the high percent agreements, the results were again discussed in light of the codebook to be sure that there were no points of confusion. This codebook was used to guide the initial coding process and, as the transcripts were read and considered, the codebook was refined to reflect emerging data, as recommended by Creswell (2014) (see Appendix L for a copy of the codebook in its final form).

At this point, study survey results were distributed and each group member again uploaded them into NVivo for analysis. The group agreed to evaluate only one of the files for coding, as guided by the codebook, and come together a week later to discuss coding results and use the software to evaluate percent agreement. Investigators agreed to work toward achieving a minimum standard of 80% agreement before progressing in the coding process (Joyce, 2013; Neuendorf, 2002). In addition, each time the group met to discuss the coded material any differences were used to inform revisions to the codebook so as to clarify meaning and maximize reliability and therefore trustworthiness (Lincoln & Guba, 1985) of the results, as demonstrated by Brand and Wilkins (2007). Examples found in the study surveys were discussed and used to further clarify the understandings of each source of self-efficacy (See Appendix L). In total, the group met 6 times before the coding process was complete and the specific results of each meeting may be found in Table 3.

Table 3

Coding Decisions

Week 1	Question 1 was assigned to be coded this week. Upon meeting, the group decided to refine the definitions of the sources of self-efficacy and these definitions are presented in their current form. The group achieved above 80% for our coding percent agreement, therefore, Question 2 was to be coded for next week.
Week 2	The group came back and we found a coding percentage of 76.78% overall. We discussed why the differences occurred and we agreed that there were two sources of psychological states that were being revealed in the data. Therefore, we agreed to separate the sources of the anxiety and only code statements directly related to the project under PS. Any statements about anxiety made in relation to the participation of the practicum were categorized under its own node. We agreed to recode Question 2 and meet again in a week.
Week 3	This week we met and achieved almost 100 % agreement on codes. Another pattern emerged from the data that the group thought was noteworthy. Time seemed to be a connecting concept between ME and A. We agreed to code question 3 and 4 over the next week and also go back to recode these mentions of time under its own node for later comparison.
Week 4	This week, we met and achieved over 80% agreement on codes, and found that codes for ME were the most prevalent in the data. We again agreed to come back together after 1 week after we coded the last question.
Week 5	This week, the group met and again achieved over 80% coding agreement. It was agreed that each member would go back to find examples to include in the codebook and we would discuss next week.
Week 6	This last week, the group met to discuss the examples that we each highlighted as the best examples to include in the codebook for each source of self-efficacy. The group reached consensus and the codebook was updated.

At the end of the coding process, individual percent agreements for each source of self-efficacy were calculated and resulting percentages ranged between 80 and 100 (Table 4) pointing to a strong trustworthiness of the collective coding decisions in this study.

Table 4

Inter-Rater Percent Agreements for Sources of Self-Efficacy Ratings

	Mastery Experiences	Social Persuasion	Vicarious Experiences	Psychological States
NVivo calculation	80.83	99.50	94.28	84.32
Hand calculation	84.00	98.33	99.83	92.33
Average	82.42	98.92	97.06	88.33

Note: The inter-rater agreements displayed in the above table include those that were calculated by NVivo software and those that were calculated by hand for each source of self-efficacy.

After coding was complete NVivo was again used, through cluster analyses, to determine correlational relationships among students and among coding categories on the basis of coding similarities and word similarities in each. NVivo then computed a similarity index between each item using Pearson's correlation coefficient and represented data in a dendogram using a "complete linkage (farthest neighbor) hierarchical clustering technique" (NVivo, 2014). Thus, the closer the data were correlated, the closer they were grouped and situated in the dendogram. NVivo was also used to perform word frequency analyses in order to identify themes within each node. NVivo displayed the results in a word cloud, displaying the most frequently used words in varying font sizes, where greater frequency was noted by larger font size (NVivo, 2014).

Finally, qualitative and quantitative data were considered in concert with one another, in a side-by-side analysis, with the primary goal of completeness and a secondary goal of convergence (Creswell, 2014; O'Cathain, Murphy, & Nicholl, 2010; Shih, 1998). Primarily, quantitative and qualitative data were considered in a complementary fashion in order to "yield an enriched, elaborated understanding" of a student's participation in the design process while overlapping the data sources to result in inferences about student self-efficacy (Greene, J., Caracelli, V., & Graham, W., 1989, p. 258). Codes from qualitative analyses were considered together with the statistical results and the data were analyzed in an effort to corroborate and deeply understand the underlying self-efficacy theory used to guide the study. Data analyses were guided using Onwuegbuzie and Teddlie's (2003) seven-stage conceptualization of the analysis process. First, data were reduced through coding and cluster analysis for qualitative sources and calculation of descriptive statistics, MANCOVA, and multiple regressions for quantitative sources. Second, all data were displayed in appropriate charts, graphs and dendograms. Third, where possible, qualitative data were quantized so statistical comparisons may be made (e.g.: demographic data). Fourth, data correlation was achieved primarily by use of statistical calculations. Fifth, data were consolidated in an effort to create one combined data set that could be considered together. Sixth, all data were compared with the goal of drawing inferences from the consolidated data set. Finally, data were integrated and from this integration, conclusions were drawn. The integration occurred when statistically triangulating the results. From these data, points of convergence and divergence were identified. Coded qualitative statements were used to enhance points of convergence and clarify points of divergence. The resulting conclusions and recommendations are discussed in chapter five of this document.

Research Question #2

In order to analyze the data generated to address research question #2, quantitative practicum scores, common question scores, and project grades were analyzed using IBM SPSS Statistics for Windows, Version 22.0. Descriptive statistics, including mean and standard deviation were first calculated. Next, a correlation analysis and subsequent calculation of Pearson's r was completed to illuminate any relationship, the statistical nature of said relationship and the power of the relationship among test scores and project grades. Multivariate analysis of variance (MANOVA) was used to determine if test scores differed as a function of the different type of design project completed. Finally, multiple regression analysis was performed to determine (a) if project type may be used as a predictor of self-efficacy (its hypothesized sources or total science) and (b) if project type may be used as a predictor of practicum scores.

Meta-Inference

Meta-inferences from the two data strands were derived from triangulating the data and results from question #1 in concert with the data and results from question #2 with the main goal of completeness (O'Cathain, Murphy, & Nicholl, 2010; Shih, 1998). Given that the primary sources of data in the study were from quantitative sources these findings were considered first to acquire a general idea of the design project and its potential effects on self-efficacy and content knowledge within the study context. Sources of self-efficacy data along with science self-efficacy scores were loaded into SPSS and a hierarchical multiple regression analysis was conducted to determine their independent contributions to the prediction of test scores with and without the impact of each project, thus achieving statistical triangulation. Then, qualitative statements were used to deepen and clarify understandings revealed by quantitative analyses.

When within-method (quantitative) results diverged, findings indicated by qualitative data were used to shed light on the issue and provide deeper understandings as to the potential reason for divergence. When within-method results converged, qualitative statements were used to support the convergence, thereby improving the consistency of the results (O'Cathain, Murphy, & Nicholl, 2010).

Summary

This research study was designed in order to understand the effect of a design project on undergraduate, community college student self-efficacy and content knowledge in the context of an anatomy and physiology course. Data were analyzed separately to produce conclusive inferences about each research question. Data were also analyzed in conjunction with each other in order to produce a meta-inference as to the research questions in total. The chosen mixed-method approach to inquiry with the primary goal of completeness and the secondary goal of convergence, combined both qualitative and quantitative forms of research in an effort to derive a more "complete understanding than either quantitative or qualitative data alone" (Creswell, 2014, p. 19) of the effect of the design process on community college Anatomy and Physiology students' self-efficacy and learning.

CHAPTER FOUR: RESULTS

The results of this study are presented in this chapter and are organized by the research question they address. Pursuant to the analysis methods outlined in Chapter 3 of this document, after initial results were realized, results were then combined into a meta-data presentation. Therefore, the final section of this chapter includes combined results that are organized based on total science self-efficacy and each of its theoretical sources.

Research Question #1.

The first research question sought to explore the potential effect of engagement in a design project on undergraduate science student science self-efficacy. In order to deepen understandings, both quantitative and qualitative data were gathered and analyzed.

Quantitative Results

Quantitative data reveal significant changes in sources of self-efficacy as the semester progressed. At the outset of the course, mastery experiences (ME), social persuasion (SP) and psychological and affective states (A) all significantly correlated with total science self-efficacy with SP being the strongest at $r = 0.500$; $p < 0.01$ (Table 5).

Table 5

Means, Standard Deviations and Zero-Order Correlations for Sources of Self-Efficacy and Total Science Self-Efficacy: Baseline Scores

	M	SD	ME	SP	VE	A
ME	3.36	.532				
SP	3.11	.720	**.604****			
VE	3.52	.547	.190	.265		
A	3.90	.425	.295	**.490****	.013	
Total Science 1	3.60	.571	.442	**.500****	.255	**.370***

Note: Means for all variables reflect the five point Likert scale. $^*p < .05$, $^{**}p < .001$

Table 6

Means, Standard Deviations and Zero-Order Correlations for Sources of Self-Efficacy and Total Science Self-Efficacy: Second Set of Scores

	M	SD	ME2	SP2	VE2	A2
ME2	3.32	.540				
SP2	3.18	.626	**.697****			
VE2	3.64	.538	.180	.107		
A2	3.90	.514	.119	-.061	.258	
Total Science 2	3.38	.717	**.474****	.245	.149	-.172

Note: Means for all variables reflect the five point Likert scale. *p < .05, **p < .001

At the time of the first practicum, only ME significantly correlated with total science self-efficacy (r = 0.474; p < 0.01) (Table 6) and at the time of the second practicum, ME, VE and SP all significantly correlated (to the 0.01 level) with total science self-efficacy, with SP again having the strongest correlation at r = 0.537; p < 0.01 (Table 7).

Table 7

Means, Standard Deviations and Zero-Order Correlations for Sources of Self-Efficacy and Total Science Self-Efficacy: Third Set of Scores

	M	SD	ME3	SP3	VE3	A3
ME3	3.27	.629				
SP3	2.95	.765	**.796****			
VE3	3.50	.591	.266	**.351***		
A3	3.95	.539	.322	.161	.270	
Total Science 3	3.38	.856	**.467****	**.537****	**.437****	.092

Note: Means for all variables reflect the five point Likert scale. *p < .05, **p < .001

Among the sources of self- efficacy, ME and SP were significantly correlated to each other in all samples ($p < 0.001$). No other consistent pairing was noted. Paired sample *t*-tests revealed no significant differences among the sources of self-efficacy scores over the semester. Additional correlation analyses indicated significant relationships between ethnicity and total science efficacy #1 ($r = .417$; $p < .01$) and #2 ($r = .375$, $p < 0.05$), prior science classes and VE1 ($r = 0.521$; $p < .01$), school status and SP2 ($r = .336$; $p < .05$), project type and ME2 ($r = .353$; $p < .05$) (see Appendix P, Part 1 for a complete listing of all correlational data associated with research question #1).

Results from MANCOVA did not reveal a significant effect of the design project on total SE or three of its four hypothesized sources (Appendix P, Part 2). However, the impact of the project on psychological states as well as the interaction between the project and psychological states were both statistically significant (Table 8).

Table 8

Significant Impacts of Design Project on Psychological States

Effect		Value	*F*	Hypothesis *df*	Error *df*	Sig	Power	Partial Eta squared
Total A	Wilks' Lambda	.758	3.989	2.000	25.000	.031	.660	.242
Total A*Project	Wilks' Lambda	.664	6.330	2.000	25.000	.006	.859	.336

Note: Data were calculated using alpha = .05.

The multivariate effect for ethnicity was also not technically significant (see Appendix P, Part 2 for a complete listing of MANCOVA ethnicity results) however based on the moderate correlation coefficient found, further pairwise analyses were completed and a significant difference was noted between total self-efficacy of African American students and Caucasian students at the entry of the course (Mean difference = -.946; $p < .05$) (see Appendix P, Part 3 for a complete listing of pairwise results). Regression analyses revealed ethnicity as a consistent predictor of entering student total science self-efficacy. Additionally, the number of prior college science courses taken was revealed as a significant predictor of entering students' vicarious experience source of self-efficacy. Finally, the design project was able to predict total science self-efficacy at the time of the first practicum (Table 9).

Table 9

Significant Predictors of Biological Science Self-Efficacy

Variable	Construct Predicted	β	ΔF	R^2
Ethnicity	TOTSE1	.462	7.226**	.281
Prior College Science Courses	VE1	.521	14.182***	.272
Project ID	TOTSE2	.577	4.665*	.109

Note: Selected regression data are displayed. **p < .01. ***p < .001. See Appendix P, Part 4 for a complete listing of regression results.

When looking for the ability of sources of self-efficacy to predict science self-efficacy, ME and SP were found as significant predictors of total science self-efficacy for entering students. At the time of the first practicum, ME was a significant predictor of total science self-efficacy, and at the time of the second practicum, ME and VE were significant predictors of science self-efficacy (Table 10).

Table 10

Sources of Self-Efficacy as Predictors of Total Biological Science Self-Efficacy

Variable	Construct Predicted	Standardized β	ΔF	R^2	Adjusted R^2
ME1	TOTSE1	.467	9.217**	.195	.174
SP1	TOTSE1	.500	3.567**	.295	.237
A1	TOTSE1	-.528	18.555***	.279	.264
ME2	TOTSE2	.474	11.020**	.225	.204
A2	TOTSE2	-.465	10.784**	.217	.197
ME3	TOTSE3	.467	8.914**	.218	.193
VE3	TOTSE3	.337	4.839*	.323	.280
A3	TOTSE3	-.598	16.173***	.358	.336

Note: *p < .05.**p < .01; ***p < .001.See Appendix P, Part 4 for a complete listing of regression results.

Qualitative Results

Using the self-efficacy codebook (Appendix L), students' statements were organized into the four hypothesized sources of self-efficacy (Bandura, 1997). Following is a description of each source of self-efficacy as it relates to the laboratory experience and a discussion of what students identified as the effect of participation in the design project on each source. Examples of student statements are provided for each category from the open ended student self-efficacy response survey and are identified by participant number.

Mastery experiences. Undergraduate level science classes are traditionally separated into lecture and laboratory sections. The lecture sections are usually dominated by didactic instruction and the lab sections provide opportunity for students to engage in learning the material with more time, in a smaller and more intimate setting and with opportunities for hands on learning and active application of lecture content to laboratory practice. The laboratory was therefore a natural place in which to assign the design project and 83% (*n* = 30) of responding students (regardless of course section or project assigned) reported that the design project provided new and unique opportunities with which to actively involve themselves in their own learning in the lab setting and to extend this opportunity outside of the lab setting as well. Examples of such perceptions are:

> [The bone project] helped me learn because it forced me to research and understand the [ossification] process. (Student self-efficacy response survey, Student #MN37)

> At first I was annoyed and felt that it was a waste of my time, however, it made me really study the tissues and think about them very thoroughly. It actually helped me think thoroughly about the tissues to find something that looked like it and function like it. Also, having to compare them in writing helped to solidify the information. (Student self-efficacy response survey, Student #MN46)

> It affected my confidence in a good way because I had to describe the ossification process in a poem. So I had to research a lot on the subject. Having a better understanding on a topic will always raise my confidence. (Student self-efficacy response survey, Student #MN38)

> Making a haiku help you to relate things in different ways… I looked deeper into the material and the steps. (Student self-efficacy response survey, Student #MN18)

> It [the project] required learning in great detail so it helped a lot... On the next exam I felt comfortable with that subject. (Student self-efficacy response survey, Student #1903)

Using NVivo to analyze the word frequencies found within the material coded for mastery experiences and present the result in a word cloud, the result is that students reported that the project helped learning and understanding. The bone project was more prominent than the tissue project, however both were represented (Appendix R).

Social persuasion. The maximum number of students who may participate in lab at the school where this study took place is 24. In addition, the seating arrangements in this forum are in tables of four, with students facing each other. Thus, the surroundings are more conducive to discussion and interaction and therefore a place where meaningful social interaction is supported. However, college students do not always decide to engage during the lab period. The intent of the design project was to encourage students to discuss the possible project solutions among their cohorts and also with their professor. Some students (n = 5) reported that they did indeed find support from the learning environment, but all of these reports specifically cited the professor and not the classmates:

> I wasn't sure that I would be successful. One of the reasons I decided to continue was that my professor is very encouraging. S(he) is very enthusiastic … and that makes me feel excited about learning the material. (Student self-efficacy response survey, Student #N48)

> I perform well when I enjoy the teacher, that they make class interesting but also challenges you. The professor challenges you but encourages is the best environment. (Student self-efficacy response survey, Student #MN46)

For the college student, the learning that occurs outside of the classroom, though, is oftentimes more significant that in the learning environment (Coppola & Krajcik, 2013). Only three students reported the design project being the stimulus to extend this learning by interacting with people in their sphere of influence outside of the classroom and one such report is represented below:

> I showed two relatives the pictures of the tissues and asked them to tell me what they thought they resembled. We then discussed the tissues and I explained the three that I

chose. (Student self-efficacy response survey, Student #N48)

Word frequency analysis performed through the use of NVivo within the node of SP shows a wider variety of prominent words. The tissue project is noteworthy and the students associated the idea of thought with social persuasion. In addition, there are associations with many different people like relatives, the teacher and students, no reference to confidence, and the word lab fits prominently in within this node (Appendix S).

Vicarious experiences. Students were encouraged to discuss and plan their design projects together. Each professor budgeted time in lab for students to bring in the projects as they were in progress so as to continue working on them, thus encouraging vicarious experiences among peers. Few students took advantage of this opportunity, even though 39% of the total group (n = 14) reported the need for visualization opportunities and group learning:

> I do well when I have the opportunity for "hands on" in a classroom with others that are doing well, where the teacher explains in detail what we are learning and where real examples that I can touch or see are given. (Student self-efficacy response survey, Student #1910)

> I perform better with visual examples and hands on learning. (Student self-efficacy response survey, Student # MN31)

Professors reported observing a total of two students bringing their projects in to work on during dedicated time in lab. Other students chose to leave or study other material during this time. It was not surprising when students reported choosing to work alone outside of class, despite being given time to do the opposite while also acknowledging that the project was "interactive and fun":

> I took several days [outside of class] to prepare what I was going to write… I was able to

> really breakdown the process and teach myself. (Student self-efficacy response survey, Student #1917)
>
> I perform well when there are a lot of interactions in the class… I took three days to complete it [outside of class]. (Student self-efficacy response survey, Student #1946)

Thematically, word frequency analysis within the VE node (as displayed in the form of a word cloud by NVivo) centered on the actions of explaining, examples and the teacher for learning in biological sciences with no references to the project or confidence (Appendix T).

Psychological states. Students wrote about many sources of anxiety when it related to the Anatomy and Physiology lab experience. These sources included, but were not limited to, lack of creativity or artistic ability, lack of time (both in and out of class), applicability of the project to what was being learned in lab, and a variety of other external life factors.

When it came to the design project, only 14% of students (n = 5) reported concern that their lack of creativity or ability to "think out of the box" would hinder their ability to succeed:

> I did not want to do anything too crazy and distract from the poem. (Student self-efficacy response survey, Student #1917)
>
> It was tough for me because I am not good at thinking outside the box – I felt it was irrelevant to the class because I just do not process things in that manner – it wasn't for me. (Student self-efficacy response survey, Student #MN14)
>
> I have no artistic ability. (Student self-efficacy response survey, Student #N38)
>
> I'm concerned that my lack of creativity will negatively impact my grade. (Student self-efficacy response survey, Student #1931)

Other students (n = 4) expressed concern about the transferability of the project to any demonstration of learning required by the practicum:

> I think I did well on the project and that gave me some confidence but a project and tests are two different things. (Student self-efficacy response survey, Student #1946)

> I wasn't exactly sure why we even did it. The project and the relationship to the material were ok. Although I really thought there was so much more to tell than the project allowed. (Student self-efficacy response survey, Student # 1928)

The researchers agreed that three other themes were apparent when students were talking about the Anatomy and Physiology lab in general and the project in specific: time, hands on learning, and confidence about taking the practicum. Many students in all sections cited time as a concern for being confident about success on the project and in the class. A small representation (n = 4) saw the project as something to be added on to the burden of studying rather than a vehicle through which deeper understandings may be achieved. The concerns are revealed below:

> I wasn't fond of the idea of the fact that I had to spend extra money or time completing something … [like the design project] (Student self-efficacy response survey, Student #MN25)

> This [project] took more time than I expected…. (Student self-efficacy response survey, Student #1900)

> … I [initially] thought this was a waste of time… (Student self-efficacy response survey, Student #MN46)

> I was worried because I had less time to study for this practical… (Student self-efficacy response survey, Student #MN46)

Conversely, 10 students (28%) specifically discussed how they found the time spent in learning the material in a different way a valuable endeavor, and even credited the project as making their time learning more efficient:

> I was able to learn the ossification process much faster this way… (Student self-efficacy response survey, Student #1917)

> It took time to think about the tissues… and it helped me to correlate the relationship between structure and function… several weeks have passed and I still remember the highlights of the tissues… (Student self-efficacy response survey, Student #N48)

The word frequency analysis and subsequent word cloud highlights higher confidence in the second practical and the prominence of studying as companion to these themes. Expectations were also a significant part of the themes in this node with no specific references to either project. However, the words creativity, poem and project were associated with psychological states (Appendix U).

Cluster analysis, through the use of NVivo software, revealed that students who made reference to mastery also made reference to "hands on learning" and the concept of time (Figure 3).

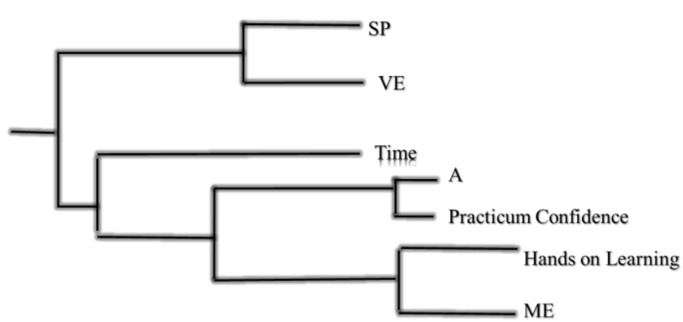


Figure 3. Dendogram showing the statistical correlational relationships among coded notes, on the basis of word similarities.

Having sufficient time to actively participate in learning equated to mastery for these students and the project helped many of them to achieve these criteria, although many of them confined their engagement in the project outside of class, where they felt more pressed for time and were directly involved in many anxiety-producing elements of life that are hallmarks of many community college students (NSF, 2013):

> I didn’t study… I just found out my 7-year old sister had cancer. (Student self-efficacy response survey, Student #1935)

> I perform well when I actually have time and am not stressed out by an almost full time job and full time classes. (Student self-efficacy response survey, Student #1921)

> I was worried… I had less time to study with balancing school, work, etc. (Student self-efficacy response survey, Student #MN46)

Interestingly, over half (58%) of the students (n = 21) articulated anxiety directly related to the unfamiliarity of the first practical as opposed to the second, with no reference to the project, as represented below:

> The first lab practical I was uncomfortable but only because I didn’t know what to expect. The second I knew what I was to expect and how to better study. (Student self-efficacy response survey, Student #N27)

> The first lab practical was somewhat intimidating because I had never taken a lab practical before and I wasn’t sure of what questions would be asked and how they would be asked. I felt more confident taking the second practical. (Student self-efficacy response survey, Student #N48)

> I was more nervous for the first one, then saw it was something I could do. (Student self-efficacy response survey, Student #1923)

> I was calmer for the second lab practical however I was still worried…I was extremely nervous for the first one because I had no idea what to expect…Experience is what made me calmer for the second. (Student self-efficacy response survey, Student #MN46)

Cluster analysis (when considering by word similarities in each coded item) placed psychological states in a branch closest to statements about practicum confidences. The concept of hands on learning as mentioned by students was more closely associated with mastery experiences; social persuasion and vicarious experiences were most closely related to each other (Figure 3). However, when comparing by coding similarities, NVivo placed hands on learning and practicum confidence squarely together in a branch separate from the sources of self-efficacy. Vicarious experiences were less associated with the other hypothesized sources and mastery experiences was most correlated with psychological states and secondarily correlated with social persuasion (Figure 4).

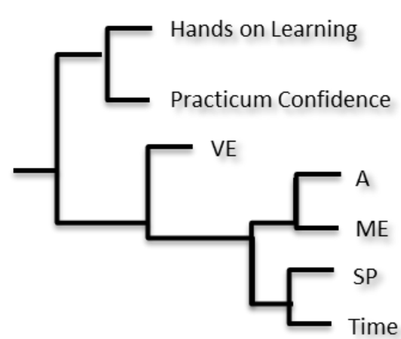


Figure 4. Dendogram showing the correlational relationships among coded notes, on the basis of research team coding similarities.

Research Question #1 focused on understanding to what extent that the design approach to teaching and learning the content of Anatomy and Physiology in the undergraduate community college laboratory result in changes to students' biological science self-efficacy.

Quantitative and qualitative results were inconclusive when it came to identifying any specific effects of the design process on student self-efficacy or its hypothesized sources. Both sets of results, however, supported self-efficacy theory in that mastery was identified as the most significant, consistent source of self-efficacy. In addition, the effects of the hypothesized sources of self-efficacy on each other were noteworthy and support other researchers' findings (Brand & Wilkins, 2007; Britner & Pajares, 2001).

Research Question #2

In order to fully evaluate the effect of student participation in the design project, additional quantitative data were gathered to explore changes in student content knowledge, as evidenced by overall practicum grades, grades on common test questions included in each practicum, and project grades. Means, standard deviations and zero-order correlations are reported in Table 11. No significant correlation was noted between the project type and any of the measures of content knowledge. In fact, the correlation coefficients that were reported may be interpreted as "zero" to weak correlations. The project grade was significantly correlated with practicum #2 and its companion common questions which were, not surprisingly, significantly correlated to each other. Similarly, there was a moderate-strong significant relationship between practical #1 and its companion common questions however no significant correlation with the design project or project grade was noted. Multivariate analysis of variance revealed no significant multivariate effect for project type on any of the measures of content knowledge (Table 12).

Table 11

Means, Standard Deviations and Zero-Order correlations for Variables in the Study, Research Question #2

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Total Science Efficacy	18.1	3.03	_																	
2. SE 2	17.1	3.49	**.413****	-																
3. SE 3	17.2	4.2	**.627****	**.621****	-															
4. Practicum #1	76.4	12.6	-0.03	**.315***	0.22	-														
5. Common questions	3.88	0.94	0.16	**.336***	0.05	**.639****	-													
6. Practicum #2	77.9	16.2	0.03	0.16	0.18	**.417****	0.07	-												
7. Common Questions 1	3.56	1.28	-0.08	**.359***	0.05	**.518****	**.332***	**.499****	-											
8. Common Questions 2	2.56	2.4	0.07	**.403****	0.24	0.22	0.09	**.444****	0.23	-										
9. Project Grade	81.7	20.3	0	0.1	-0.12	0.19	0.1	**.338***	**.289***	**.348***	-									
10. Age	1.9	1.91	-0.03	0.08	0.12	-0.11	-0.03	0.1	-0.02	0.14	0.11	-								
11. Ethnicity	1.83	0.94	**.417****	**.375***	0.27	0.05	0.2	0.15	0.16	0.26	-0.01	-0.17	-							
12. School Status	0.5	0.51	0.19	-0.04	0.13	-0.11	-0.12	-0.13	**-.350***	0.1	-0.15	-0.25	**.309***	-						
13. Prior Science	1.02	0.96	0.01	0.12	0.25	0.1	0.02	-0	0.01	-0.15	-0.09	0.2	-0.19	-0.26	-					
14. Prior Art	0.31	0.56	-0.05	-0.12	-0.07	-0.02	-0.01	-0.01	0.11	-0.19	0.04	-0.22	-0.01	0.07	-0.05	-				
15. Gender	0.12	0.32	-0.12	0.16	0.02	0.15	0.11	-0	0.08	-0.07	-0.03	0.11	0.07	-0.24	0.18	-0.09	-			
16. Project Type	1.65	0.48	-0.02	0.16	0.06	0.06	0.13	-0.21	-0.03	0.06	0.12	-0.04	-0.18	0	0.06	-0.24	0.01	-		
17. Professor	1.63	0.49	-0.04	0.16	-0.1	-0.19	0.04	0.09	0.02	-0.15	0.02	**.278***	0.03	**.359****	0.14	-0.15	-0.1	-0.13	-	
18. Course code	1.31	0.98	0.12	-0.19	-0.08	-0.26	0.06	0.01	-0.23	-0.13	0.04	**.277***	0.02	0.04	0.16	-0.21	-0.24	-0.19	**.405****	.-

Note: **Correlation is significant at the .01 level (2-tailed); *Correlation is significant at the .05 level (2-tailed)

Table 12

Multivariate Effects of Design Project on Measures of Content Knowledge

Effect		Value	*F*	Hypothesis *df*	Error *df*	Sig	Partial Eta squared	Noncent. Parameter	Observed Power
Project Type	Wilks' Lambda	.868	1.190	6.000	47.000	.328	.132	7.143	.421

Note: Measures on content knowledge included: Practicum #1 scores, five common tissue question scores (associated with practicum #1), Practicum #2 scores, five common bone question scores (associated with practicum #2), five common ossification question scores (associated with practicum #2), and project grade. Significance computed using alpha = 0.05.

Results reveal inconsistent indicators of project impact on measures student content knowledge. Project grade was significantly correlated with practicum #2 and its corresponding common questions, irrespective of professor, but this was not the case for project grade and practicum #1 and its common questions. Significant correlation was not found between the type of project and measures of content knowledge (Table 11).

Regression analyses indicated that project type was a reliable predictor of total self-efficacy measure #2. In addition, project grade was a reliable predictor of ME measure #2 and scores on practicum #2 and both sets of its associated common questions. No other significant predictive relationships were noted (Table 13).

Table 13

Predictors of Self-Efficacy and Content Knowledge

Variable	Model 1			Model 2		
	Standardized β	ΔF	R^2	Standardized β	ΔF	R^2
Practicum #1	.067	.235	.005	.170	1.516	.033
Common Questions: Tissue	.106	.596	.011	.102	.538	.022
Total SE 2	.335	**4.941***	.112	-.085	.007	.120
ME2	.060	.139	.004	-.325	**4.495***	.109
SP2	-.041	.066	.002	-.229	2.012	.054
VE2	-.118	.549	.014	-.007	.002	.014
A2	-.172	1.183	.029	.184	1.373	.063
Practicum #2	-.224	2.758	.050	.356	**7.752****	.176
Common Questions: Bone	-.054	.151	.003	.292	**4.722***	.087
Common Questions: Ossification	.067	.235	.005	.345	**6.857***	.122
Total SE3	.075	.164	.006	-.079	.178	.012
ME3	.304	2.943	.092	-.096	.284	.101
SP3	.183	1.000	.033	-.025	.019	.034
VE3	-.215	1.401	.046	-.116	.397	.059
A3	-.299	2.844	.089	.138	.593	.108

Note: *N* = 54; Model 1 = Project Type; Model 2 = Project Type, Project Grade; *p < .05; **p < .01

Research question #2 was concerned with the effect of the design approach on student content knowledge in the undergraduate, community college Anatomy and Physiology laboratory environment. Results indicate short-term exposure to design projects are not sufficient for establishment of improved content knowledge.

Combined Data

In keeping with the analysis procedures outlined by Onwuegbuzie and Teddlie (2003), all data were considered in concert with one another in order to ultimately create one combined data set from which to draw inferences. Following are the results from this consolidation, presented by total self-efficacy and each of its hypothesized sources.

Total Science Self-Efficacy

Results from regression analysis gave no indication that total self-efficacy or any of its hypothesized sources were significant predictors of any of the measures of content knowledge used in this study (Table 14).

Table 14

Regression Statistics for the Prediction of Content Knowledge

Variable	Construct Predicted	Standardized β	ΔF	R^2
Total Self-Efficacy 2	Practicum #1	.246	2.502	.060
	Common Questions: Tissue	.265	2.936	.070
	Project Grade	-.066	.173	.004
Total Self-Efficacy 3	Practicum #2	.276	2.392	.076
	Common Questions: Bone	.075	.162	.006
	Common Questions: Ossification	.253	1.992	.064
	Project Grade	-.075	.163	.006

Note: Selected regression data are displayed and none were significant where $p < .05$.

Sources of self-efficacy changed throughout the semester. For this predominately Caucasian, female population, the dominant source of self-efficacy upon entry into the course was social persuasion (SP) ($r = .500$, $p < .001$). A significant, but weaker source of self-efficacy that contributed to overall science self-efficacy upon entry into the class was psychological states (A) ($r = .370$, $p < .05$). In addition, SP showed a moderate, positive correlation with both mastery experiences (ME) and psychological states ($r = .604$ and $.490$, $p < .001$, respectively). These sources of self-efficacy changed after two of the four lab sections engaged in the design process through being assigned the tissue project. The only source of self-efficacy that significantly correlated with total science self-efficacy at the time of the first practicum was ME ($r = .474$, $p < .001$). Interestingly, the correlation between ME and SP strengthened at this time ($r = .697$, $p < .001$) and no significant correlation between ME and A, ME and VE, SP and A, or SP and VE were noted. Qualitative data support the correlation of SP with the Tissue project, and thus the first practicum, as revealed in the word cloud (Appendix S) and also support a closer relationship between ME and SP as seen in Figure 4.

After the remaining students completed the second design project (bone), the sources of self-efficacy again changed to show significant impacts of ME ($r = .467$, $p < .001$), SP ($r = .537$, $p < .001$) and VE ($r = .437$, $p < .001$) on total science self-efficacy. An even stronger correlational relationship between ME and SP was revealed ($r = .796$, $p < .001$) and a new, significant relationship between SP and VE appeared ($r = .351$, $p < .001$). A repeated-measures MANCOVA was used to tease out the specific interactions among these sources of self-efficacy and total self-efficacy at the time of the first and second practicum. It was first determined, through using Levene's test for homogeneity that there was indeed a variance between groups as a result of the project. Knowing this, MANCOVA was used to determine if the effect shown by each source of self-efficacy still manifested itself when controlling for the project type. In both cases, the answer was no. The project had a statistically significant effect on only one source of self-efficacy (psychological states) and no statistically significant effect on total self-efficacy (Table 15).

Table 15

Effects of the Design Project on Total Self-Efficacy and its Hypothesized Sources

	Wilks' Lambda Value	F	Partial Eta Squared	Observed Power
Total SE	.987	.170	.013	.073
Total SE (holding all variables constant)	.999	.013	.001	.052
Total ME(holding all variables constant)	.919	.795	0.81	.164
Total VE(holding all variables constant)	.984	.145	.016	.069
Total SP(holding all variables constant)	.979	.195	.021	.076
Total A(holding all variables constant)	.625	**5.410***	.375	.776

Note: Calculations were completed using alpha = .05 in repeated measures MANCOVA. *p < .05.

When no other study variables were held constant, it appeared that total self-efficacy decreased throughout the semester, with larger decreases noted when students were not engaging in the design project. Remembering that the investigative context is filled with many possible confounding variables, repeated measures MANCOVA was again used to isolate the potential effects of the project when all other identified independent variable interactions were held constant. In reality, therefore, the influence of the project on science-self efficacy was more impactful for the first project group than the second. In addition, the drop in self-efficacy was more drastic for the first project group when they had no design task than the second, when they did. Remembering that qualitative results indicated that students specifically associated reduced anxiety during the second practicum (Appendix U) and a clear association between ME and improved learning and confidence (Appendix R), repeated measures MANCOVA analysis was used to not only hold constant the independent variable impacts but also all impacts from each hypothesized source of self-efficacy. These results are also not considered statistically significant (Table 15), although the isolated effects on total self-efficacy can be clearly revealed when graphing the results and the data trends become clear (Figure 5). For students who were involved in the tissue project, increases in self-efficacy were noted, whereas in the comparison group, drops in total self-efficacy occurred. It was at this time that the project became a significant predictor of total self-efficacy ($F = 4.665$, $\beta = .331$, $R^2 = .109$, $p < .05$). Subsequently, when students involved in the tissue project did not participate in the design task, their self-efficacy decreased; students who engaged in the bone project at this time showed further drop in total self-efficacy, however, not to the same level as noted at the first practicum. At this time, the design project was no longer a significant predictor of total SE.

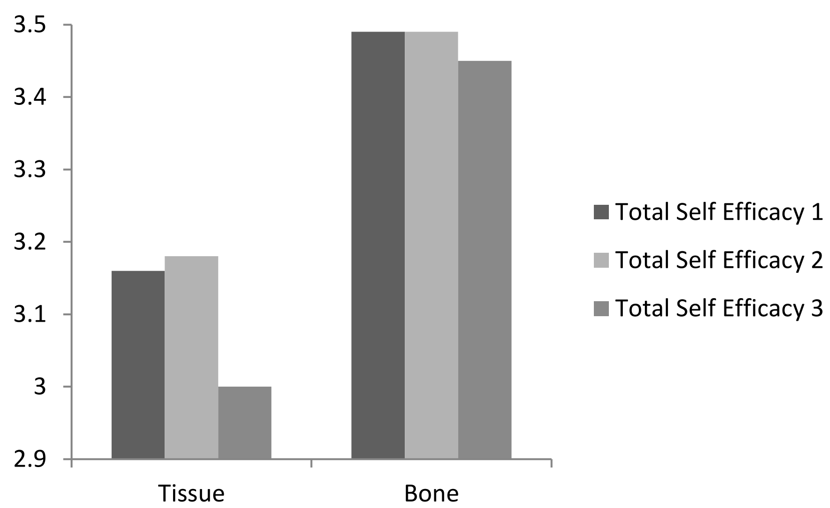


Figure 5. Effects of the design project on total science self-efficacy for the two different project groups as determined by MANCOVA analysis.

Mastery Experiences

Regression analysis showed that mastery experiences were not reliable predictors of any of the content knowledge measures used in the study (Appendix L). For both treatments, mastery was significantly, positively correlated with total science efficacy and social persuasion (See Appendix P, Part 1 for highlighted correlation data). In fact, in the case of the second design project, the effect of ME and SP was considered significant, as determined by ANCOVA analysis ($F(2,31) = 5.854$, $p = .019$, $R^2 = .881$)(Appendix V). The effect of the project on total ME was isolated using repeated measures MANCOVA and was not significant (Table 15). When graphing the data trends, it became clear that mastery experiences (Figure 6) trended similarly to what was observed in overall SE in that when the project was being completed, it was associated with higher levels of both mastery and total SE in the treatment group than in the reference group. These observations are supported by qualitative data which indicate that students identified participation in the project as opportunity to positively affect ME and as revealed by word frequency analyses (Appendix R). In addition, these results are supportive of information that pervades in self-efficacy theory (Bandura, 2007) demonstrating ME as the most impactful hypothesized source of self-efficacy on overall SE.

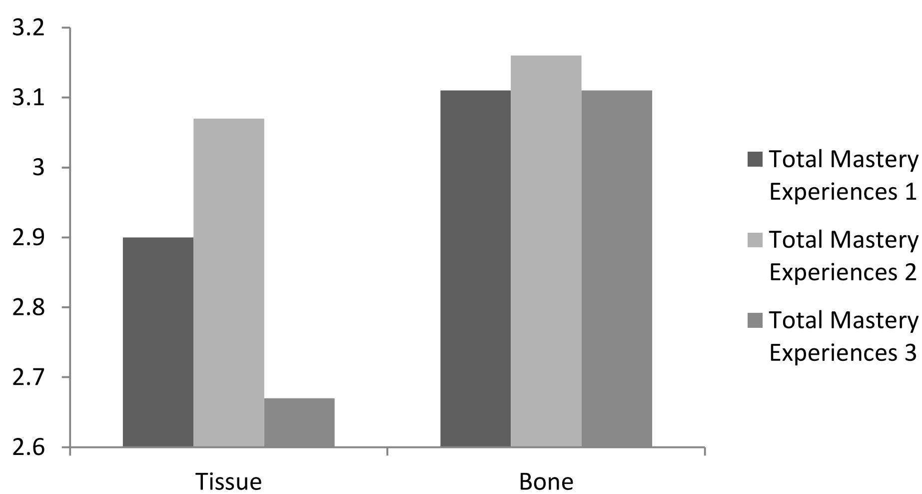


Figure 6. Effects of the design project on total mastery experiences (ME) for the two different project groups as determined by MANCOVA analysis.

Vicarious Experiences

Vicarious experiences were significantly correlated with total science self-efficacy in the case of the second lab practicum only ($r = .437$, $p < .001$). In addition, it is only during this time that a significant correlation with SP was noted ($r = .537$, $p < .001$). No significant multivariate effect was noted between the project and VE (Table 15) however, regression analysis revealed the significant predictive power of VE to total self-efficacy for all students, as previously reported in the results section of this document ($F = 4.839$, $p < .05$, $\beta = .337$, $R^2 = .323$). When combining all data, regression analysis did not show VE as a predictor of any of the content knowledge measures used in the study (Appendix L). When comparing the trends as shown on the graphs, the group who participated in the tissue project had much wider differences in VE

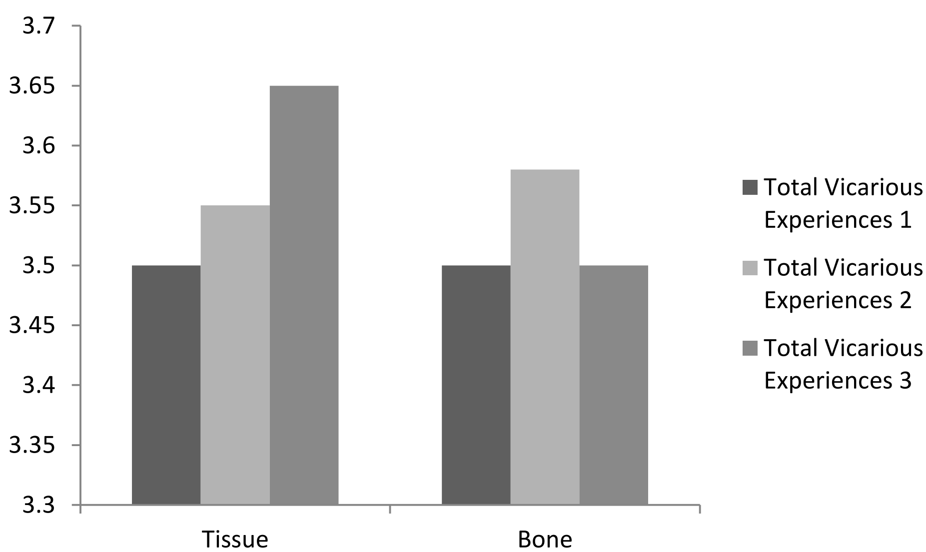


Figure 7. Effects of the design project on vicarious experiences (VE) for the two different project groups as determined by MANCOVA analysis.

with a downward trend throughout the semester and the exact opposite is noted for students who participated in the bone project (Figure 7). Finally, lower VE trended with higher SP, in general, for each project group.

Social Persuasion

Repeated measures MANCOVA did not show a statistically significant effect of the design project on SP (Table 14). Nor was there a significant effect of SP on any measure of content knowledge (see Appendix Q for a display of all regression results that predict measures of content knowledge by total self-efficacy and its hypothesized sources). However, remembering that there was a strong correlation between ME and SP for the tissue project ($r = .697$, $p < .001$), MANCOVA was used to test for the isolated effect of the first project on SP ($F (1, 37) = 3.585$, $R^2 = .506$) and was assigned a significance of 0.06 with an observed power of .5. While this statistic is not strictly interpreted as significant, considering the power and the relative small sample size, the effect should be considered, especially in light of qualitative findings whereby students articulated opportunities for meaningful interactions with their professor, relatives, and other students as necessary for performance, thinking, and learning (Appendix S). When graphically depicted, repeated measure MANCOVA results for SP (Figure 8) are similar to the trends seen for ME and VE.

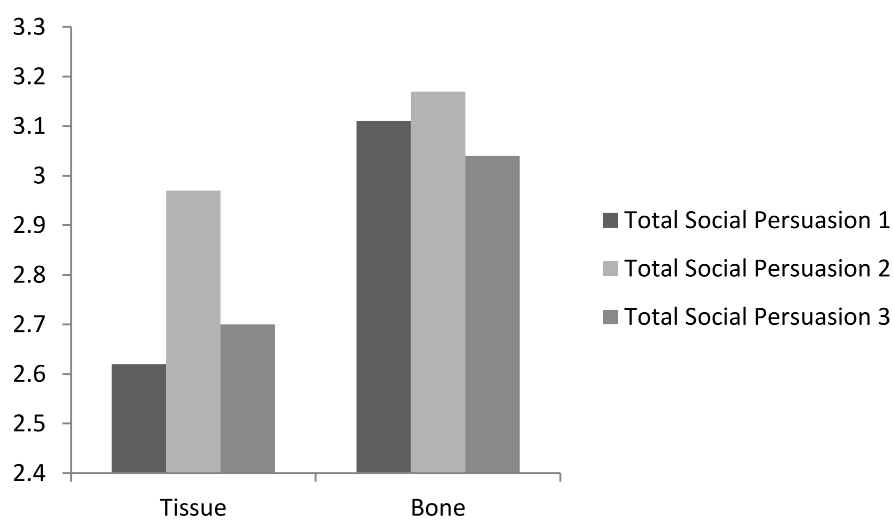


Figure 8. Effects of the design project on student perceptions of social persuasion (SP) for the two different project groups as determined by MANCOVA analysis.

Further investigation of the isolated effect of the project on SP using MANCOVA revealed no significant differences in project groups (Table 15). Finally, SP was shown to have no significant predictive effect on any of the measures of content knowledge used (Appendix L).

Psychological States

Qualitative results identified the presence of heightened psychological states (A) in the students being studied. In an effort to clarify the sources and nature of A, regression analysis was used to determine if the design project was a significant predictor of A, if A was a significant predictor of any measure of content knowledge (Appendix L) and if A was a significant predictor of total SE. Regression analysis did not show A to predict the outcomes on any of the content measures used in the study (see Appendix Q for a display of all regression results that predict measures of content knowledge by total self-efficacy and its hypothesized sources). The effect of the design project on total A, however, was significant ($F = 5.410$, $p < .05$, $\Lambda = .6725$, $\eta^2 = .375$, $1- \beta = .776$). Regression analyses showed A as being predictive of total SE across the study period (Table 16).

Table 16

Psychological States as a Predictor of Self-Efficacy

Variable	Model 1			Model 2		
	Standardized β	ΔF	R^2	Standardized β	ΔF	R^2
Total SE 1	-.164	1.327	.027	-.517	16.649***	.281
Total SE 2	.335	4.941*	.112	-.420	9.096**	.284
Total SE 3	.075	.164	.006	-.632	16.185***	.370

Note: Model 1 included the design project only. Model 2 included the design project and A. *p < .05; **p < .01***p<.001

In addition, the negative standardized β values indicate the inverse nature of the relationship between A and Total SE. Finally, R^2 values, indicate that A accounted for more variance in the case of SE3 versus the other two measures, despite students reporting that they were more anxious during the first practicum versus the second. The group that was exposed to the tissue project demonstrated lower anxiety at the first practicum and an increase in anxiety at the second when they did not participate in a project (Figure 9).

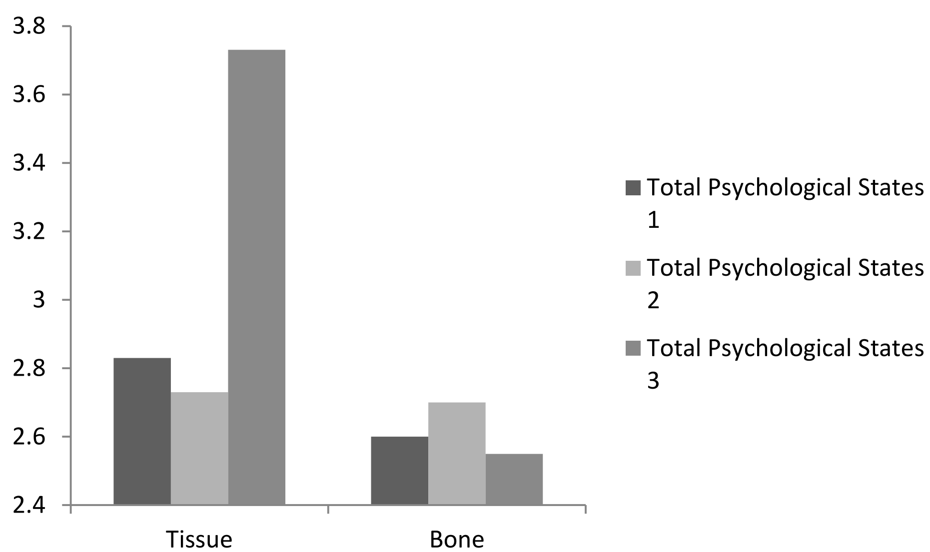


Figure 9. Effects of the design project on total differences in psychological states (A) for the two different project groups as determined by MANCOVA analysis.

Of specific interest was the amount that reported anxiety went up for the tissue group as compared to the bone group before the second practicum. No statistically significant differences between individual treatment groups were noted from a subsequent ANOVA analysis (Table 17).

Qualitative analyses revealed strong anxiety states reported with the first practicum as opposed to the second (Appendix U). Students indicated that their comfort level was greater with the second practical since they had completed one already and knew what to expect.

Table 17

Differences Between Treatment Groups With Regard to Psychological States

	SS	*df*	*MS*	*F*	Significance
Total A	1.915	1.49	1.915	2.335	.133
Total A2	1.155	1.40	1.155	1.183	.283
Total A3	2.889	1.30	2.889	2.844	.102

Note: The ANOVA table shows results between groups. Calculations used alpha = .05.

When using NVivo to determine similarity across nodes in terms of word usage and researcher coding, the results were similar. The results from ME and A appeared as sister branches off of the same trunk. Interestingly, when clustered by coding similarity, SP was situated off of the same branch as ME and A, which is consistent with the quantitative results described above, and vicarious experiences were less related to the others. When analyzing the actual word similarities used by students in the nodes, SP and VE were grouped together as a part of the same trunk, separate from the trunk which housed ME and A (Figure 10b.). This dendogram is supportive of the sources of self-efficacy descriptions found throughout self-efficacy theory (Bandura, 2007).

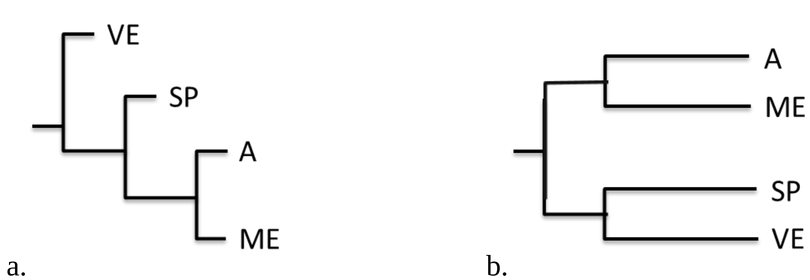


Figure 10. Comparison of dendograms indicating nodes clustered by coding similarities (a) and clustered by word similarities (b).

Summary of the Combined Results

Results reveal mixed effects of the design process on total biological science self-efficacy but clear data about the effect of the design process on measures of content knowledge. Data were consolidated in an effort to create one combined data set that could be considered together and then compared with the goal of drawing inferences from the consolidated data. Overall, the design project was determined to have interaction effects on total self-efficacy and each source of self-efficacy, however not with any of the measures of content knowledge. When interaction effects were not held constant, the project was associated with a minimal drop in total self-efficacy for the treatment group; conversely, the reference group experienced a much greater drop in total self-efficacy. However, when all interaction effects were held constant, completion of the tissue project was associated with improved total self-efficacy and completion of the bone design project was associated with decreased self-efficacy.

Results revealed clear interaction effects between all sources of self-efficacy and for this group, the correlational link between ME and SP was especially prominent throughout the study. Finally, the influence of psychological states was revealed to be impactful *against* the positive effects of the other sources. In fact, qualitative data draws the researcher's eye toward the specific effects between A and ME.

CHAPTER FIVE: CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

This chapter presents the conclusions for each research question that result from the previously discussed findings. Combined results were triangulated to result in a final, meta-inference for the study and is presented as such. Implications and recommendations for the educator follow conclusions.

Research Question #1

Research question #1 was concerned with exploring to what extent the design approach to teaching and learning the content of Anatomy and Physiology in the undergraduate, community college laboratory results in changes to students' biological science self-efficacy. Both quantitative and qualitative data were gathered using the Sources of Biological Science Self-Efficacy Scale, the Science Self-Efficacy Scale, Demographic survey, and Sources of Self-Efficacy Survey. Resultant data were considered separately and then together toward the primary goal of completeness (O'Cathin, Murphy & Nicholl, 2010; Shih, 1998).

- Design projects used in this study did not have a consistent meaningful effect on total self-efficacy. Repeated measures MANCOVA and multiple regression analyses results were performed using quantitative data to determine possible effects of the project on total science self-efficacy and each of its hypothesized sources (see Appendix P, Part 2 and 3 for a complete listing of all MANCOVA and regression data associated with research question #1) . Project effects, while statistically present, were not considered statistically significant on total self-efficacy (SE), mastery experiences (ME), vicarious experiences (VE) or social persuasion (SP). The design projects, when considered collectively, were considered a statistically significant predictor of total SE2, as measured at the time of the first practicum (see Appendix P, Part 4b).

- A majority of participating students (83%), when asked in an open-ended, student self-efficacy response survey (see Appendix K for a copy of the response survey), stated that the design project was a meaningful context in which to actively apply knowledge and deeply learn content, thus master the material. Cluster and word frequency analyses of these same data converged to link student described "hands on learning" with overall "mastery", all closely aligned with "practicum confidence". Qualitative results therefore lead to the conclusion that by engaging in the design project students may experience meaningful, positive effects on total self-efficacy most likely though increased mastery experiences.
- When considering statistical results in light of the small sample size, in combination with data trends and qualitative results, it is reasonable to conclude that impacts of the design projects align with improvements in ME, especially for the students who were involved in the tissue project. For these students, total self-efficacy increased with the project, as did ME; similarly, both of these measures dropped without the project. Additionally, the design project was found to be a significant predictor of total self-efficacy at this time (see Appendix P, Part 4b), which, in turn, was only significantly correlated with ME ($r = .474$, $p < .001$) For those involved with the bone project, self-efficacy dropped, but dropped less when timed with the project completion. Quantitative data linked the tissue projects with mastery experiences, and qualitative data converged at this point by linking both projects to mastery (see Appendix R). As in many other investigations that have shown mastery to be the biggest contributor to self-efficacy with many different student populations and in many academic areas (Bandura, 2007; Lent et al., 1991; vanDinther, Dochy & Segers, 2011), these results

again reiterate the importance of mastery experiences in science, extend this importance specifically into a biological science, and, more specifically, an Anatomy and Physiology context.

Research Question #2

The second research question guided the researcher to seek understanding about the potential effect(s) of the design approach on undergraduate, community college students' content knowledge in Anatomy and Physiology. Several sources of data were used as indicators of content knowledge and included practicum scores (percentages), scores on corresponding common questions, and grades (percentages) on the completed design project.

- Quantitative data were not sufficient to document significant impacts by the design approach on undergraduate, community college students' content knowledge in Anatomy and Physiology. Analytical results from repeated measures MANCOVA and multiple regression procedures failed to establish an effect or a predictive value of the design projects on measures of content knowledge used in this study. Thus, one is led to conclude that the design project was not helpful for students when it came to improving content knowledge. These results are similar to other investigations in the context Anatomy and Physiology whereby stronger self-efficacy did not resulted in higher measures of academic success (Burgoon et al., 2012).
- Students questioned the value of completing the project, despite admitting the alignment with course objectives, as revealed in qualitative results. Perhaps their lack of buy-in translated into little to no correlation with this study's measures of content knowledge. Looking beyond self-efficacy theory may be useful in understanding this outcome. Expectancy-value theory leads one to realize that if someone does not

value the task at hand, the completion of that task may not happen or may not be completed using a standard of excellence (Battle, 1965, 1966; Eccles et al., 1983). Therefore, the task, no matter how valuable in the professor's eyes, will not be valuable in the student's eyes. Lowanto & Stewardson, when evaluating students' interest and expectancy for success when engaged in design activities found that task value was a significant predictor of student expectancy for success (2011). In addition, students "were more intrinsically motivated to engage in a design activity that involves a predictive analysis than a creative approach" (Lowanto & Stewardson, 2011, p. 213). Based on this knowledge, it is reasonable to expect, therefore, that the self-efficacy of a student who has little background in creative approaches and who questions the value of such a project would not increase, as noted in these results.

Meta-Inference

The data from research question #1 and #2 were merged into one data set and all data were analyzed together using statistical triangulation with the goal of more fully understanding the interactions of the design project, self-efficacy and content knowledge.

- Combined quantitative data lead to the conclusion that, within the context of undergraduate Anatomy and Physiology laboratory in the community college that is predominantly (86%) female, mastery and social persuasion are of equal importance when it comes to influencing total biological science self-efficacy. Correlation data discussed in Chapter Four show that over the course of the study, social persuasion was increasingly tied with mastery experiences while also showing a statistically significant correlation to total SE (see Appendix P, Part 1 for all highlighted, significant correlational data). These results are supportive of a prior study which identified SP as a more significant source of self-efficacy for females than for males in an undergraduate science course (Zelden & Pajares, 2000). In addition, this research study supports conclusions made by Brand and Wilkins (2007) whereby mastery experiences may, in fact, "exist as a function of the other three" (p. 313). Certainly, in this case and in this context, data indicate that ME may exist at least as a function of SP.

- For community college undergraduates, psychological states may be more impactful on total self-efficacy than for other students in other learning contexts. Regression data support this conclusion, as A was the only consistent predictor of total SE throughout the study (see Appendix P, Part 4 for a complete listing of all regression data). Despite identifying the design opportunities as important to success and supportive of their self-stated desire for "hands-on" and "interactive" learning opportunities, all but two students opted to do most of the work on the project outside of the laboratory environment despite having ready access to their cohort and professor as well as a dedicated block of time in which to work. This behavior aligns with the assertions made by Coppola and Krajcik (2013) that the classroom is not necessarily the most impactful place for the undergraduate student. However, the effect of the life stressors that are hallmark characteristics of the community college student who is also less prepared for the rigors of college coursework (NSF, 2013) may have interfered more prevalently in the learning process as the students tried to manage learning on their own. Students did not indicate their experiences working on the design project as being influenced by overall perceived self-confidence. They did, however, report anxiety about the project, about having enough time to complete the project, and about having not enough ability to do well with the project. A majority of students (58%) also reported concern about the expectations of the practicum and the process which was used to participate in the performance-based test.

- Quantitative and qualitative data converge by showing strong relationship between ME and A. Data trends for students with a project, as revealed in graphical representations presented in Chapter 4, showed mastery experiences improving as psychological states decreased and the reverse being true for students without a project. The task of applying knowledge outside of the learning context, such as in design-based learning may be an anxiety-provoking endeavor. However, as these students reported, pushing through the problem resulted in their perception of improvement. If opportunities to engage in a design task would become more available throughout the semester, rather than only one time, students, as they successfully navigate through the task, may potentially improve personal development of a “resilient sense of efficacy” (Bandura, 1995, p. 3) and perhaps have a more notable effect on total self-efficacy. Thus, it is reasonable to conclude that the opportunity to engage in a design project with an artistic outcome may be a way to not only improve ME but also lower A.

Implications and Recommendations

The results of this study have direct implications for the STEM/STEAM educator within Biological Sciences, and for the field of integrative STEM education. Improved understandings of science self-efficacy and the sources through which it is built are necessary to guide teachers/professors as they make data-driven decisions about content presentation, especially through grade 14, when meaningful opportunities to spark interest in STEM disciplines may dwindle (Maltese and Tai, 2010).

- With regard to the actual implementation of the design project in an undergraduate setting, it was a good decision to assign this project in the laboratory. For these students, SP was an important factor affecting ME and total SE. The laboratory setting includes seating arrangements and a less formal atmosphere that afford natural groupings and interactions which are necessary to support social persuasion and vicarious experiences, and, in turn, mastery experiences.
- To further strengthen the impact of SP, the project should have parts that must be completed within the lab context so that students can capitalize on the support that is there from the professor and/or TA in addition to their lab mates. In addition, a peer-review process should be added to the project so that peers will have the opportunity to interact in a meaningful critique of the content being presented in each other's work. By making these elements required, the students will be less likely to leave, thereby enhancing SP and discouraging the psychological states that interfered when students left the classroom.
- For future research, it is important for any researcher to strive to separate out the efficacy (and its hypothesized sources) associated with the mechanics of the actual doing of the practicum versus any efficacy effects from participation in the treatment. With this obvious effect in mind (as stated by the students themselves and implied by the statistical results) teachers/professors should be concerned with desensitizing students to the testing processes so as to minimize the potential negative effects of psychological states on other sources of self-efficacy. Building a practice practicum the week before the actual assessment whereby the time constraints and question

types are introduced may be one solution to directly affect ME and A. In addition, for a group with a high amount of girls, such as this one, students may be randomly grouped in pairs to move through the practice together (with no use of books or outside materials) for additional support to the sources of VE and SP.

- Results of the study impress the need for teacher/professor professional development in the specific learning activities and techniques which affect learning in science and learning for undergraduate students. Participants essentially chose to complete the design task away from the laboratory where sources of self-efficacy such as social persuasion and vicarious learning had the most opportunity to be positively influenced. This behavior is consistent with what is known about undergraduates preferring to learn outside of the context of the school (Coppola & Krajcik, 2013). However, remembering that professors at this level spend 16% more time lecturing and little time utilizing classroom practices that support student learning and self-confidence (Hyde & Gess-Newsome, 2000) they may not have been effective at creating the need for students to make the alternative choice to use class time to complete the project. The study did not explore the teacher's role in the implementation of the project and this focus should be further considered in future research.
- Similarly, evaluation of the students' beliefs about how important the project was to learning outcomes and also their thoughts on their own ability to complete the project were not included in the study but should be considered in the future for a complete view of project impact. To this end, additional measures of academic achievement should be added in the form of a cumulative final exam so that long-term impacts of

project participation on knowledge retention may be evaluated.

- It is further recommended that the qualitative questions used at the end of the study should be reworded to illicit expanded answers from students as to the sources of self-efficacy they perceive as being affected, either negatively or positively, by project participation. These surveys should be followed by a purposively sampled group to be interviewed by the researcher about their impressions and underpinning explanations of project effects.
- The opportunity to repeat this study in a community college classroom with a larger sample and a demographic that has a higher percentage of males and underrepresented ethnic groups so as to derive statistics that are more reliable and would lend themselves to generalizable results would be useful. Maltese and Tai (2010) point us to younger grades as perhaps more fertile for cultivating STEM interests. In addition, remembering the aforementioned results from Lowanto & Stewardson (2011) which found that students resisted projects that required increasing creativity, strong consideration should be given to moving this research into the high school or middle school arena to see if participating in the design project would (a) help to desensitize students to creative endeavors, (b) act to spark interest in a STEM discipline in a younger group and (c) correlate to the interest effect maintaining over time.
- Finally, the design-based approach whereby students have the opportunity to engage in an ill-designed problem and work to resolve it through construction of either a technological or artistic artifact should continue to be investigated across grade levels and demographics. More data is needed to determine its usefulness and effectiveness

not only at sparking interest in STEM subjects, but also at improving the sources of self-efficacy which may be correlated with academic success and persistence in the pathways of STEM learning.

References

American Federation of Teachers (AFT). (2010). American *Academic: A National Survey of Part-Time/ Adjunct Faculty*. Retrieved from https://www.aft.org/pdfs/highered/aa_partimefaculty0310.pdf.

American Association for the Advancement of Science (AAAS). (2011). Vision *and Change: A Call to Action*. Washington, DC: AAAS as downloaded from: http://visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf.

American Association of Community Colleges. (2014). http://www.aacc.nche.edu/AboutCC/Trends/Pages/studentsatcommunitycolleges.aspx

Andrew, S. (1998). Self-efficacy as a predictor of academic performance in science. *Journal of advanced nursing*, *27*(3), 596-603.

Angle, J., & Faster, G. (2011). Art in motion: A sailboat regatta. *Science Scope, 35* (2), 56-62.

Arum, R., & Roksa, J. (2011). *Academically adrift: Limited learning on college campuses*. University of Chicago Press.

Atkinson, R., & Mayo, M. (2010). Refueling the US innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education. *The Information Technology & Innovation Foundation, Forthcoming*.

Atkinson, R., & Andes, S. (2009). The *Atlantic Century: Benchmarking EU and U.S. Innovation and Competitiveness*. Washington, DC: Information Technology and Innovation Foundation, Retrieved from http://www.itif.org/files/2009-atlantic- century.pdf.

Baldwin, J., Ebert-May, D., & Burns, D. (1999). The development of a college biology self-efficacy instrument for nonmajors. *Science Education*, *83*(4), 397-408.

Bamberger, J. (2003). The development of intuitive musical understanding: A natural experiment. *Psychology of Music 31*(1), 7–36.

Bandura, A. (1995). Exercise of personal and collective efficacy in changing societies. In *Self-Efficacy in Changing Societies*. In Bandura, A. (Ed.). Cambridge, UK: Cambridge University Press.

Bandura, A. (2007). *Self-Efficacy: The exercise of control*. New York: Freeman.

Bandura, A. (2006). Guide for constructing self-efficacy scales. *Self-efficacy beliefs of adolescents*, *5*(307-337).

Barab, S & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*, 1-14.

Battle, E. (1965). Motivational determinants of academic task persistence. *Journal of Personality and Social Psychology*, *2*, 209-218.

Battle, E. (1966). Motivational determinants of academic competence. *Journal of Personality and Social Psychology*, *4*, 534-642.

Becker, K. & Kyungsuk, P. (2011). Effects of integrative approaches among science technology, engineering and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 23-37.

Bonett, D. G. & Wright, T. A. (2014). Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *Journal of Organizational Behavior*, *36*(1), 3-15. doi: 10.1002/job.1960

Borgdorff, H. (2011). *The production of knowledge in artistic research*. In M. Biggs , H. Karlsson, & J. Riksbankens (Eds.). *The routledge companion to research in the arts* (pp. 44-63). New York: Routledge.

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Behavior*, *23*(3), 329-345.

Betz, N. & Hackett, G. (1993). Manual for the Mathematics Self-Efficacy Scale. Redwood City: Mind Garden.

Boix-Mansilla V. *2005. Assessing student work at disciplinary crossroads. Change 37: 14–21.*

Boix-Mansilla, V., & Duraisingh, E. (2007). Targeted assessment of students' interdisciplinary work: An empirically grounded framework proposed. *The Journal of Higher Education*, *78*(2), 215-237.

Boix-Mansilla, V., Duraisingh, E., Wolfe, C., & Haynes, C. (2009). Targeted assessment rubric: An empirically grounded rubric for interdisciplinary writing. *The Journal of Higher Education*, *80*(3), 334-353.

Bonser, F. G. & Mossman, L. C. (1923). *Industrial arts for elementary schools*. New York: Macmillan.

Bowman, J. (2011). Program design of STEAM education initiatives in urban communities. In *IIIS Proceedings of International Conference on Design and Modeling in Science, Education, and Technology (p, 257-262). Winter Gardens, Fl.*

Brand, B., & Wilkins, J. (2007). Using self-efficacy as a construct for evaluating science and mathematics methods courses. *Journal of Science Teacher Education*, *18*(2), 297-317.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3-11.

Britner, S. (2002). *Science Self-Efficacy of African American Middle School Students: Relationship to Motivation Self-Beliefs, Achievement, Gender, and Gender Orientation* (Doctoral dissertation, Emory University). Retrieved from http://www.uky.edu/~eushe2/Pajares/BritnerDissertation.pdf.

Britner, S. L., & Pajares, F. (2001). Self-efficacy beliefs, motivation, race, and gender in middle school science. *Journal of Women and Minorities in Science and Engineering*, *7*(4), 269-283.

Britner, S., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485-499.

Burgoon, J., Meece, J. & Granger, N. (2012), Self-efficacy's influence on student academic achievement in the medical anatomy curriculum. *Anatomical Sciences Education*, *5*, 249–255. doi: 10.1002/ase.1283

Burke, B. The ITEEA 6E Learning byDeSIGN™ Model. (2014). *Technology and Engineering Teacher, 73*(6), 14-19.

Burnham, J. R. (2011). *A case study of Mathematics self-efficacy in a freshman engineering mathematics course* (Doctoral dissertation, Washington State University). Retrieved from http://www.dissertations.wsu.edu/Thesis/Spring2011/J_Burnham_041211.pdf.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Bybee, R. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30-35.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Cajas, F. (2001). The science/technology interaction: Implications for science literacy. *Journal of Research in Science Teaching, 38*(7), 715-729.

Chen, J., & Usher, E. (2013). Profiles of the sources of science self-efficacy. *Learning and Individual Differences, 24*, 11-21.

Chen, X., & Weko, T. (2009). Students who study science, technology, engineering & math in postsecondary education. Washington DC: US Department of Education, National Center for Education Statistics 2009-161. Retrieved from: http://nces.ed.gov/pubs2009/2009161.pdf

Chinn, C. & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175-218.

Cook, T. D., Campbell, D. T., & Day, A. (1979). *Quasi-experimentation: Design & analysis issues for field settings* (pp. 19-21). Boston: Houghton Mifflin.

Coppola, B. P., & Krajcik, J. S. (2013). Discipline-centered post-secondary science education research: Understanding university level science learning. *Journal of Research in Science Teaching, 50*(6), 627-638. doi:10.1002/tea.21099

Corbin, J. & Strauss, A. (2008). *Basics of Qualitative Research, 3rd Edition*. California: Sage Publications, Inc.

Creswell, J. (2003). Research *Design: Qualitative, Quantitative & Mixed Methods Approaches, 2nd Edition*. California: Sage Publications, Inc. As retrieved from: http://isites.harvard.edu/fs/docs/icb.topic1334586.files/2003_Creswell_A%20Framework%20for%20Design.pdf

Creswell, J. (2014). Research *Design: Qualitative, Quantitative & Mixed Methods Approaches, 4th Edition*. California: Sage Publications, Inc.

Crismond, D. P. & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, 101:738-797. doi: 10.1002/j.2168-9830.2012.tb01127.x.

Cross, N. (2006). Designerly *ways of knowing*. London: Springer.

Dalgety, J., Coll, R., & Jones, A. (2003), Development of chemistry attitudes and experiences questionnaire (CAEQ). *Journal of Research in Science Teaching, 40*, 649–668. doi: 10.1002/tea.10103

Davidson, W., Beck, H., & Silver, C. (1999). Development and validation of scores on a measure of six academic orientations in college students. *Educational and Psychological Measurement*, *59*(4), 678-693.

Davis, M. (2011). Creativity, innovation and design thinking. In S.A. Warner & P. R. Gemmill, (Eds.), *Creativity and Design in Technology & Engineering Education* (pp. 149-181). Reston, VA: Council on Technology Teacher Education.

DeHoff, M., Clark, K., & Meganathan, K. (2011). Learning outcomes and student-perceived value of clay modeling and cat dissection in undergraduate human anatomy and physiology. *Advances in physiology education*, *35*(1), 68-75.

Dewey, J. (1909). Moral *Principles in Education*. New York: Houghton Mifflin Company.

Dewey, J. (1934). *Arts as Experience*. USA: Penguin.

Dewey, J. (1916). *Democracy and Education*. New York: Macmillan.

Dominiczak, M. (2013). The biological aesthetic. *Clinical Chemistry*, *59*(9), 1425-1426. doi: 10.1373/clinchem.2012.199935

Drake, S. & Burns, R. (2004). *Meeting Standards Through Integrated Curriculum*. USA: Association for Supervision and Curriculum Development.

Dugger, W. E. (2010). Evolution *of STEM in the U.S.* (Power Point) Presentation to the 6th Biennial International Conference on Technology Education Research, Australia. Retrieved from http://iteea.org/Resources/PressRoom/pressroom.htm.

Dunham, T., Wells, J. G. & White, K. (2002). Biotechnology Education: A multiple strategies approach. *Journal of Technology Education, 14*(1), 65-81.

Eccles, J., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., et al. (1983). *Expectancies, values and academic behaviors*. In J. T. Spence (Ed.), Achievement and motivation (pp. 75-146). San Francisco: Freeman.

Ercikan, K. & Roth, W.M. (2014). Limits of generalizing in educational research: Why criteria for research generalization should include population heterogeneity and uses of knowledge claims. *Teachers College Record*, *116*(5), 1-28.

Ertmer, P., & Newby, T. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *26*(2), 43-71.

Fairweather, J. (2009). Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education A Status Report for The National Academies National Research Council Board of Science Education.

Fencl, H., & Scheel, K. (2005). Research and teaching: engaging students–An examination of the effects of teaching strategies on self-efficacy and course in a non-majors physics course. *Journal of College Science Teaching*, *35*(1), 20-24.

Fenwick, T. J. (2000). Expanding conceptions of experiential learning: A review of the five contemporary perspectives on cognition. *Adult Education Quarterly, 50*(4), 243-272.

Findlater, G. S., Kristmundsdottir, F., Parson, S. H., & Gillingwater, T. H. (2012). Development of a supported self-directed learning approach for anatomy education. *Anatomical Sciences Education*, 5, 114-121.

Forester, J., McWhorter, D., & Cole, M. (2002). The relationship between premedical coursework in gross anatomy and histology and medical school performance in gross anatomy and histology. *Clinical Anatomy*, 15, 160-164.

Fortus, D., Dershimer, R. C., Krajcik, J., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081–1110.

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W., & Mamlok-Naaman, R. (2005). Design-based science and real-world problem-solving. *International Journal of Science Education*, *27*(7), 855-879.

Fosnot, C. T. (Ed.). (2013). *Constructivism: Theory, perspectives, and practice*. New York: Teachers College Press.

Foster, K. M., Bergin, K. B., McKenna, A. F., Millard, D. L., Perez, L. C., Prival, J. T., ... & Hamos, J. E. (2010). Partnerships for STEM Education. *Science*, *329*(5994), 906.

Froyd, J. & Ohland, M. (2005). Integrated engineering curricula. *Journal of Engineering Education, 94*(1), 147-164.

Findlater, G., Kristmundsdottir, F., Parson, S., & Gillingwater, T. (2012). Development of a supported self-directed learning approach for anatomy education. *Anatomical Sciences Education*, *5*, 114–121. doi: 10.1002/ase.1255

Furnham, A., Batey, M., Booth, T. W., Patel, V., & Lozinskaya, D. (2011). Individual difference predictors of creativity in art and science students. *Thinking skills and creativity*, *6*(2), 114-121.

Gess-Newsome, J., Southerland, S. A., Johnston, A., & Woodbury, S. (2003). Educational reform, personal practical theories, and dissatisfaction: The anatomy of change in college science teaching. *American Educational Research Journal*, *40*(3), 731-767.

Gottlieb, E. (2014). Stem art learning outcomes. *The STEAM Journal, 1*(2), 1-3.

Greene, J., Caracelli, V., & Graham, W. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255-274.

Gwilliam, L. R., & Betz, N. E. (2001). Validity of measures of math-and science-related self-efficacy for African Americans and European Americans. *Journal of Career Assessment*, *9*(3), 261-281.

Hacker, M., & Burghardt, D. (2004). *Technology education: Learning by design*. Upper Saddle River, NJ: Pearson Prentice-Hall.

Hackett, G. & Betz, N. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education, 20*, 263-271.

Haspel, C., Motoike, H. K. and Lenchner, E. (2014). The implementation of clay modeling and rat dissection into the human anatomy and physiology curriculum of a large urban community college. *Anatomical Sciences Education*, *7*, 38–46. doi: 10.1002/ase.1369.

Henriksen, D. (2014). Full STEAM ahead: Creativity in excellent STEM teaching practices. *The STEAM Journal, 1*(2), p. 3-8.

Hmelo, C., Holton, D., & Kolodner, J. (2000). Designing to learn about complex systems. *The Journal of the Learning Sciences, 9*(3), 247-298.

Hoffman, E., Starobin, S., Laanan, F., & Rivera, M. (2010). Role of community colleges in STEM education: Thoughts on implications for policy, practice and future research. *Journal of Women and Minorities in Science and Engineering*, *16*(1): 85-96.

Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., & Zemp, E. (Eds.). (2008). *Handbook of transdisciplinary research*. Dordrecht: Springer.

Hopper, M. (2011). Student Enrollment in a Supplement Course for Anatomy and Physiology Results in Improved Retention and Success. *Journal of College Science Teaching*, *40*(3), 70-79.

Huber, M. & Hutchings, P. (2005). *Integrative learning: Mapping the terrain*. Washington, DC: Association of American Colleges and Universities.

Humphreys, D. (2005). Why integrative learning? Why now? *peerReview*, 30-31. Retrieved from http://www.aacu.org/peerreview/pr- sufa05realitycheck.cfm

Hutchison-Green, M.A., Follman, D. & Bodner, G. (2008). Providing a Voice: Qualitative 64 investigation of the impact of a first-year engineering experience on students' efficacy beliefs. *Journal of Engineering Education, 97*(2), 177-190.

Hyde, M. S., & Gess-Newsome, J. (2000). Factors that increase persistence of female undergraduate science students. In Bart, J. (Ed). *Women succeeding in the sciences: Theories and practices across disciplines* (pp. 115-137). USA: Purdue University Press.

IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Institute of Education Sciences (IES). 2014. Retrieved from http://ies.ed.gov/whatsnew/newsletters/july10.asp?index=roundnces#timss

International Technology Education Association. (1996). *Technology for all Americans: Rationale & structure for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2000, 2002, 2006). *Standards for Technological Literacy: Content for the Study of Technology*. Reston, Virginia: Author.

Jacobs, J. A. & Sax, L. (2014, April). STEM Fields, the Liberal Arts and the Great Recession. Paper presented at the meeting of the American Educational Research Association, Philadelphia, PA.

Jacobson, C., & Lehrer, R. (2000). Teacher appropriation and student learning of geometry through design. *Journal for Research in Mathematics Education, 31*(1), 71–88.

Jiang, Y., Song, J., Lee, M., & Bong, M. (2014). Self-efficacy and achievement goals as motivational links between perceived contexts and achievement. *Educational Psychology, 34*(1), 92-117.

Joyce, M. (2013, May 11). Picking the best intercoder reliability statistic for your digital activism content analysis [Web log post]. Retrieved from http://digital-activism.org/2013/05/picking-the-best-intercoder-reliability-statistic-for-your-digital-activism-content-analysis/

Jonassen, D. H. (1991a). Evaluating constructivistic learning. *Educational Technology, 31*(9), 28–33.

Kang, M., Park, Y., Kim, J., & Kim, Y. (2012, August). Learning outcomes of the teacher-training program for steam education. In *Proceedings of the 10th International Conference for Media in Education, Beijing* (pp. 22-24).

Katz-Buonincontro, J. 2008. Using the Arts to Promote Creativity in Leaders. *Journal of Research on Leadership Education*, *3*(1).

Keefe, B. (2010). The perception of STEM: Analysis, issues, and future directions. Survey. Entertainment and Media Communication Institute.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1). Englewood Cliffs, NJ: Prentice-Hall.

Kim, Y., & Park, N. (2012). Development and Application of STEAM Teaching Model Based on the Rube Goldberg's Invention. In *Computer Science and its Applications* (pp. 693-698). Springer Netherlands.

Klomegah RY. 2007. Predictors of academic performance of university students: An application of goal efficacy model. *College Student Journal*, *41*,407–415.

Knopke, V. (2012). Gender and technology education: Some theoretical implications. In Middleton, H. (Ed.), *Explorations of Best Practice in Technology, Design & Engineering Education, Vol. 2* (pp. 1-8).

Kranzler, J. & Pajares, F. (1997). An exploratory factor analysis of the mathematics self-efficacy scale-revised. *Measurement & Evaluation in Counseling & Development*, *29*(4), 215-229.

Kuenzi J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action*. CRS Report for Congress. Washington DC: Congressional Research Service. Retrieved from http: //www.fas.org/sgp/crs/misc/RL33434.pdf. Accessed October 2012.

Kuenzi, J. J., Matthews, C. M., & Mangan, B. F. (2006). Science, technology, engineering, and mathematics (STEM) education issues and legislative options. Library of Congress Washington DC Congressional Research Service. As downloaded from: http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA474889

Kuh, G. D., Jankowski, N., Ikenberry, S. O., & Kinzie, J. (2014). Knowing What Students Know and Can Do: The Current State of Student Learning Outcomes Assessment in US Colleges and Universities. National Institute for Learning Outcomes Assessment, Retrieved from http://www.learningoutcomeassessment.org/documents/2013%20Survey%20Report%20Final.pdf.

Lawson, A. E., Banks, D. L., & Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching*, *44*(5), 706-724.

Lent, R., F. Lopez, and K. Bieschke. 1991. Mathematics Self-Efficacy Sources and Relation to Science-Based Career Choice. *Journal of Counseling Psychology*, *38*(4), 424-430.

Levy, J. A. (2014). *Causal-comparative study analyzing student success in hybrid anatomy and physiology courses* (Doctoral dissertation, Northern Arizona University). Retrieved from http://gradworks.umi.com/36/06/3606821.html.

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Loepp, F. (2004). Standards: Mathematics and science compared to technological literacy. *Journal of Technology studies*, *30*(1), 2-10.

Lowanto, O., & Stewardson, G. (2011). Students' interest and expectancy for success while engaged in analysis- and creative design activities. *International Journal of Technology and Design Education*, *23*(2), 213-227.

MacPhee, D., Farro, S., & Canetto, S. S. (2013). Academic Self-Efficacy and Performance of Underrepresented STEM Majors: Gender, Ethnic, and Social Class Patterns. *Analyses of Social Issues and Public Policy*, *13*(1), 347-369.

Madden, M. E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., ... & Plague, G. (2013). Rethinking STEM Education: An Interdisciplinary STEAM Curriculum. *Procedia Computer Science*, *20*, 541-546.

Maltese, A. V., Melki, C. S., & Wiebke, H. L. (2014). The nature and experiences responsible for the generation and maintenance of interest in STEM. *Science Education*, *98*(6), 937-962.

Maltese, A. V. & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science, International *Journal of Science Education*, *32*(5), 669-685.

McGill, I. & Weil, S. W. (1989). Continuing the dialogue: New possibilities for experiential learning. In S. W. Weil & I. McGill, (Eds.). *Making Sense of Experiential Learning: Diversity in Theory and Practice*. (pp. 245-272). Buckingham: Open University Press.

Mehalik, M., Doppelt, Y., & Schunn, C. (2008). Middle school science through design-based learning versus scripted inquiry: Better overall science concept learning and overall gender gap reduction. *Journal of Engineering Education*, 71-85.

Messick, S. (1994). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist*, *50*(9), 741-749. doi: 10.1037/0003-066X.50.9.741.

Mezirow, J. (1997). Transformative learning: Theory to practice. *New directions for adult and continuing education*, *1997*(74), 5-12.

Moon, J. A. (1999). Reflection in learning & professional development: Theory & Practice. Psychology Press.

National Academy of Engineering (NAE) and National Research Council (NRC) (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: The National Academies Press.

National Center for Education Statistics, 2009. "Students who Study Science Technology Engineering and Mathematics (STEM) in Postsecondary Education. http://nces.ed.gov/pubs2009/2009161.pdf

National Center for Education Statistics, 2011, "Program for International Student Assessment".http://nces.ed.gov/surveys/pisa/pisa2012/pisa2012highlights_1.asp

National Center for Education Statistics, 2011, "Trends in International Math and Science Study". 2012. http://nces.ed.gov/pubs2013/2013009rev.pdf Downloaded February 2014.

National Center for Education Statistics, 2013. US States in a global context: Results from the 2011 NAEP-TIMSS linking study. http://nces.ed.gov/nationsreportcard/subject/publications/studies/pdf/2013460.pdf Downloaded, February, 2014.

National Governor's Association (NGA). 2011. Building a science, technology, engineering and math agenda: An update of state actions. Washington DC, Retrieved from http://www.nga.org/files/live/sites/NGA/files/pdf/1112STEMGUIDE.PDF

National Research Council (NRC). (2013). Next *Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

National Research Council (NRC), (2012). Discipline-based education research: Understanding and improving learning in undergraduate science and engineering. Washington, DC: The National Academies Press. Retrieved from http://nap.edu/catalog.php?record_id=13362 .

National Research Council (NRC). (2011). Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering and mathematics. Washington DC: National Academies Press.

National Research Council (NRC). (2009). A new biology for the 21st century. Washington DC: National Academies Press

National Science Board, Task Committee on Undergraduate Science and Engineering Education, (1986). *Undergraduate science, mathematics, and engineering education: Role for the National Science Foundation and recommendations for action by other sectors to strengthen collegiate education and pursue excellence in the next generation of U.S. leadership in science and technology*, (Washington DC: National Science Foundation, NSB 86-100). Retrieved from https://www.nsf.gov/nsb/publications/1986/nsb0386.pdf

National Science Board (NSB). (2014). Science *and Engineering Indicators 2014.* Arlington, VA: National Science Foundation (NSB 14-01). http://www.nsf.gov/statistics/seind14/content/chapter-1/c01.pdf . Downloaded February 2014.

National Science Board (NSB). (2007). National action plan for addressing the critical needs of the US science, technology, engineering and mathematics education system. Arlington, VA: National Science Board. Accessed February 2014.

National Science Foundation (NSF). (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering & technology.* Retrieved from http://www.nsf.gov/pubs/stis1996/nsf96139/nsf96139.txt

National Science Foundation (NSF). (2013). Women, *Minorities and Persons with Disabilities in Science and Engineering: 2013*. Retrieved from http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf

Neuendorf, K. A. (2002). *The content analysis guidebook.* Thousand Oaks, California: Sage Publications.

NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2012.

NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2014.

O'Cathain, A., Murphy, E., & Nicholl, J. (2010). Three techniques for integrating data in mixed method studies. *British Medical Journal*, *341*(7783), 1147-1150.

Onwuegbuzie, A. J., & Teddlie, C. (2003). A framework for analyzing data in mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 351-383). Thousand Oaks, CA: Sage.

Organization for Economic Cooperation and Development (OECD). *About PISA: PISA FAQ*. N.p., n.d. Retrieved from http://www.oecd.org/pisa/aboutpisa/pisafaq.htm 22 Aug. 2014.

Organization for Economic Cooperation and Development (OECD). (2006). Assessing *scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD. doi: 10.1787/9789264026407-en

Organization for Economic Cooperation and Development (OECD). (2013). Pisa 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264190511-en

Ostler, E. (2012). 21st century STEM education: A tactical model for long-range success. *International Journal of Applied Science and Technology, 2*(1), 28-33.

Pascarella, E., and Terenzini, P. (1991). How college affects students: Findings and insights from twenty years of research. San Francisco: Jossey-Bass.

Painter, S., & Bates, R. (2012). Statistical models of self-efficacy in STEM students. *Journal of Undergraduate Research*, 1-13.

Palinesar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Reviews in Psychology, 49*, 345-375.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Education Research, 66*(4), 543-578.

Pajares, F., & Miller, M. D. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity of assessment. *Journal of counseling psychology*, *42*(2), 190.

Pajares, F., Miller, M. D., & Johnson, M. J. (1999). Gender differences in writing self-beliefs of elementary school students. *Journal of Educational Psychology*, *91,* 50-61.

Partnership for 21st Century Skills. (2008). 21st century skills, education and competitiveness: A resource and policy guide. As downloaded from: http://www.21stcenturyskills.org

Pennington, D. D., Simpson, G. L., McConnell, M. S., Fair, J. M., & Baker, R. J. (2013). Transdisciplinary research, transformative learning, and transformative science. *BioScience*, *63*(7), 564-573.

Peterson, C. & Tucker, R. (2005). Undergraduate coursework in anatomy as predictor of performance: comparison between students taking a medical gross anatomy course of average length and a course shortened by curricular reform. *Clinical Anatomy, 18*, 540-547.

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million college graduates with degrees in science, technology, engineering and mathematics*. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Rhode Island School of Design. (2011). Rhode Island School of Design presents "Bridging STEM to STEAM: Developing new frameworks for art-science-design pedagogy". [press release] 1/20/2011.

Riffe, D., Lacy, S., & Fico, F. (1998). *Analyzing Media Messages: Using Quantitative Content Analysis in Research*. Mahwah, N. J.: Erlbaum.

Root-Bernstein, R., & Root-Bernstein, M. (1999). Sparks of genius. *Boston and New York: Houghton Mifflin*.

Root-Bernstein, R., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., ... & Weinlander, S. (2008). Arts foster scientific success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi members. *Journal of the Psychology of Science and Technology*, *1*(2), 51-63.

Rossman, G. & Rallis, S. (2012). An Introduction to Qualitative Research, 3rd Edition. California: Sage Publications, Inc.

Rossouw, A., Hacker, M., & de Vries, M. J. (2011). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education*, *21*(4), 409-424.

Russell, J. (2003). Making use of new assessment standards to enhance technological literacy. *The Technology Teacher*, *63*(2), 27-32.

Sanders, M. (2009). Stem, stem education, stem mania. *The Technology Teacher*, *68*(4), 20-26.

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-based Learning*, *1*(1). Available at: http://dx.doi.org/10.7771/1541-5015.1002

Sawtelle, V., Brewe, E., & Kramer, L. (2012). Exploring the relationship between self-efficacy and retention in introductory physics. *Journal of Research in Science Teaching*, *49*(9), 1096-1121.

Sawyer, K. (2007). Group *genius: The creative power of collaboration*. New York: Basic Books.

Sax, L., Jacobs, J. & Riggers, T. (2010, November). Women's Representation in Science and Technology (STEM) Fields of Study, 1976-2006. Paper presented at the annual meeting of the Association for the Study of Higher Education (ASHE), Indianapolis, Indiana.

Schreiber, L. M. & Valle, B. E. (2013). Social constructivist teaching strategies in the small group classroom. *Small Group Research*, *44*: 395-411. doi: 10.1177/1046496413488422

Seymour, E. & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. USA: Westview Press.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. New York: Houghton Mifflin Company.

Shih, F. J. (1998). Triangulation in nursing research: Issues of conceptual clarity and purpose. Journal of Advanced Nursing, 28(3), 631-641.

Sidawi, M. (2009). Teaching science through designing technology. *International Journal of Technology Design Education*, *19*(3), 269-287. doi: 10.1007/s10798-007-9045-1

Snelbecker, G.E. (1983). *Learning theory, instructional theory, and psychoeducational design*. New York: McGraw-Hill.

St. Rose, A. & Hill, C. (2013). Women *in community colleges: Access to success*. American Washington DC: Association of University Women.

Starobin, S. & Laanan, F. (2008). Broadening female participation in science, technology, engineering and mathematics: Experiences at community colleges. *New Directions for Community Colleges*, 142: 37-46.

Stone, J., Alfeld, C. & Parson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Education Research Journal*, *45*(3), 767-795. doi: 10.3102/0002831208317460.

Testimony to the U.S. House of Representatives Committee on science and technology: Subcommittee on research and science education (2009) (testimony of Darryll J. Pines). Retrieved from http://gop.science.house.gov/Media/hearings/research09/oct22/Pines.pdf

Teddlie, C. & Tashakkori, A. (2006). A general typology of research designs featuring mixed methods. *Research in the Schools. 13*(1), 12-28.

Tortora, G. & Derrickson, B. (2013). Principles of Anatomy and Physiology, 14th Edition. New Jersey: John Wiley & Sons.

Tsapogas, J. (2004). More than one-78h of all individuals employed in science and engineering occupations have less than a bachelor's degree education. Infobrief. Arlington, VA: National Science Foundation

Uitto, A. (2014). Interest, attitudes and self-efficacy beliefs explaining upper-secondary school students' orientation towards biology-related careers. *International Journal of Science and Mathematics Education*, 1-20.

Usher, E. (2009). Sources of Middle School Students' Self-Efficacy in Mathematics: A Qualitative Investigation. *American Educational Research Journal, 46*(1), 275-314.

Usher, E., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research, 78*(4), 751-796.

Usher, E., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary Educational Psychology, 34*, 89-101.

Usher, E., & Pajares, F. (2006a). Inviting confidence in school: Invitations as a critical source of the academic self-efficacy beliefs of entering middle school students. *Journal of Invitational Theory and Practice, 12*, 7-16.

Usher, E., & Pajares, F. (2006b). Sources of academic and self-regulatory efficacy beliefs of entering middle school students. *Contemporary Educational Psychology*, *31*, 125-141.

vanDinther, M., Dochy, F., & Segers, M. (2011). Factors affecting students' self-efficacy in higher education. Educational Research Review, 6, 95-108. Doi: 10.1016/j.edurev.2010.10.0003

Vasan, N. S., DeFouw, D. O. and Compton, S. (2011), Team-based learning in anatomy: An efficient, effective, and economical strategy. *Anatomical Sciences Education, 4*: 333–339. doi: 10.1002/ase.257.

Wagner, T. (2012). *Creating innovators: The making of young people who will change the world*. New York: Scribner.

Walsh, A. (2008). The relationship among mathematics anxiety, beliefs about mathematics, mathematics self-efficacy, and mathematics performance in associate degree nursing students. *Nursing Education Perspectives 29*(4): 226-229.

Wells, J. G. (2008). STEM *education: The potential of technology education*. Paper presented at the 95th Annual Mississippi Valley Technology Teacher Education Conference. St. Louis, Missouri.

Wells, J. G. (2014). Integrative STEM education: U.S. education reform, pedagogical commons, design based biotechnology literacy exemplar. *Proceedings of the 60th Anniversary International Elementary Education Conference on Issues and Prospects for Sustainable Integrative Education in the 21st Century*, Seoul National University of Education, Seoul, South Korea.

Wells, J., & Ernst, J. (2012). Integrative STEM education. *Virginia Tech School of Education*.

Williamson, P. (2011). The creative problem solving skills of arts and science students—The two cultures debate revisited. *Thinking Skills and Creativity, 6* (1), 31-43. ISSN 1871-1871, http://dx.doi.org/10.1016/j.tsc.2010.08.001.

Witt-Rose, D. L. (2003). *Student self-efficacy in college science: An investigation of gender, age, and academic achievement* (Doctoral dissertation, University of Wisconsin). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.390.5301&rep=rep1&type=pdf

Yeats, W. S. (1906). *Personality and the Intellectual Essences* as read in http://www.readbookonline.net/readOnLine/53094/

Zeldin, A., & Pajares, F. (2000). Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technological careers. *American Educational Research Journal, 37*, 215-246.

Zelden, A., Britner, S. and Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science and technology careers. *Journal of Research in Science Teaching, 45*(9), 1036-1058.

Zimmerman, B. (1995) Self-efficacy and educational development. In Bandura (Ed.) In *Self-Efficacy in Changing Societies*, Bandura (Ed.). Cambridge, UK: Cambridge University Press.

Zollman, A. (2012). Learning for STEM literacy: STEM literacy for learning. *School Science and Mathematics, 112*(1), 12-19.

Appendix A

Institutional Review Board Approval Letter: Virginia Polytechnic and State University

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: September 1, 2014

TO: John Wells, Ashley Harding Gess

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: The Impact of the Design Process on Student Self-Efficacy and Content Knowledge

IRB NUMBER: **14-852**

Effective August 29, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date:	**August 29, 2014**
Protocol Expiration Date:	**August 28, 2015**
Continuing Review Due Date*:	**August 14, 2015**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix B

Institutional Review Board Approval Letter: Virginia Western Community College

VIRGINIA WESTERN
COMMUNITY COLLEGE

WE'LL TAKE YOU | THERE

INSTITUTIONAL EFFECTIVENESS OFFICE

September 4, 2014

Approval date: September 4, 2014
Expiration Date: September 3, 2015

Ashley Gess
Virginia Western Community College

RE Protocol Title: **The Impact of the Design Process on Student Self-Efficacy and Content Knowledge**

IRB Number: 14-010

Dear Ms. Gess:

I am pleased to notify you that the Virginia Western Community College Institutional Review Board (IRB) has granted expedited approval to the above mentioned research. Approval to the study is granted for a period of twelve months, effective today. This letter conveys IRB approval and separate arrangements must be made with the appropriate academic division, department or program.

This expedited approval was possible because the protocol:

- has been reviewed and approved by the Virginia Tech Institutional Review Board, and
- meets the procedures under 45 CFR 46.110 and 21 CFR 56.100.

The research was determined to present no more than minimal risk to human subjects and was found to have appropriate protections so that risks related to breach of confidentiality are no more than minimal.

Per 45 CFR 46.111, the following requirements were satisfied in order for approval to be granted:

- Risks were minimized;
- Risks to subjects are reasonable in relation to anticipated benefits, if any, to the subjects, and to the importance of the knowledge that may reasonably result from the study;
- Selection of the subjects was equitable given the purpose of research;
- Informed consent will be sought from and documented for each prospective subject unless the conditions for a waiver of documentation for consent were met;
- When appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure safety of subjects; and
- Adequate provisions to protect the privacy of the subjects and to maintain the confidentiality of the data were made.

<u>**Your responsibilities include:**</u>

We do require that subjects be provided with a written information and documentation of informed consent regarding the research.

Additionally, the following documentation must be provided to Virginia Western Community College IRB:

- Completion of Close Out Report, due 30 days after the expiration date, providing a summary of the project. See attached form.
- Any unplanned protocol variance that could adversely affect the safety or welfare of subjects, or the integrity of research data, within ten days of becoming aware of the variance.

P.O. Box 14007, Roanoke, Virginia 24038 • (540) 857-7277 • Fax: (540) 857-6297 • crowlett@virginiawestern.edu

VIRGINIA WESTERN
COMMUNITY COLLEGE

WE'LL TAKE YOU THERE

INSTITUTIONAL EFFECTIVENESS OFFICE

The Virginia Western IRB thanks you for permitting us the opportunity to review the protocol. We look forward to learning of your results.

Sincerely,

Carol Rowlett

Carol Rowlett
Virginia Western IRB Co-Chair

cc: Dr. Robert H. Sandel, President
cc: Dr. Elizabeth Wilmer, Interim Vice President of Academic and Student Affairs
cc: Ms. Marilyn Herbert-Ashton, Virginia Western IRB Chair
cc: Dr. John Anderson, Dean of the School of Science, Technology, Engineering and Mathematics

attachment: Close Out Report

P.O. Box 14007, Roanoke, Virginia 24038 • (540) 857-7277 • Fax: (540) 857-6297 • crowlett@virginiawestern.edu

Appendix C

Student Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: **The Impact of the Design Process on Student Self-Efficacy and Content Knowledge**

Investigator(s): **Ashley Gess** _agess@virginiawestern.edu/ **540.857.6573**

I. Purpose of this Research Project

The purpose of this study is to determine the effect of creating an art artifact on students' self-efficacy and students' knowledge gains. The study efforts to inform science instructors at Community Colleges about what teaching method(s) help students the most. The results of this study will be used for publication and for the investigator's dissertation. Total number of participants is anticipated to be approximately 100 and the age range of these participants will be from 16 to 60.

II. Procedures

As a normal part of Anatomy curriculum, you will complete one design project during this semester. This project will directly relate to the topic you are studying in anatomy.

You will then be given surveys, which ask questions about your experience when completing the project.

By signing this form, you are giving the researchers permission to analyze the results of the surveys along with your practical grades.

III. Risks

There are no risks that are known to be associated with this investigation.

IV. Benefits

According to earlier studies, students are significantly helped in their academic performance and their self-confidence about Anatomy when completing design projects.

No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

You will be given a student number in class today that will identify you, so the investigator will not know your name. Please remember your student number. You will use your student number on the survey so your name will not be used and you will not be able to be identified. These surveys will be locked in a cabinet in the investigator's office.

At no time will the researchers release identifiable results of the study to anyone other than individuals working on the project without your written consent.

The Virginia Tech (VT) and Virginia Western (VWCC) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

There is no compensation associated with this study.

VII. Subject's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________
Subject signature

____
Subject printed name

VIII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue as a subject.

Should you withdraw or otherwise discontinue participation, you will be compensated for the portion of the project completed in accordance with the Compensation section of this document.

Virginia Tech Institutional Review Board Project No. 14-852
Approved August 29, 2014 to August 28, 2015

IX. Questions or Concerns

Should you have any questions about this study, you may contact one of the research investigators whose contact information is included at the beginning of this document.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Appendix D

Teacher Schedule

Teacher Semester Schedule

Week	Exercise Number	Title
1	1	Introduction The Language of Anatomy
2	3 4	Introduction to the Microscope The Cell
ASSIGN TISSUE PROJECT		
3	6	Classification of Tissues: Epithelial
4	6	Classification of Tissues: Connective
5	**Lab Practical 1**	***TISSUE PROJECT DUE***
ASSIGN BONE PROJECT		
6	8 9	Classification of Bones The Axial Skeleton (Skull)
GRADE TISSUE PROJECT		
7	9	The Axial Skeleton
	10	The Appendicular Skeleton
8	**Lab Practical 2**	***BONE PROJECT DUE*** ***GRADE BONE PROJECT***
9	13	Anatomy of the Muscular System
10	13	Anatomy of the Muscular System
11	**Lab Practical 3**	
12	17	Anatomy of the Brain and Cranial Nerves
13	19 21	Spinal Cord and Nerves Human Reflex Physiology
14	23 25	Special Senses: The Eye Special Senses: The Ear

Appendix E

Practicum Objectives and Common Questions

Practicum Objectives and Common Questions

1. Common Objectives tested on the lab practicum.

    a. Classification of Tissues (Practicum #1)

        i. The following tissues should be investigated in these laboratory sessions: A. Connective tissues (areolar, adipose, reticular, dense regular, elastic dense connective, dense irregular, hyaline cartilage, elastic cartilage, fibrocartilage, bone, blood), B. Nervous tissue (neuron cell bodies, axons, and glial cell nuclei), C. Muscle tissue (skeletal, cardiac, and smooth) and D. Epithelial tissues (simple squamous, simple cuboidal, stratified cuboidal, stratified columnar, simple columnar, pseudostratified columnar, stratified squamous, and transitional)
        ii. Students will be able to:
            1. Name the four primary tissue types in the human body.
            2. Identify the subcategories of tissue types in the human body.
            3. State the location of each tissue type in the human body.
            4. Recall the general function of each tissue type.
            5. Recall the general characteristics of each tissue type.
            6. Identify the tissue types and subcategories through microscopic inspection.

    b. Bone and Bone Development (Practicum #2)

        i. Students will be able to:
            1. Identify all the bones (on a list provided) of the axial skeleton on an articulated or disarticulated skeleton.
            2. Identify all the markings of each bone (on a lit provided) on the axial skeleton on an articulated or disarticulated skeleton.
            3. Identify all the parts (and function of each part) of compact bone on a model or slide: canaliculi, osteon, concentric lamellae, osteocyte, periosteum, Sharpey's fibers, circumferential lamellae, interstitial lamellae, Haversian canal, Volkmann's canal, and lacunae.
            4. Trace the path of blood from the exterior of bone to the interior of bone and vice versa.
            5. Identify all parts (and function of each part) of spongy bone on a model or slide: trabeculae.
            6. Identify all parts (and function of each part) of a long bone on a model or slide: diaphysis, epiphyses, epiphyseal line, medullary cavity, periosteum, and endosteum.
            7. Discuss the processes of intramembranous and endochondral ossification with respect to content and process of each.

Practicum Objectives and Common Questions (continued)

2. Common Questions for the lab practicum

   a. Tissue practicum (#1) must include the following questions in addition to your regular assessment:

      Areolar (function), Reticular (identification under microscope), Smooth muscle (identification under microscope), Simple Cuboidal (identification under microscope), Simple squamous (function).

   b. Bone practicum (#2)

      i. Must include the identification of the bones/markings as a part of your regular assessment:

      Frontal bone, Medial malleolus, Olecranon process, Tibial tuberosity, Navicular.

      ii. Must include all of the following ossification questions as a part of your regular lab assessment:
         1. Where is the primary ossification center located in a long bone?
         2. When does secondary ossification take place in a long bone?
         3. When describing endochondral ossification, some say "bone chases cartilage". What does this mean?
         4. The flat bones of the skull develop from a. areolar tissue, b. hyaline cartilage, c. fibrous connective tissue, d. compact bone
         5. Which of the following bones are formed as a result of intramembranous ossification:
            a. parietal, b. humerus, c. vertebrae, d. femur, e. all bones listed are correct

Appendix F

Tissue Project Handouts: Assignment Pages Given to Students and Grading Rubric

Tissue Project Handouts

1. Assignment Pages

Tissue Photography Project

After completing this assignment, the student will be able to:

1. Accurately identify tissues assigned.
2. Characterize tissues on the basis of structure and function.
3. Identify where the tissues are found in the human body.
4. Demonstrate the acquired knowledge on a practical examination.

Your assignment is to take an original digital picture of three tissues of your choice in the lab. You must choose one tissue from each group (see list below). Then, you are to photograph something that reminds you of the structure AND function of that tissue. These both MUST be ORIGINAL pictures. Both pictures must be printed out on glossy or matte finish photography paper and mounted, matted and framed in an artistic style. Below each picture, you must have a typed paragraph which includes, at a minimum, all of the following information:

A. Under the tissue photo

- a. Name of the tissue type
- b. Magnification
- c. Cell size
- d. Date of photograph
- e. Place of photograph
- f. Photographer
- g. Hallmark features of tissue (in complete sentences)
- h. Function(s) of tissue (in complete sentences)
- i. Specific locations in the human body (list)

B. Under the companion photograph

- a. Date of photograph
- b. Place of photograph
- c. Photographer

C. Centered under both pictures

- a. Title of the artwork
- b. Name of Artist
- c. Explanation of how the two pictures are linked in BOTH structure and function (complete sentences)

- The IPEVO photo-microscope will be available during lab with instructor assistance. Digital photos will be emailed to the student from the lab computer.
- **Specific expectations are detailed in the attached grading rubric**
- Please attach in a copy of the grading rubric on the back of your project.
- You must complete the work yourself – no group collaboration
- **Absolutely no late work will be accepted.**
- All projects will be returned at the end of the semester.
- This project is worth a total of up to 100 points toward your grade.

<u>Project due date:</u>

<u>Tissue Group A: Pick One</u>

Simple Squamous Epithelium
Simple Cubodial Epithelium
Simple Columnar Epithelium
Pseudostratified Columnar Epithelium
Stratified Squamous Epithelium
Stratified Columnar Epithelium
Transitional Epithelia

<u>Tissue Group B: Pick One</u>

Embryonic Mesenchyme
Areolar Loose Connective Tissue (CT)
Adipose Loose CT
Reticular Loose CT
Dense Regular CT
Dense Irregular CT
Dense Elastic CT

<u>Tissue Group C: Pick One</u>

Hyaline Cartilage
Elastic Cartilage
Fibrocartilage
Bone
Blood
Skeletal Muscle
Cardiac Muscle
Smooth Muscle
Nervous Tissue

Tissue Project Handouts (continued)

2. Grading Rubric

Tissue Project Grading Rubric

	Superior (20 Points)	Very Good (17 Points)	Average (14 Points)	Below Average (11 Points)	Poor (9 Points)	Points earned
Science: Technical (40%)	Idea is communicated well in photos without giving more that is needed. Excellent connection between tissue content and comparison. The structure and function are correct, clear and congruous across pictures.	Idea is communicated well pictorially but is somewhat reliant upon description. Very good connection between tissue content and comparison Structure and function are correct and clear but may not be completely congruous.	Idea is evident pictorially but is quite reliant upon description. Images satisfy assignment. Adequate connection between tissue content and comparison Structure and function are correct but lacking in detail and may not be clear.	Project ideas needs further polish to effectively convey the idea. Further brainstorming recommended. Structure and function of one or two pictures are not correct.	Project idea is incomplete. More than two pictures have incorrect structure and function. Comparison does not make sense.	
Photography: Technical (30%)	High quality images. Zoom is appropriate to accurately represent the tissue / subject selected. Images edited to maximize effect and continuity. Non-distracting background and angle. No overexposure or lighting issues. Use of color appropriate to convey message.	Good quality images. Zoom somewhat appropriate. Images edited to maximize effect and continuity. Non-distracting background/angle. Minor lighting problems. Use of color is good.	Magnification may not be appropriate; Editing is not complete and includes extraneous images. Background is a little distracting. Overexposure and/or lighting issues present. Color of pictures may not lend to continuity of message.	Extraneous images compete with understanding and focus. Background is very distracting. Many overexposure/lighting issues present. Color usage is similar but does not add to the conveyance of message.	Images are blurry and unedited. Random exposure and lighting used. Angle, background and use of color are random and show lack planning.	

Mechanics (20%)	All required information present plus additional relevant information. No spelling/gra-mmatical errors. Artwork turned in on time.	All required information is present. One spelling/gra-mmatical error. Artwork turned in on time.	One required element missing. Two-three spelling/gra-mmatical errors. Artwork turned in on time.	Two required elements missing. Four spelling/gra-mmatical errors. Artwork turned in on time.	More than two required elements missing. More than four spelling/gra-mmatical errors. Artwork turned in on time. Note: Artwork turned in late will not be accepted for a grade.	
Artistry (10%)	Framing and matting enhance project presentation. Space used wisely.	Framing and matting do not distract from presentation. Use of color is adequate. Space used well, but some mis-proportion may exist.	Framing and matting do not distract from presentation. Use of color is haphazard. Execution needs improvement.	Framing and matting come across as an "afterthought". Work is messy, appears haphazard. No evidence of planning.	Work may be unframed or lacking in matting. No color continuity. Poor artistry and craftsmanship.	

For grading use only:

Photo Group A		**Photo Group B**		**Photo Group C**	
Tissue:		**Tissue:**		**Tissue:**	
	magnification		magnification		magnification
	cell size		cell size		cell size
	date		date		date
	place		place		place
	photographer		photographer		photographer
	hallmark features		hallmark features		hallmark features
	tissue functions		tissue functions		tissue functions
	locations		locations		locations
Photo:		**Photo:**		**Photo:**	
	date		date		date
	place		place		place
	photographer		photographer		photographer

Centered:		**Centered**:		**Centered**:	
	title		title		title
	artist		artist		artist
	explanation		explanation		explanation
	Notes:		Notes:		Notes:

Appendix G

Bone Project Handouts: Assignment Pages Given to Students and Grading Rubric

Bone Project Handouts

1. Assignment Pages

Bone Ossification Project

Purpose: To demonstrate understanding of the content and process of ossification (either endochondral OR intramembranous) through artistic interpretation.

Objective: The student will be able to demonstrate in-depth understanding of the ossification process through creating and submitting ONE of the following:

Poem (haiku): submitted TO THE INSTRUCTOR no later than due date and time. The following words may **NOT** be used in the piece: bone, ossification, endochondral, intramembranous; final copy must be finished with some kind of matting and/or frame; all parts of presentation should accentuate the poem and not detract from presentation of content. Neatness counts. No spelling errors are acceptable. A descriptive title should be included in the final presentation. Include a copy of the rubric on the back of your submission.

http://volweb.utk.edu/school/bedford/harrisms/haiku.htm

http://www.wikihow.com/Write-a-Haiku-Poem

OR

Interpretative dance: BETWEEN 3-5 minutes; performance recorded on video; video uploaded on You Tube and working link submitted on BLACKBOARD no later than due date and time; be aware that costuming counts and should add to the overall effect. A title should be creatively included as a part of the presentation.

OR

Musical piece: Between 3-5 minutes; performance recorded as mp3 file; piece will be instrumental ONLY; mp3 recording uploaded on BLACKBOARD no later than due date and time. The composition must be original. IF OTHER EXISTING PIECES OF MUSIC ARE INCORPORATED INTO YOUR FINAL PRODUCT, YOU MUST CITE THE REFERENCES IN APA STYLE. A lack of citation will constitute a zero for this project. A descriptive title must be included as the file name.

OR

Pantomime: Between 3-5 minutes; performance recorded on video; video uploaded on You Tube and working link submitted on BLACKBOARD no later than due date and time. Be aware that costuming counts and is unique for pantomime. A descriptive title must be creatively included as a part of the performance.

http://www.suite101.com/content/the-art-and-history-of-pantomime-a108233

http://www.youtube.com/watch?v=C9xCZI12XEo

Each student must be careful to clearly represent their chosen process by including appropriate relevant processes and terms.

A *minimum* of the following content / process elements of the ossification process must be included / obvious and in correct order. In order to achieve above average for this criterion, you must include more than the minimum (see rubric for details):

<u>Endochondral</u>	**<u>Intramembranous</u>**
Osteoblast	Osteoblast
Osteoclast	Osteoclast
Osteocyte	Osteocyte
Trabeculae	Trabeculae
Primary ossification center	Ossification centers
Secondary ossification center	Diploe
Bone collar	Invasion
Invasion	Calcification
Calcification	Secrete
Secrete	Lacunae
Osteoid	Osteoid
Lacunae	Canaliculi
Canaliculi	Mesenchyme

This assignment will be graded according to the following rubric (attached). Any assignment submitted late will not be graded. No matter what you choose, you should be able to CLEARLY demonstrate / represent BOTH the content and process of your chosen process. This project is worth up to 100 points toward your total grade.

<u>Project due date:</u>

Bone Project Handouts (continued)

2. Grading Rubric

Bone Project Grading Rubric

	Superior (20 Points)	Very Good (17 Points)	Average (14 Points)	Below Average (11 Points)	Poor (9 Points)	Points earned
Science: Technical (40%)	All content elements are present and obvious (see included list) PLUS 3 or more additional.	All content elements present and obvious (see list above) PLUS 2 additional.	All content elements present and obvious (see list above).	Two content elements missing or not obvious (see list above).	More than 2 content elements missing or not obvious (see list above).	
Presentation: Technical (30%)	Evidence of careful thought, creativity and planning; appropriate chosen color scheme / costuming; Connection to ossification processes are complete and clear throughout the piece.	Evidence of careful thought, creativity and planning; use of color / costuming is adequate; connection to ossification process is evident throughout however some transitions are not clear.	Assignment completed adequately, shows lack of planning as evidenced by haphazard: color / costuming; connection to parts of ossification process is evident, however not congruous.	Assignment completed and turned in. Work is messy, appears haphazard. No evidence of planning. Connection to ossification process is not readily evident. eg. Timeline, dynamic continuous process	Assignment was turned in but incomplete. No costuming, confusing to the observer.	

Mechanics (20%)	All guidelines met. (see list) No spelling/grammatical errors. Artwork turned in on time.	All but one guideline met. (see list) One spelling/grammatical error. Artwork turned in on time.	All but two guidelines met. (see list) Two-three spelling/grammatical errors. Artwork turned in on time.	All but three guidelines met. (see list) Four spelling/grammatical errors. Artwork turned in on time.	More than 3 guidelines not met. (see list) More than four spelling/grammatical errors. Artwork turned in on time. Note: Artwork turned in late will not be accepted for a grade.	
Artistry (10%)	The project is beautiful and patiently done; it was a good as hard work could make it.	With a little more effort, the work could have been outstanding; lacks the finishing touches.	Student showed average craftsmanship; adequate, but not as good as it could have been, a bit careless.	Student showed below average craftsmanship; lack of pride in finished work.	Student showed poor craftsmanship; evidence of laziness or lack of understanding.	

Appendix H

Self-Efficacy Measuring Instruments, Implementation 1: Sources of Biological Science Self-Efficacy (SBSES) + Science Self Efficacy (SES) + Demographic Survey

Self-Efficacy Measuring Instruments, Implementation 1: Sources of Biological Science Self-Efficacy (SBSES) + Science Self Efficacy (SES) + Demographic Survey

1. Sources of Biological Science Self-Efficacy (SBSES)

Level of Confidence in Biological Sciences I Student Id#__________

Your answers will remain strictly confidential and will NOT affect your grade in this course. If at any time you would prefer not to participate in the survey, please fill out the student ID number above and submit a blank form to your instructor.

For each of the following items below, circle ONE number that BEST describes how you feel about each description.

1. Strongly Disagree (SD)
2. Disagree (D)
3. Neutral (N)
4. Agree (A)
5. Strongly Agree (SA)

	SD	D	N	A	SA
1. I make excellent grades in Biological Sciences.	1	2	3	4	5
2. I have always been successful with Biological Sciences.	1	2	3	4	5
3. Even when I study very hard, I do poorly in Biological Sciences.	1	2	3	4	5
4. I got good grades the last time I took a class in Biological Sciences.	1	2	3	4	5
5. I do well on Biological Science assignments.	1	2	3	4	5
6. I do well on even the most difficult Biological Science assignments.	1	2	3	4	5
7. Seeing other adults do well in Biological Science pushes me to do better.	1	2	3	4	5
8. Many people I know have jobs that involve Biological Science.	1	2	3	4	5
9. Seeing peers do better than me in Biological Sciences pushes me to do better.	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 1: Sources of Biological Science Self-Efficacy (SBSES) + Science Self Efficacy (SES) + Demographic Survey (continued)

10. People I admire are good at science.	1	2	3	4	5
11. The people I want to be like are mostly people who are involved in Biological Science.	1	2	3	4	5
12. I compete with myself in Biological Sciences.	1	2	3	4	5
13. My professors/teachers have told me that I am good at learning Biological Sciences.	1	2	3	4	5
14. People have told me that I have a talent for Biological Sciences.	1	2	3	4	5
15. Adults in my family have told me what a good science student I am.	1	2	3	4	5
16. I have been praised for my ability in Biological Sciences.	1	2	3	4	5
17. Other students have told me that I am good at learning Biological Sciences.	1	2	3	4	5
18. My classmates like to work with me in Biological Sciences because they think I'm good at it.	1	2	3	4	5
19. Just being in Biological Science class makes me feel stressed and nervous.	1	2	3	4	5
20. Doing Biological Science work takes all of my energy.	1	2	3	4	5
21. I start to feel stressed-out as soon as I begin my Biological Science work.	1	2	3	4	5
22. My mind goes blank and I am unable to think clearly when doing Biological Science work.	1	2	3	4	5
23. I get depressed when I think about learning Biological Sciences.	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 1: Sources of Biological Science Self-Efficacy (SBSES) + Science Self Efficacy (SES) + Demographic Survey (continued)

24. My whole body becomes tense when I have to do Biological Sciences.	1	2	3	4	5

2. Science Self-Efficacy (SES)

* Please note that this is a continuation of the previous page, but split apart here so as to highlight the different parts.

25. How confident are you that you will pass this class at the end of the semester?	1	2	3	4	5
26. How confident are you that you will pass this class with a grade better than a D?	1	2	3	4	5
27. How confident are you that you will pass this class with a grade better than a C?	1	2	3	4	5
28. How confident are you that you will pass this class with a grade better than a B?	1	2	3	4	5
29. How confident are you that you will pass this class with a grade better than an A?	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 1: Sources of Biological Science Self-Efficacy (SBSES) + Science Self Efficacy (SES) + Demographic Survey (continued)

3. Demographic Survey (Included in SBSES/SES #1)

For each of the following, check ONE that best describes you:

1. School Status: ________________Full time student
________________Part-time student

2. Prior COLLEGE science courses taken within the last 5 years (circle all that apply):
Introductory Biology I (BIO 101) Anatomy & Physiology I
Introductory Biology II (BIO 102) Anatomy & Physiology II
College Chemistry I College Chemistry II
Other:____
____
____

3. Prior art/music/dance courses taken within the last 5 years in college or otherwise:
Dance (Ballet, tap, jazz, hip-hop, etc) Sculpture Drawing
Music (band, any instrument, vocal, etc) Photography
Other:____
____
____

4. Gender: ________ Male _________Female

5. Age:

_________________15-20	_________________36-40
_________________21-25	_________________41-45
_________________26-30	_________________46-50
_________________31-35	_________________ over 50

6. Ethnicity: ______________ African American
______________Asian
______________Caucasian
______________ Hispanic
______________ Indian
______________other (please specify)

THANK YOU FOR YOUR PARTICIPATION IN THIS SURVEY!

Appendix I

Self-Efficacy Measuring Instruments, Implementation 2: SBSES+SES

Self-Efficacy Measuring Instruments, Implementation 2: SBSES+SES

Level of Confidence in Biological Sciences II Student Id#__________

Your answers will remain strictly confidential and will NOT affect your grade in this course. If, at any time you would prefer not to participate in the survey, please fill out the student ID number above and submit a blank form to your instructor.

For each of the following items below, circle ONE number that BEST describes how you feel about each description.

1. Strongly Disagree (SD)
2. Disagree (D)
3. Neutral (N)
4. Agree (A)
5. Strongly Agree (SA)

SD D N A SA

1. I make excellent grades in Biological Sciences.	1	2	3	4	5
2. I have always been successful in Biological Sciences.	1	2	3	4	5
3. Even when I study very hard, I do poorly in Biological Sciences.	1	2	3	4	5
4. I got good grades the last time I took a class in Biological Sciences.	1	2	3	4	5
5. I do well on Biological Science assignments.	1	2	3	4	5
6. I do well on even the most difficult Biological Science assignments.	1	2	3	4	5
7. Seeing other adults do well in Biological Science pushes me to do better.	1	2	3	4	5
8. Many people I know have jobs that involve Biological Science.	1	2	3	4	5
9. Seeing peers do better than me in Biological Sciences pushes me to do better.	1	2	3	4	5
10. People I admire are good at science.	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 2: SBSES+SES (continued)

11. The people I want to be like are mostly people who are involved in Biological Science.	1	2	3	4	5
12. I compete with myself in Biological Sciences.	1	2	3	4	5
13. My professors/teachers have told me that I am good at learning Biological Sciences.	1	2	3	4	5
14. People have told me that I have a talent for Biological Sciences.	1	2	3	4	5
15. Adults in my family have told me what a good science student I am.	1	2	3	4	5
16. I have been praised for my ability in Biological Sciences.	1	2	3	4	5
17. Other students have told me that I am good at learning Biological Sciences.	1	2	3	4	5
18. My classmates like to work with me in Biological Sciences because they think I'm good at it.	1	2	3	4	5
19. Just being in Biological Science class makes me feel stressed and nervous.	1	2	3	4	5
20. Doing Biological Science work takes all of my energy.	1	2	3	4	5
21. I start to feel stressed-out as soon as I begin my Biological Science work.	1	2	3	4	5
22. My mind goes blank and I am unable to think clearly when doing Biological Science work.	1	2	3	4	5
23. I get depressed when I think about learning Biological Sciences.	1	2	3	4	5
24. My whole body becomes tense when I have to do Biological Sciences.	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 2: SBSES+SES (continued)

25. How confident are you that you will pass this class at the end of the semester?	1	2	3	4	5
26. How confident are you that you will pass this class with a grade better than a D?	1	2	3	4	5
27. How confident are you that you will pass this class with a grade better than a C?	1	2	3	4	5
28. How confident are you that you will pass this class with a grade better than a B?	1	2	3	4	5
29. How confident are you that you will pass this class with a grade better than an A?	1	2	3	4	5

THANK YOU FOR YOUR PARTICIPATION IN THIS SURVEY!

Appendix J

Self-Efficacy Measuring Instruments, Implementation 3: SBSES + SES

Self-Efficacy Measuring Instruments, Implementation 3: SBSES + SES

Level of Confidence in Biological Sciences III, Part I Student Id#__________

Your answers will remain strictly confidential and will NOT affect your grade in this course. If, at any time you would prefer not to participate in the survey, please fill out the student ID number above and submit a blank form to your instructor.

For each of the following items below, circle ONE number that BEST describes how you feel about each description.

1. Strongly Disagree (SD)
2. Disagree (D)
3. Neutral (N)
4. Agree (A)
5. Strongly Agree (SA)

	SD	D	N	A	SA
1. I make excellent grades in Biological Sciences.	1	2	3	4	5
2. I have always been successful with Biological Sciences.	1	2	3	4	5
3. Even when I study very hard, I do poorly in Biological Sciences.	1	2	3	4	5
4. I got good grades the last time I took a class in Biological Sciences.	1	2	3	4	5
5. I do well on Biological Science assignments.	1	2	3	4	5
6. I do well on even the most difficult Biological Science assignments.	1	2	3	4	5
7. Seeing other adults do well in Biological Science pushes me to do better.	1	2	3	4	5
8. Many people I know have jobs that involve Biological Science.	1	2	3	4	5
9. Seeing peers do better than me in Biological Sciences pushes me to do better.	1	2	3	4	5
10. People I admire are good at science.	1	2	3	4	5
11. The people I want to be like are mostly people who are involved in Biological Science.	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 3: SBSES + SES (continued)

12. I compete with myself in Biological Sciences.	1	2	3	4	5
13. My professors/teachers have told me that I am good at learning Biological Sciences.	1	2	3	4	5
14. People have told me that I have a talent for Biological Sciences.	1	2	3	4	5
15. Adults in my family have told me what a good science student I am.	1	2	3	4	5
16. I have been praised for my ability in Biological Sciences.	1	2	3	4	5
17. Other students have told me that I am good at learning Biological Sciences.	1	2	3	4	5
18. My classmates like to work with me in Biological Sciences because they think I'm good at it.	1	2	3	4	5
19. Just being in Biological Science class makes me feel stressed and nervous.	1	2	3	4	5
20. Doing Biological Science work takes all of my energy.	1	2	3	4	5
21. I start to feel stressed-out as soon as I begin my Biological Science work.	1	2	3	4	5
22. My mind goes blank and I am unable to think clearly when doing Biological Science work.	1	2	3	4	5
23. I get depressed when I think about learning Biological Sciences.	1	2	3	4	5
24. My whole body becomes tense when I have to do Biological Sciences.	1	2	3	4	5
25. How confident are you that you will pass this class at the end of the semester?	1	2	3	4	5

Self-Efficacy Measuring Instruments, Implementation 3: SBSES + SES (continued)

26. How confident are you that you will pass this class with a grade better than a D?	1	2	3	4	5
27. How confident are you that you will pass this class with a grade better than a C?	1	2	3	4	5
28. How confident are you that you will pass this class with a grade better than a B?	1	2	3	4	5
29. How confident are you that you will pass this class with a grade better than an A?	1	2	3	4	5

THANK YOU FOR YOUR PARTICIPATION IN THIS SURVEY!

Appendix K

Self-Efficacy Measuring Instruments: Student Self-Efficacy Response Survey

Self-Efficacy Measuring Instruments: Student Self-Efficacy Response Survey

<u>Level of Confidence in Biological Sciences III, Part II</u> Student Id#___________

Your answers will remain strictly confidential and will NOT affect your grade in this course. If, at any time you would prefer not to participate in any or all of the survey, please fill out the student ID number above and submit a blank form to your instructor.

For each of the following items below, answer honestly and to the best of your ability. If you need more space, please feel free to use the back of the page.

1. Under what conditions do you perform well in Biological Sciences? Under what conditions do you perform less well? Why?

2. Describe your participation in the design project this semester.

3. Discuss the design project and its relationship to learning the material.

4. Did participation in the design project affect your confidence in Anatomy? Explain.

5. How did you feel when taking the first lab practical this semester? How about the second lab practical? If there was a difference, what do you think caused that difference? Why?

Appendix L

Self-Efficacy Codebook

Self-Efficacy Codebook

Source of Self Efficacy	Code Label	Definition	Description of code use	Example(s)
Mastery Experience	ME	Successes by learners through their own active involvement in learning.	Statements from students connecting active experiences to having a positive or negative influence on their perceptions of Biological science content.	"I felt like I understood the material & was able to apply it in another way." "The project helped relate the visual aspects to the function."
Vicarious Experience	VE	Observing others perform tasks and judging personal capability in relation to that of others.	Statements about the impact of watching other people being successful with regard to the class or project.	"I perform well in an environment with others who are doing well."
Social (Verbal) Persuasion	SP	Verbal and non-verbal feedback from peers, professor or others in the students' sphere of influence.	Statements from students addressing the impact of verbal and nonverbal feedback in the learning of Biological Sciences.	"… Dr. X is very encouraging…" "…the professor challenges and encourages me…"
Psychological and Emotional States	A	Physiological condition that may result from mood or state of mind.	Statements about mood or state of mind as related to learning Biological Science.	"I tend to freak myself out before tests." "I'm concerned that my lack of creativity will negatively impact my grade."

Note: Based on Bandura (1995) and Brand & Wilkins (2007)

Appendix M

Regression Statistics: Predictors of Total Self-Efficacy

Regression Statistics: Predictors of Total Self-Efficacy

Predictors of Total Science Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1[a]	.68	.47	.33	.59	.47	3.36	8	31	.01
2[b]	.69	.47	.31	.60	.00	.23	1	30	.63
3[c]	.69	.47	.30	.71	.47	2.80	8	25	.02
4[d]	.70	.48	.29	.72	.01	.47	1	24	.50

Note: a. Predictors: gender, schoolstatus, ethnicity, age, VE2, PH2, ME2, P2
b. Predictors: gender, schoolstatus, ethnicity, age, VE2, PH2, ME2, P2, project id
c. Predictors: gender, schoolstatus, ethnicity, age, VE3, PH3, ME3, P3
d. Predictors: gender, schoolstatus, ethnicity, age, VE3, PH3, ME3, P3, projected

Appendix N

Student Demographics at Study Outset

Student Demographics at Study Outset

		Number of Student Participants	Gender		Age Range								School Status		Number of Prior College Science Courses	Number of Prior College Art Courses	Ethnicity					
			Male	Female	15-20	21-25	26-30	31-35	36-40	41-45	46-50	Over 50	Full Time	Part Time	**M**	**M**	African American	Asian	Caucasian	Hispanic	Indian	Other
Professor #1	Lab Section #1	20	5	15	13	1	2	2	0	1	0	1	12	8	0.60	0.40	3	2	13	1	0	1
	Lab Section #2	6	0	6	3	1	1	0	0	0	0	1	5	1	1	0.33	0	0	6	0	0	0
Professor #2	Lab Section #1	19	6	13	4	6	2	4	1	1	0	0	5	14	1	0.32	0	0	19	0	0	0
	Lab Section #2	18	0	18	3	4	1	4	3	3	0	0	8	10	1.3	0.06	3	0	15	0	0	0
	TOTAL	63	11	52	23	12	6	10	4	5	0	2	30	33	0.98	0.28	6	2	53	1	0	1

Note: This table displays a complete listing of participant demographics at the outset of the study.

Appendix O

Student Demographics at Study Ending

Student Demographics at Study Ending

		Number of Student Participants	Gender		Age Range								School Status		Number of Prior College Science Courses	Number of Prior College Art Courses	Ethnicity					
			Male	Female	15-20	21-25	26-30	31-35	36-40	41-45	46-50	Over 50	Full Time	Part Time	**M**	**M**	African American	Asian	Caucasian	Hispanic	Indian	Other
Professor #1	Lab Section #1	15	5	10	9	1	2	1	0	1	0	1	12	3	.73	.53	3	2	9	0	0	1
	Lab Section #2	6	0	6	3	1	1	0	0	0	0	1	5	1	1.0	.33	0	0	6	0	0	0
Professor #2	Lab Section #1	5	0	5	1	2	0	1	0	1	0	0	1	4	.40	.60	0	0	5	0	0	0
	Lab Section #2	10	0	10	3	3	0	1	2	1	0	0	4	6	1.1	0	0	0	10	0	0	0
	TOTAL	36	5	31	16	7	3	3	2	3	0	2	22	14	.80	.37	3	2	30	0	0	1

Note: This table displays a complete listing of participant demographics at the end of the study.

Appendix P

Data Addressing Research Question #1

Data Addressing Research Question #1

Part 1: Correlations Among Variables Addressing Research Question #1

Zero-Order Correlations for Variables in the Study, Research Question #1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Total Science Efficacy	-																				
2. Mastery Experience 1	**.442****	--																			
3. Vicarious Experience 1	.255	.190	-																		
4. Social Persuasion 1	**.500****	**.604****	.265	-																	
5. Psychological States 1	**.370***	.295	.013	**.360***	-																
6. Total SE 2	**.383***	**.458****	.260	.081	.237	-															
7. ME 2	**.319***	**.716****	**.324***	**.478****	.284	**.474****	-														
8. VE 2	.133	.042	**.556****	.207	.207	.133	.180	-													
9. SP 2	**.591****	**.684****	.226	**.740****	**.740****	**.591****	**.697****	.107	-												
10. A 2	-.256	.090	.166	.102	.102	-.172	.119	.258	-.061	-											
11. Total SE 3	**.627****	**.356***	**.360***	**.403***	**.403***	**.639****	.331	.284	.305	.305	-										
12. ME 3	**.368***	**.727****	.330	**.572****	**.572****	**.565****	**.805****	.294	**.689****	**.689****	**.467****	-									
13. VE 3	.194	.108	**.524****	.196	.196	.305	.250	**.724****	.164	.164	**.437****	.266	-								
14. SP 3	**.443****	**.680****	**.372***	**.773****	**.773****	**.529****	**.680****	.319	**.804****	-.100	**.537****	**.796****	**.351***	-							
15. A 3	.121	.272	.228	**.360***	**.360***	.237	.284	.261	.215	**.365***	**.627****	.322	.270	.161	-						
16. Age	-.083	.059	.122	-.002	-.002	.181	-.018	.003	-.136	-.055	.207	-.104	.216	-.046	.004	-					
17. Ethnicity	**.462****	.182	.034	.204	.204	**.355***	.078	.024	.223	-.122	.316	.033	.042	.210	.230	.127	-				
18. School Status	.160	.219	-.081	.240	.240	-.011	.230	.083	**.336***	.003	.091	.245	-.042	.169	.175	-.185	.079	-			
19. Prior Science	.075	.005	**.521****	.179	.179	.102	-.054	.298	.041	.138	.213	.050	.248	.214	.087	.190	.079	-.091	-		
20. Prior Art	-.015	-.169	-.105	.010	.010	-.078	-.065	.038	.141	-.165	.011	-.073	.250	.075	-.095	-.146	-.037	-.012	.211	-	
21. Gender	-.054	.102	.175	.134	.134	.267	.127	.065	.173	-.099	.166	.221	-.003	.229	.068	.173	.148	-.114	.205	.047	-
22. Project Type	-.099	.171	-.033	-.078	-.078	.188	**.353***	-.204	.047	-.140	-.048	.158	-.163	.193	-.172	-.104	-.080	.006	.017	-.131	.233

Note: **Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Part 2: Repeated Measures MANCOVA results for Research Question #1

a. Effects of the Design Project on Total Self-Efficacy and its Hypothesized Sources

Effect		Value	*F*	Hypothesis *df*	Error *df*	Sig	Power	Partial Eta squared
Total SE	Wilks' Lambda	.987	.170	2.000	25.000	.845	.073	.013
Total SE* Project	Wilks' Lambda	.994	.076	2.000	25.000	.927	.060	.006
Total ME	Wilks' Lambda	.834	2.484	2.000	25.000	.104	.452	.166
Total ME*Project	Wilks' Lambda	.895	1.474	2.000	25.000	.248	.285	.105
Total VE	Wilks' Lambda	.987	.170	2.000	25.000	.844	.074	.013
Total VE*Project	Wilks' Lambda	.985	.190	2.000	25.000	.828	.076	.015
Total SP	Wilks' Lambda	.871	1.846	2.000	25.000	.179	.348	.129
Total SP*Project	Wilks' Lambda	.949	.677	2.000	25.000	.517	.151	.051
Total A	**Wilks' Lambda**	**.758**	**3.989**	**2.000**	**25.000**	**.031**	**.660**	**.242**
Total A*Project	**Wilks' Lambda**	**.664**	**6.330**	**2.000**	**25.000**	**.006**	**.859**	**.336**

Note: All statistics computed using alpha = .05.

b. Effects of the Design Project on Total Self-Efficacy and its Hypothesized Sources: Within Subjects Effects

Effect	Measure	Type III Sum Of Squares	Mean Square	*F*	Sig	Power	Partial Eta squared
Total SE	Sphericity Assumed	.116	.058	.228	.797	.084	.009
Project* Total SE	Sphericity Assumed	.051	.025	.100	.905	.065	.004
Total ME	Sphericity Assumed	.417	.209	3.132	.052	.577	.108
Project*Total ME	Sphericity Assumed	.260	.130	1.951	.152	.386	.070
Total VE	Greenhouse-Geisser	.059	.039	.199	.760	.076	.008
Project *Total VE	Greenhouse-Geisser	.043	.028	.146	.807	.069	.006
Total SP	Sphericity Assumed	.452	.226	1.938	.154	.384	.069
Project *Total SP	Sphericity Assumed	.167	.083	.714	.494	.164	.027
Total A	**Sphericity Assumed**	**1.972**	**.986**	**3.494**	**.038**	**.628**	**.118**
Project*Total A	**Sphericity Assumed**	**3.110**	**1.555**	**5.512**	**.007**	**.831**	**.175**

c. Effects of the Design Project on Total Self-Efficacy and its Hypothesized Sources: Between Subjects Effects

Effect	Type III Sum Of Squares	Mean Square	*F*	Sig	Power	Partial Eta squared
Project* Total SE	1.615	1.615	1.465	.237	.214	.053
Project*Total ME	.757	.757	1.386	.250	.205	.051
Project *Total VE	.015	.015	.025	.874	.053	.001
Project *Total SP	1.489	1.489	1.149	.294	.178	.042
Project*Total A	2.858	2.858	1.443	.241	.212	.053

Note: *df* = (1, 26)

d. Repeated Measures MANCOVA: Ethnicity and Total Self-Efficacy, Using Project ID as a Covariate

Effect		Value	*F*	Hypothesis *df*	Error *df*	Sig	Partial Eta squared
Ethnicity	Wilks' Lambda	.971	.396	2.000	27.000	.677	.029
Total SE *Project ID	Wilks' Lambda	.987	.177	2.000	27.000	.839	.013
Total SE* Ethnicity	Wilks' Lambda	.875	.468	8.000	54.000	.873	.065

Note: Design: Intercept + projected = ethnicity; Within subjects design: Total SE

Part 3: Pairwise Comparisons for Ethnicity

Pairwise Comparisons for Ethnicity and its Effect on Total Science Self-Efficacy

					95% Confidence Interval for Difference	
Ethnicity	Ethnicity	Mean Difference	Standard Error	Significance	Lower Bound	Upper Bound
African American	Asian	-0.900	0.511	0.089	-0.195	0.146
	Caucasian	-0.936	0.344	0.011	-1.641	-0.231
	Hispanic	-0.933	0.646	0.159	-2.256	0.389
	Other	-1.733	0.646	0.012	-3.056	-0.411
Asian	African American	0.900	0.511	0.089	-0.146	1.946
	Caucasian	-0.036	0.413	0.930	-0.882	0.810
	Hispanic	-0.033	0.685	0.962	-1.436	1.370
	Other	-0.833	0.685	0.234	-2.236	0.570
Caucasian	African American	0.936	0.344	0.011	0.231	1.641
	Asian	0.036	0.413	0.930	-0.810	0.882
	Hispanic	0.003	0.572	0.996	-1.168	1.174
	Other	-0.797	0.572	0.174	-1.968	0.374
Hispanic	African American	0.933	0.646	0.159	-0.389	2.256
	Asian	0.033	0.685	0.962	-1.370	1.436
	Caucasian	-0.033	0.572	0.996	-1.174	1.168
	Other	-0.800	0.791	0.320	-2.420	0.820
Other	African American	1.733	0.646	0.012	0.411	3.056
	Asian	0.833	0.685	0.234	-0.570	2.236
	Caucasian	0.797	0.572	0.174	-0.374	1.968
	Hispanic	0.800	0.791	0.320	-0.820	2.420

Part 4: Regression Tables

a. Predictors of Entering Students' Biological Science Self-Efficacy (Measure 1)

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	0.099	0.01	-0.016	0.576	0.010	0.378	1	38	0.542
2b	**0.466**	**0.217**	**0.175**	**0.519**	**0.207**	**9.794**	**1**	**37**	**0.003**
3c	0.479	0.229	0.165	0.522	0.012	0.577	1	36	0.453
4d	0.497	0.247	0.161	0.523	0.017	0.799	1	35	0.377
5e	0.505	0.255	0.145	0.528	0.008	0.367	1	34	0.549
6f	0.512	0.263	0.128	0.533	0.008	0.353	1	33	0.556
7g	0.514	0.264	0.103	0.541	0.002	0.067	1	32	0.797

a. Predictors: Project ID
b. Predictors: Project ID, ethnicity
c. Predictors: Project ID, ethnicity, gender
d. Predictors: Project ID, ethnicity, gender, age
e. Predictors: Project ID, ethnicity, gender, age, schoolstatus
f. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience
g. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience, priorart

b. Predictors of Students' Biological Science Self-Efficacy (Measure 2)

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	**.331**	**.109**	**.086**	**.731**	**.109**	**4.665**	**1**	**38**	**.037**
2b	**.482**	**.232**	**.191**	**.688**	**.123**	**5.915**	**1**	**37**	**.020**
3c	.486	.236	.172	.696	.004	.177	1	36	.677
4d	.490	.240	.153	.704	.004	.179	1	35	.675
5e	.495	.245	.134	.712	.005	.221	1	34	.641
6f	.539	.291	.162	.700	.046	2.151	1	33	.152
7g	.540	.292	.137	.710	.001	.044	1	32	.835

a. Predictors: Project ID
b. Predictors: Project ID, ethnicity
c. Predictors: Project ID, ethnicity, gender
d. Predictors: Project ID, ethnicity, gender, age
e. Predictors: Project ID, ethnicity, gender, age, schoolstatus
f. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience
g. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience, priorart

Part 4: Regression Tables (continued)

c. Predictors of Students' Biological Science Self-Efficacy (Measure 3)

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.075	.006	-.029	.876	.006	.164	1	29	.689
2b	.336	.113	.050	.842	.108	3.395	1	28	.076
3c	.355	.126	.029	.851	.013	.397	1	27	.534
4d	.362	.131	-.003	.865	.005	.149	1	26	.702
5e	.402	.162	-.006	.867	.031	.910	1	25	.349
6f	.483	.233	.041	.846	.072	2.240	1	24	.148
7g	.483	.233	.000	.864	.000	.000	1	23	.996

a. Predictors: Project ID
b. Predictors: Project ID, ethnicity
c. Predictors: Project ID, ethnicity, gender
d. Predictors: Project ID, ethnicity, gender, age
e. Predictors: Project ID, ethnicity, gender, age, schoolstatus
f. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience
g. Predictors: Project ID, ethnicity, gender, age, schoolstatus, priorscience, priorart

Part 4: Regression Tables (continued)

d. Sources of Self-Efficacy as Predictors of Total Biological Science Self-Efficacy

Variable	Construct Predicted	Standardized β	ΔF	R^2	Adjusted R^2
ME1	TOTSE1	.442	**9.217****	.195	.174
VE1	TOTSE1	.177	1.446	.225	.184
SP1	TOTSE1	.500	**3.567****	.295	.237
A1	TOTSE1	-.528	**18.555*****	.279	.264
ME2	TOTSE2	.474	**11.020****	.225	.204
VE2	TOTSE2	0.66	.201	.229	.187
SP2	TOTSE2	-.165	.663	.243	.180
A2	TOTSE2	-.465	**4.140***	.323	.246
ME3	TOTSE3	.467	**8.914****	.218	.193
VE3	TOTSE3	.337	**4.839***	.323	.280
SP3	TOTSE3	.343	.347	.364	.301
A3	TOTSE3	-.598	16.173***	.358	.336

Note: *p < .05. **p < .01; ***p < .001.

Part 5: *Paired t tests among sources of self-efficacy*

					95% CI			
		M	SD	SEM	Lower	Upper	*t*	Significance
Pair 1	Total ME1 - Total ME2	-.04	.33	.05	-.15	.07	-.75	.46
Pair 2	Total ME2 - Total ME3	.10	.42	.08	-.06	.26	1.34	.19
Pair 3	Total VE1 - Total VE2	-.19	.58	.09	-.38	.00	-2.00	.05
Pair 4	Total VE2 - Total VE3	.06	.43	.08	-.10	.22	.73	.47
Pair 5	Total PS1 - Total PS2	-.15	.55	.09	-.33	.03	-1.70	.10
Pair 6	Total PS2 - Total PS3	.17	.45	.09	-.01	.35	1.95	.06
Pair 7	Total A1 - Total A2	-.20	.78	.13	-.45	.06	-1.56	.13
Pair 8	Total A2 - Total A3	-.05	.81	.15	-.36	.26	-.34	.73

Appendix Q

Regression Statistics: Prediction of Content Knowledge

Regression Statistics: Prediction of Content Knowledge

a. Prediction of Content Knowledge (Practicum #1) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.141	.020	-.005	12.8664	.020	.791	1	39	.379
2b	.253	.064	.015	12.7367	.044	1.798	1	38	.188
3c	.263	.069	-.006	12.8717	.005	.207	1	37	.652
4d	.303	.092	-.009	12.8891	.023	.900	1	36	.349
5e	.307	.094	-.035	13.0563	.002	.084	1	35	.773
6f	.352	.124	-.031	13.0307	.029	1.137	1	34	.294

a. Predictors: Project ID
b. Predictors: Project ID, Total SE2
c. Predictors: Project ID, Total SE2, Total ME2
d. Predictors: Project ID, Total SE2, Total ME2, Total VE2
e. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2
f. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2, Total A2

b. Prediction of Content Knowledge (Common Tissue Questions) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.072	.005	-.020	1.0199	.005	.205	1	39	.654
2b	.265	.070	.021	.9988	.065	2.661	1	38	.111
3c	.279	.078	.003	1.0081	.008	.309	1	37	.582
4d	.292	.085	-.017	1.0181	.007	.274	1	36	.604
5e	.389	.151	.030	.9944	.066	2.735	1	35	.107
6f	.395	.156	.007	1.0060	.005	.201	1	34	.657

a. Predictors: Project ID
b. Predictors: Project ID, Total SE2
c. Predictors: Project ID, Total SE2, Total ME2
d. Predictors: Project ID, Total SE2, Total ME2, Total VE2
e. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2
f. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2, Total A2

Regression Statistics: Prediction of Content Knowledge (continued)

c. Prediction of Content Knowledge (Practicum #2) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.218	.048	.015	14.9994	.048	1.447	1	29	.239
2b	.365	.133	.072	14.5597	.086	2.778	1	28	.107
3c	.365	.134	.037	14.8265	.000	.001	1	27	.970
4d	.387	.150	.019	14.9659	.016	.499	1	26	.486
5e	.393	.155	-.014	15.2183	.005	.145	1	25	.707
6f	.397	.158	-.053	15.5032	.003	.090	1	24	.767

a. Predictors: Project ID
b. Predictors: Project ID, Total SE3
c. Predictors: Project ID, Total SE3, Total ME3
d. Predictors: Project ID, Total SE3, Total ME3, Total VE3
e. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3
f. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3, Total A3

d. Prediction of Content Knowledge (Common Questions: Bone) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.116	.013	-.021	1.1476	.013	.394	1	29	.535
2b	.143	.020	-.050	1.1637	.007	.199	1	28	.659
3c	.145	.021	-.088	1.1847	.001	.016	1	27	.900
4d	.250	.062	-.082	1.1815	.041	1.150	1	26	.293
5e	.432	.187	.024	1.1222	.124	3.819	1	25	.062
6f	.465	.217	.021	1.1240	.030	.919	1	24	.347

a. Predictors: Project ID
b. Predictors: Project ID, Total SE3
c. Predictors: Project ID, Total SE3, Total ME3
d. Predictors: Project ID, Total SE3, Total ME3, Total VE3
e. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3
f. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3, Total A3

Regression Statistics: Prediction of Content Knowledge (continued)

e. Prediction of Content Knowledge (Common Questions: Ossification) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.179	.032	-.001	2.3377	.032	.957	1	29	.336
2b	.300	.090	.025	2.3068	.058	1.784	1	28	.192
3c	.319	.102	.002	2.3337	.012	.357	1	27	.555
4d	.441	.195	.071	2.2520	.093	2.996	1	26	.095
5e	.484	.234	.081	2.2394	.040	1.292	1	25	.266
6f	.539	.290	.113	2.2001	.056	1.902	1	24	.181

g. Predictors: Project ID
h. Predictors: Project ID, Total SE3
i. Predictors: Project ID, Total SE3, Total ME3
j. Predictors: Project ID, Total SE3, Total ME3, Total VE3
k. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3
l. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3, Total A3

f. Prediction of Content Knowledge (Project Grade) by Project, Total Self-Efficacy and Sources of Self-Efficacy

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.055	.003	-.023	18.6384	.003	.120	1	39	.731
2b	.106	.011	-.041	18.8048	.008	.313	1	38	.579
3c	.330	.109	.036	18.0935	.097	4.047	1	37	.052
4d	.338	.115	.016	18.2830	.006	.237	1	36	.630
5e	.338	.115	-.012	18.5424	.000	.000	1	35	.993
6f	.345	.119	.036	18.7614	.005	.187	1	34	.668

m. Predictors: Project ID
n. Predictors: Project ID, Total SE2
o. Predictors: Project ID, Total SE2, Total ME2
p. Predictors: Project ID, Total SE2, Total ME2, Total VE2
q. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2
r. Predictors: Project ID, Total SE2, Total ME2, Total VE2, Total SP2, Total A2

g.   Prediction of Content Knowledge (Common Questions: Ossification) by Project, Total Self-Efficacy and Sources of Self-Efficacy

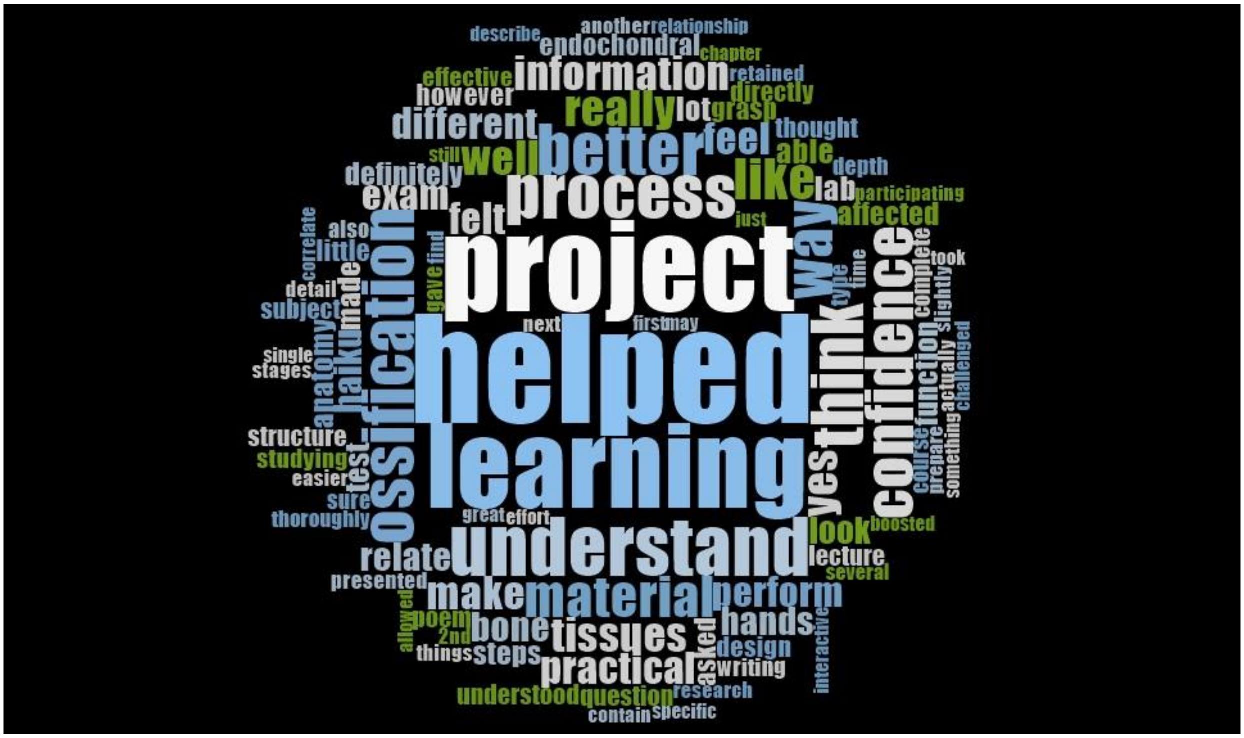
Model	R	R^2	Adjusted R^2	Standard Error of the Estimate	ΔR^2	ΔF	*df 1*	*df* 2	Sig. ΔF
1a	.060	.004	-.031	14.7085	.004	.104	1	29	.749
2b	.099	.010	-.061	14.9214	.006	.178	1	28	.676
3c	.123	.015	-.094	15.1554	.005	.142	1	27	.709
4d	.153	.023	-.127	15.3782	.008	.223	1	26	.641
5e	.187	.035	-.158	15.5900	.012	.298	1	25	.590
6f	.202	.041	-.199	15.8635	.006	.145	1	24	.706

s. Predictors: Project ID
t. Predictors: Project ID, Total SE3
u. Predictors: Project ID, Total SE3, Total ME3
v. Predictors: Project ID, Total SE3, Total ME3, Total VE3
w. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3
x. Predictors: Project ID, Total SE3, Total ME3, Total VE3, Total SP3, Total A3

Appendix R

Word Cloud: Word Frequencies Within Mastery Experiences

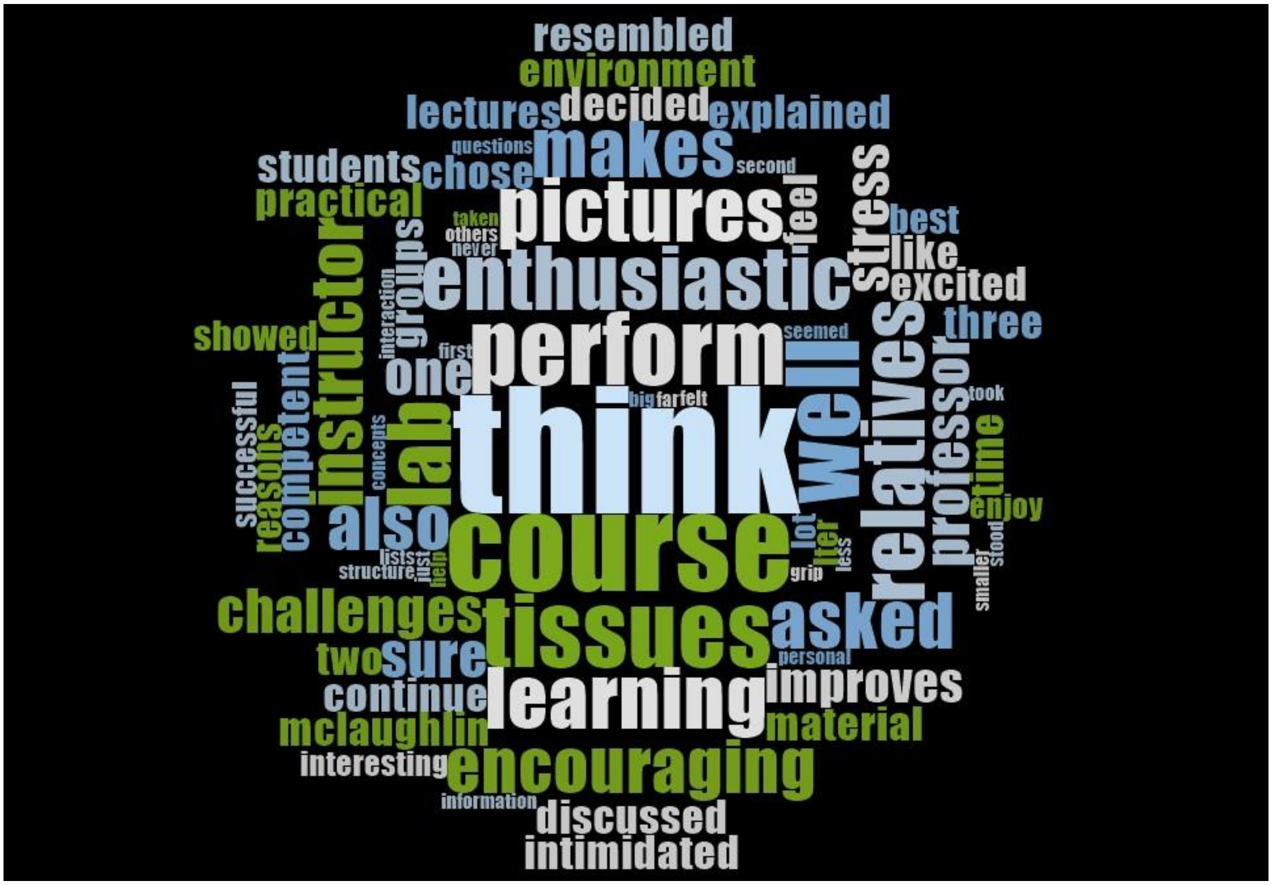
Word Cloud: Word Frequencies Within Mastery Experiences



Appendix S

Word Cloud: Word Frequencies Within Social Persuasion

Word Cloud: Word Frequencies Within Social Persuasion



Appendix T

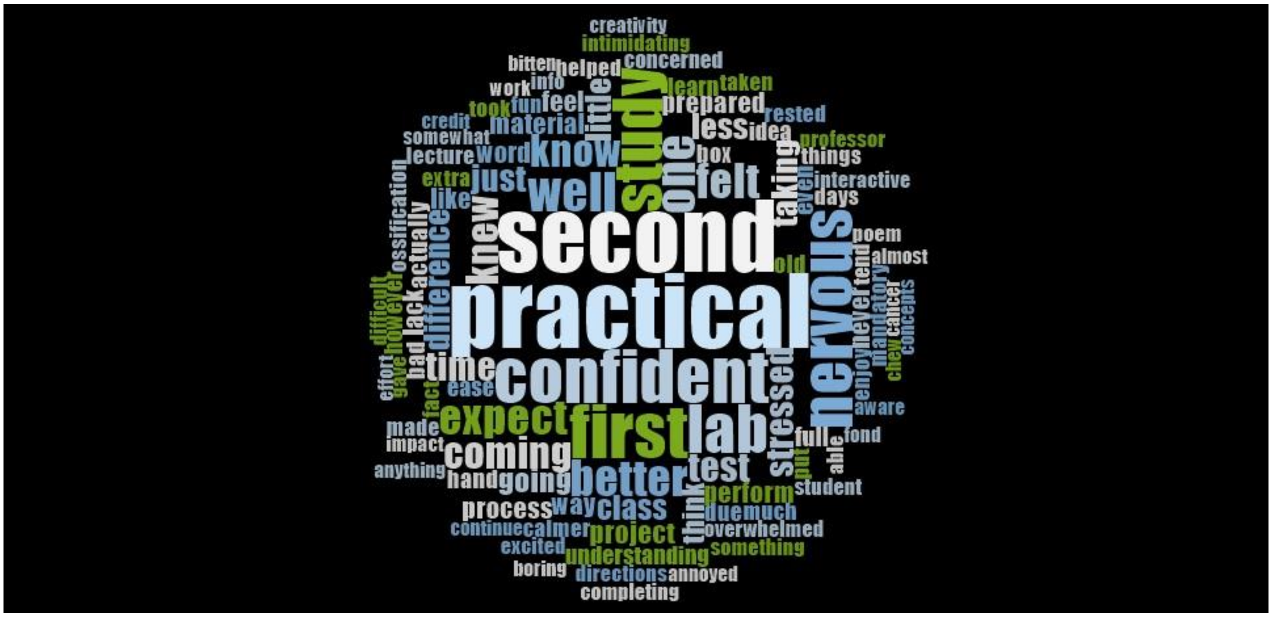
Word Cloud: Word Frequencies Within Vicarious Experiences

Word Cloud: Word Frequencies Within Vicarious Experiences

Appendix U

Word Cloud: Word Frequencies Within Psychological States

Word Cloud: Word Frequencies Within Psychological States



Appendix V

Effects of Project Type on Mastery Experiences

Effects of Project Type on Mastery Experiences

Multivariate Effects of Design Project on Mastery Experiences, Measurement #3

Effect	Mean Square	R2	Adj. R2	Sig.	*F*	Partial Eta squared	Noncent. Parameter	Observed Power
Project Type	.133	.956	.881	.084	3.607	.247	3.607	.411

Note: Measures included ME3 while holding all other sources of self-efficacy and Total self-efficacy constant. Significance computed using alpha = 0.05.