EFFECTS OF STEM PROJECTS' AUTHENTICITY IN HIGH SCHOOL AGRICULTURAL MECHANICS

A Dissertation

by

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ABSTRACT

Researchers have reported that participation in agricultural education reinforces STEM concepts. The use of projects in instruction is common in agricultural education. However, the foundational understanding of certain tenets of this method of instruction is not clear. I conducted a quasi-experimental study to test how real and/or authentic projects need to be to affect learning. Agriculture Food and Natural Resources students in Texas were sampled and assigned as a cohort group to one of four treatment groups (N = 219). Fourteen cohort groups (class periods) were identified in five sites. I assigned randomly each of the 14 cohort groups to one of the four project types varying in their design according to the degree of project authenticity when learning about electricity.

I used analysis of covariance (ANCOVA) to test the effects of project authenticity, student perceptions of the projects, tenure in high school agricultural education, STEM perceptions, and perceived novelty on change scores in a pretest posttest quasi-experimental design. Project type varied on authenticity. A test of project type groups yielded statistically significant results ($p < .025$) with small effect size ($\omega^2 = .04$). Pairwise comparisons revealed no differences between the most and least authentic projects but statistically significant differences between the two projects with medium levels of authenticity and the other two kinds of projects (i.e., least authentic and most authentic). Projects with medium levels of authenticity were also projects that offered most cognitive dissonance to the participants. Student perceptions of novelty were also statistically significant with small effect size. No other statistically significant effects were found of the independent variables on change scores.

DEDICATION

For my family.

I believe in the promise of better days through better ways, even as the better things we now enjoy have come to us from the struggles of former years. *FFA Creed*

I believe that the life of service is the life that counts; that happiness endures to mankind when it comes from having helped lift the burdens of others. *NFA Creed*

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Always trust your cape…

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Contributors

This work was supervised by a dissertation committee consisting of Dr. Timothy H. Murphy (advisor), Dr. Billy R. McKim, and Dr. Gary E. Briers all of the Department of Agricultural Leadership, Education, and Communications and Dr. Carol L. Stuessy of Department of Teaching, Learning, and Culture. All work for the dissertation was completed independently by the student.

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CHAPTER I

INTRODUCTION

The rationale behind the comment "Context is king" speaks to one of the many reasons agricultural education is effective and different from other areas of education. Practitioners of agricultural education, myself included, believe that the context provided by the discipline can make the rest of school matter. In the following pages I will present an argument that agricultural education was originally intended to be a context or application piece to many disciplines of education. I will argue that through political and economic pressure, agricultural education was changed into a vocational training regime that removed core academic (now read to mean STEM) classwork. I will argue that influential decision makers in education took these actions deliberately to separate core academic concepts from agricultural education. I will also conclude that agricultural education, and education as a whole, would have served student learning more efficiently had agricultural education remained part of the physical and life sciences. I pose these arguments to explain the circumstances that were presented to me when I began this study. I was told that agricultural education should "stay on its side of the building" and leave science and mathematics instruction to the "real teachers." I was told that agriculture teachers should stick to showing cattle and welding. Within the discipline, the saying is that agricultural education is "more than sows, cows, and plows." If that is true, why do agricultural educators continuously have to remind colleagues of the saying? I hope that the study performed here will inform the practice of agricultural education in a meaningful way to support agricultural education's correct place as part of the sciences.

Background

Referendum and reform in the current landscape of education have become commonplace. In 2015, President Obama signed into law the Every Student Succeeds Act, a revision of the venerable Elementary and Secondary Education Act (ESEA) (1965). Known in its original form as No Child Left Behind (NCLB), this 2015 law attempted to make strides toward what was considered modernization of our education system (No Child Left Behind Act, 2001). Although the ESEA, and more so the NCLB, garnered interest and incited national discussions, there are two instances in the history of education (specifically, science education) that have been more influential: The National Defense Education Act (NDEA) in 1958 and the report, *A Nation at Risk*, written nearly 25 years later.

A Nation at Risk, published in 1983, was a warning to the contemporarily accepted norm of American academic primacy. Its primary concern was Russian intellectual dominance in science and mathematics. The United States immediately responded to this warning with widespread conversation about the standards of education. Educators scrambled to find more effective ways to teach science and math concepts. Now, thirty-plus years after its publication, a more unified, standards-based system of accountability has emerged in NCLB (Graham, 2013).

The push to increase the rigor of the educational system, in response to both the NDEA (1958) and *A Nation at Risk*, caused abandonment of much of what was then known as progressive education of the prewar period. Since the end of the Cold War, the tenets of progressive education (specifically the more holistic nature of education), and the experience-based systems championed by the fathers of modernism, reemerged in the shift from a teacher-centered to a student-centered paradigm (Von Secker & Lissitz, 1999). Research is being conducted to investigate project-, problem-, and inquiry-based education, along with other student-centered methods of teaching. These methods are held up as the way to help work toward the revived ideals of rigor, relevance and relationships in promoting educational effectiveness (Daggett, 2014).

As student-centered methods lead to discussions of hands-on learning, educators are exploring the integration of science, technology, engineering, and mathematics (STEM) into agriculture. Outside of agricultural education, the integration of agriculture and science/math looks more like a "rediscovery" of agriculture devoid of traditional agricultural education. Many in core education tend to bypass formal agricultural education due to its history of non-engagement in conversations with general education. The move to a more overt inclusion of science in agriculture has drastically increased in the past few decades; however, this is not a wholly new concept. In 1950, Hammonds suggested…

> The "organized body of knowledge" we [practitioners] call the science of agriculture is deeply rooted in the sciences that contribute to agriculture. If we strip away from agriculture the portions of other sciences that bear upon it, we

perhaps do not have left a science of agriculture. To teach agriculture as a science is to recognize that it is a science. (p. 22)

In this recognition of agriculture as a science, many vocational agriculture programs went so far as to change their names in the 1980s to agricultural science (National Research Council, 1988). The reported reason was to highlight the connection between agriculture and STEM disciplines. Agricultural education is a viable place for the delivery of the STEM concepts (Myers & Deyer, 2006). Agricultural science integrates concepts of chemistry, biology, and the physical sciences by teaching agricultural examples to highlight the concepts (Conroy & Walker, 1998, p. 12). Buriak (1989) described agricultural science as "instruction in agriculture emphasizing the principles, concepts, and laws of science and their mathematical relationship supporting, describing, and explaining agriculture" (p. 4).

Agricultural education, a primarily practical and experiential segment of education (Newcomb, McCracken, & Warmbrod, 1993; Phipps & Osborn, 1988), is a prime place to give credence, context, and relevance to the information taught in core area classes (Lee, 1994; National Research Council, 1988). Overt incorporation of science into agriculture courses strengthens the rigor of the agriculture classes and increases the relevancy of traditional academic courses (Thompson & Balschweid, 1998). Purposefully integrating science concepts into agriculture course work has a net positive effect for both students in agriculture and students in science (Clark, Parr, Peake, & Flanders; 2013; Chaisson & Burnett, 2001; Enderlin & Osborne, 1992; Myers & Dyer, 2006; Myers & Thompson, 2009; Rickets, Duncan & Peake, 2006). In light of this, many schools allow students to earn science credit for certain agricultural science courses (Connors & Elliot, 1995; Conroy & Walker, 1998; Johnson, 1996; Meyers, Thoron & Thompson, 2009; Thompson & Balshwied, 1998).

Barrick (1989) outlined six points that act as guiding premises in agricultural education. The points pertinent to this study are: agricultural education is based in real life contexts and settings; and lessons must include application in those real settings (Barrick, 1989). He also points out that the teaching of agricultural educational practices must be grounded in a sound theoretical framework and but that agricultural educators are more than skill trainers. Agricultural education serves a “bridge between agricultural science and the other disciplines” (p. 27). He goes on to write that “educating the person as a human must remain the forerunner to education the person as an agriculturalist” (p. 27).

As agriculture teachers are pushed to fully integrate science and to more overtly teach science concepts in agricultural education, researchers report model programs integrating science in areas of horticulture, animal science, wildlife, and agricultural mechanics (Baker, Bunch & Kelsey, 2015; Connors & Elliot, 1993, 1995; Miller, 2000; Thompson & Balschweid, 1999, 1998; Myers & Thompson, 2009; Stubbs & Myers, 2015; Valez, Lambert, & Elliot, 2015; Wooten, Rayfield, & Moore, 2013). As practitioners, agricultural education teachers and faculty members are encouraged to integrate more “core” concepts into lessons. Researchers should explore the practicality of using real-world examples and problems concerning modern core class testing systems.

The project-centered courses in agricultural mechanics are the second most popular courses in agricultural education, trailing only the required introductory course (Texas Education Agency, 2015). The opportunities to integrate the concepts of science, primarily physics and chemistry, along with mathematics, engineering, and technology, make agricultural mechanics courses a logical place to focus integration efforts (Blackburn, 2013; Edney, 2009; Scales, Terry, & Torres, 2009).

In most segments of society, it is reasonable to expect that students leave the classroom with the ability to apply what they have learned. Therefore, it has long been an established tenet of education that students need to understand the principles, context, and motivations surrounding their lessons to be able to apply the concepts in a natural environment (Dewey, 1916, 1938). Teachers have noted, however, that the information as it exists outside of a classroom does not always appear to operate the same in its natural setting. A science lab, or any hands-on learning activity divorced from the teaching of the scientific principle, is mechanical in nature and therefore separates the mind from the task (Dewey, 1916). Contextual application is necessary to learn a scientific principle. Student application of the information in “real-life” contextualized situations supports student learning (Dewey, 1916, 1938). Educators run the risk of wasting time on lessons that are not pertinent to the lives of the students. When students cannot see the connections or the broader picture, the goal for that student is to simply get through the lesson, and quickly move on to things that are more interesting or contextually relevant to their lives.

Students have many classes and activities that require their attention throughout the day. They have very little time, and lack the basic context, to connect the dots between these lessons. Educators have to foster and encourage those connections (Hummel & Hummel, 1913). As such, R. W. Stimson, one of the most important voices in the early days of school-based agricultural education (Moore, 1988) would have argued that the most valuable projects are directly related and as closely proximal to reality as possible (Stevenson, 1925). “Little by little we shall doubtless learn to teach mathematics and the sciences, history and civics, literature and the languages, so as to start from actual life for knowing and to come back to it for doing” (Lang, A. F, as quoted in Hummel & Hummel, 1913, p. 26). It is through the natural application of projects in context that agriculture succeeds, or has the potential to succeed, in being the connection needed to help students.

> Agriculture is not only a vocational or industrial course. It is a scientific course. To understand and practice agriculture properly, the elementary principles of all the high school sciences must be understood. By agriculture these are vitalized and their application to real life made evident” (Hummel & Hummel, 1913. p. 27.)

School learning activities must be central to the curriculum, of value, properly implemented, focused on problems and questions that motivate students to engage with the information, driven by the student in some way, able to engage the students in systematic discovery, and not school-like (Steinberg, 1998; Thomas, 2000). Arguably, activities should be authentic (Mergendoller & Thomas, 2000; Thomas, 2000). The value of authenticity is implicit in the very fabric of the method. However, the use of the word "authentic" is problematic. What is authenticity? Are there different levels of authentic; and if so, how authentic is authentic enough?

In and out of agricultural education, modern methodologists advocate for the use of student-centered methods (Bonwell & Eisen, 1991; Johnson, Johnson, & Smith, 1998). These methods all have an aspect of "authenticity" or "proximity to reality" woven into their frameworks. The project-based learning method is one of these approaches recommended under the heading of student-centered learning. While the renewed energy for projects and what they can do for student learning is relatively recent in its promotion, the idea of projects for educative purpose is far from such. The method of using projects to help teach students was notably advocated by Rufus Stimson at the beginning of the 20th century (Moore, 1988; Stevenson, 1925). The method was championed by Kilpatrick in 1918 to his own notoriety (Moore, 1988). By 1925, the use of the term "project" was so associated as a teaching method, specifically in the vocational or trades education, that Stevenson would refer to its use as "wide" (p. 1). However, at that time, debate existed as to the nature of the project, the role personal feelings about the project, the project's placement in the education cycle, and the necessary proximity of a project to real life occurrences, among many other questions (Stevenson, 1925). Those arguments have never been settled, unequivocally.

Since these first writings, the terms "project" and "problem" have been used alongside each other, and at times interchangeably. The relatively loose use of these two terms has led to further misunderstandings in the field of teaching as to what and how projects, or problems for that matter, are to be used. It has been postulated that the crux of the argument lies in the fundamental differences between W. Kilpatrick's project method and J. Dewey's more problem-based methods that rely on a belief in the importance of reflection in the use of problems to help students develop understandings (Sutinen, 2012). Stevenson suggested that, in practice, agricultural education uses what could be considered a combination of both Kilpatrick's and Dewey's ideas, that "a project is a problematic act carried to completion in its natural setting" (Stevenson, 1925, p. 43). Kilpatrick proposed that in the scheme of projects, problem analysis was one of the various ways that projects could be used, albeit one that is relied on too heavily in the opinion of more modern research (Parr & Edwards, 2004; Roberts & Harlin, 2007). Dewey's method relies heavily on students feeling that the problem is difficult, its location and definition, suggestion of a possible solution, development by reasoning of the bearings of that suggestion, further observation, and experimentation leading to the acceptance or rejection of the solution (Sutinen, 2012).

Statement of the Problem

Career and technical education, including agricultural education, have been moving philosophically toward the tenets of constructivism and away from behaviorism (Doolittle & Camp, 1999), and is based in the foundations of experiential learning (Baker, 2012; Knobloch, 2003; Roberts, 2006). Specifically, the developments of Jean Piaget and his predecessors define the interactions agricultural educators have with students and information (Doolittle & Camp, 1999). While the academy and the training of educators in the field has been grounded in Deweyian pragmatism, the works of David Snedden and Charles Prosser seem to permeate the practicality of school-based agricultural education in practice (Labraree, 2010). Arguably, this is due to Prosser's appointment to the 1913 congressional inquiry into the viability of funding vocational education, commissioned by President Woodrow Wilson on behalf of the combined voice of the National Association of Manufacturers and the American Federation of Labor (Hyslop-Margison, 2000). Additionally, Snedden quickly rose to the commissioner's position in the department of education in Massachusetts in 1909, a move orchestrated by business interests (namely, AT&T head Fredrick Fish) favorable to his outward arguments against literacy education, and his focus on social efficiency (Gordon, 2014).

These two camps (Dewey and Prosser/Snedden) posit and that while teachers must continue to teach the psychomotor skills common in vocational training (behaviorism), career and technical education must be concerned with "higher order thinking skills, problem solving, and collaborative work skills" (Doolittle & Camp, 1999, para. 1). This ideal is most soundly housed within Piagetian constructivism, specifically the tenets of cognitive constructivism. According to the literature, cognitive constructivism is bounded with two basic understandings: (a) Learning is an active process: experience must be specific, students must be allowed to make errors, and the discovery of problems and solutions are integral to the assimilation of information; (b) learning should be *authentic* and *real* (Pulaski, 1980).

This research focused on the question: How real and/or authentic do projects need to be to affect learning? Therefore, two intended outcomes of this study were (1) to add to the body of information that exists on the methods of teaching cognitive concepts through applied skills; and (2) to inform the selection of appropriate techniques.

Agricultural/Vocational/Career Education's Relationship with Science

School-based agricultural education likely began with the support of the University of Minnesota in 1888 (Hummel & Hummel, 1913; True, 1902). Although this is the first known instance of school-based agricultural education, it could be said that universities and colleges of agriculture cultivated relationships with secondary schools instructing in agriculture well before even the Morrill Act, initially introduced in 1857 (Harren & Hillson, 1996; Morrill Act of 1862). By 1908, each federal territory, state, or possession had a form of agricultural education in practice (Crosby, 1908). Most of the territories housed some form of formal secondary agricultural education. The notable exceptions to this were Alaska and Arizona. Alaska began formal agricultural education with the founding of Alaska Agriculture College in 1915 and Arizona began formal agricultural education in 1914.

States were quick to engage in the formal teaching of agriculture, and thought it so integrally important to the wellbeing of the population that it was a legal matter in eleven states (Crosby, 1908). The states of Alabama, Georgia, Louisiana, Mississippi, North Carolina, Oregon, South Carolina, South Dakota, Tennessee, Texas, and Wisconsin each passed laws that mandated that rural schools offer agriculture courses, and stipulated that conferral of degrees be contingent on students taking agricultural courses (Crosby, 1908).

By the early 20th century, agricultural education had expanded to the point that it could be called prevalent. Since agricultural education's beginnings, the idea of teaching science based agriculture, or the science of agriculture, has been at the foundations. For more than a century, it has been stated that high school students graduating from a program of agricultural courses should be able to recognize and articulate the scientific basis of agriculture (Hummel & Hummel, 1913). Agricultural education was, at its founding, a study of the sciences; evidence of such can be seen in the preparation of its teachers. In 1908, many of the state schools of agriculture, typically those founded by the Land Grant Acts of 1862 and 1890, were training students for the field of agriculture (Crosby, 1908). The curriculum, at the time, demonstrated the view of the field of agriculture as one based in science.

In 1908, according to Crosby, The New York State College of Agriculture at Cornell University offered multiple specialized courses and/or curriculum inclusive of agriculture. Those included a two-year specialized curriculum to prepare preservice teachers to teach agriculture content. The coursework included physical and biological sciences (e.g., botany, chemistry, and zoology) in both years. Additionally, agriculture-specific coursework (e.g., farm crops and soils) and electives were also included in the curriculum. The Hampton Institute offered a four-year, specialized agriculture curriculum. Elementary sciences were included in first-year coursework, followed by agriculture-specific coursework in the second, third, and fourth years (Crosby, 1908).

These programs, offered by The New York State College of Agriculture at Cornell University and The Hampton Institute, were just two of many examples of the importance of science in the teaching of agriculture. If our actions and practices speak to our values, as has been suggested, agricultural education, as it was envisioned at its infancy, was not just a pseudo-science, it was science. In Crosby's (1908) circular, written for experiment station distribution, he reported that teachers of agriculture in higher grades "will be called upon to give more advanced instruction in agriculture, which will involve some knowledge of the principles of botany, chemistry, and physics" (p. 216).

In a few short years, the focus of agricultural education shifted from what was then known as nature schools in the elementary years, to a focus on agriculture (as an extension of science, and as a science in its own right) in high schools. This process, reported with a historical tone by Crosby in 1908, and preceded by True, to the almost visceral scathing of Eugene Davenport, the Dean of the College of Agriculture at University of Illinois in the same year (Hillison, 1986). Davenport attacked the idea of agriculture being an extension of science and truly attempted to fight for agriculture as its own discipline of merit, not simply a piggyback on the existing sciences.

> …When I speak of teaching agriculture in our high schools, I mean *agriculture*. I do not mean Nature study, nor do I mean that some sort of pedagogical link should be given to chemistry or botany or even geography and arithmetic. Let these arts and sciences be taught from their own standpoint, with as direct application to as many affairs of real life as possible; but let chemistry continue

> to be chemistry; let agriculture introduce new matter into the schools and with it a new point of view. Nor should this new matter be "elementary agriculture." In some ways I could with the phrase had never been coined. What is wanted in our high schools is not elementary agriculture, but elemental, fundamental agriculture. (Davenport, 1908, p. 17)

The argument made by Davenport (1908) was one of the first blows to the progressive understanding of vocationalism as a means to move people up through society by becoming educated beyond the teaching of skills and tasks. This argument would transmute into the now famous multi-year argument between David Snedden (being the voice of Prosser) and John Dewey (Hyslop-Margison, 2000).

The crux of the argument between Snedden and Dewey is the immediacy of the need for education, the proximity of the information to real life, and the ability to transfer knowledge from one discrete learning task to another. Prosser, Snedden, and Thorndike argued for the immediate impact of the theory and practice to real-life, while Dewey, Kilpatrick, and most other pedagogical progressives appreciated theory and learning in abstraction (Gordon, 2014; Labaree, 2010). Due to the winners' (Prosser and Snedden) proximity to the decision-making process of Congress, the tenets of administrative progressivism were quite literally written into law under the Smith-Hughes Act (Hyslop-Margison, 2000). Though reforms never went as far as Snedden intended, the more direct and immediate methods of vocational training prevailed in America.

This explicitly vocational education, devoid of academic training, upset the others in the progressive movement. Dewey gave answer to the ideas of the Smith-Hughes Act by saying “Any scheme of vocational education, which takes as its point of departure from the industrial regime that now exists, is likely to assume and perpetuate its divisions and weaknesses, and thus become an instrument in accomplishing the feudal dogma of social predestination” (1916, p. 318). In short, according to Dewey, if Prosser and Snedden got their way, the US would institutionalize classism through education. European systems were being put in place that tested the arguments between pedagogical progressives and administrative progressives.

The western pinnacle of administrative progressivism of Prosser/Snedden was first instituted before World War I in the German system “Arbeitsschulle” and “Fort-buildungsschule” or “activity school” (elementary schools) and “continuation school” (vocational schools). Georg Kerschensteiner, the spiritual and practical founder of these schools, wrote lamentations on the development of apprenticeship schools modeled after the traditional trades education of students in France, Austria, and Switzerland due to the lack of craft training in continuation schools of the time in Germany (Gonon, 2009).

Georg Kerschensteiner founded the system his colleagues and chance-encountered friends (Prosser/Snedden) intended to be the hallmark for school-based education in what became known as the “Munich Model” as described in “The Problem of the Continuation School and Its Successful Solution in Germany: A Consecutive Policy” (Best, Ogden, & Ogden, 1914). Kerschenstiener is famous for his desire to teach vocaitonalism, and through that, citizenship (Gonon, 2009). His system of vocational centrist education was designed to do just that. Kershensteiner's system outlines school designs that teach in ways that will lead to specific skills for their repetition in a similar, if not exact, manner. It bears mentioning, however, that Kershensteiner has been quoted saying "all the rights that were valued most highly in the modern state, i.e. freedom of speech, freedom of press, right of association, right of assembly, universal suffrage, and freedom of trade, led to excessive and state-threatening individualism" (Gonon, 2009, p. 15). In short, teaching students to do more than complete repetitive tasks will build adults who can think too much to be ruled by the state. These schools sought to move the working class students through the system by leading students away from the socialist ideals of liberalism, and into the working lower classes (Brockman, Clarke, & Winch, 2008). This does not lead to incorporation of theoretical or connected education outside of the needed skills for the given task, as seen in the narrowness of the later adopted English system (Brockman et al., 2008).

The ideals of Kershensteiner, as well as many of the administrative progressives, pushed back against agricultural science or nature school movements that originally powered the vocational education movement into the modern era. In his sixth annual speech to Congress, President Theodore Roosevelt most perfectly summed up the American argument against incorporation: "[The] education superintended by the State must seek rather to produce a hundred good citizens than merely one scholar, and it must be turned now and then from the class book to the study of the great book of nature itself" (Roosevelt, T., 1906).

It is my current understanding that a mixture of both arguments is true: agriculture is an extension of science and a science unto its own. Vocational Education, or Career and Technical Education as it is called now, provides an opportunity for the hard or bench sciences to be more present in the lives of students. It is not an application piece for science; agriculture uses the theoretical of science in the physical. Modern vocationalism is more than teaching how to do a skill for the world. As Dewey said during the height of the debate, the benefit of experiences are in their perceived relationships to the real-world (1916, 1938).

Agricultural Mechanics

Agricultural mechanics instructors teach students math and physical science through hands-on technical skill development. (Johnson, Wardlow, & Franklin, 1997; Parr, Edwards & Leising, 2008; Rosencrans, 1997) “Agricultural engineering and mechanics is applied mechanics and applied physics; the applications directed to agriculture. As such, basic physical principles, concepts, and laws of science, interact to govern the applications” (Buriak, 1989, p. 22).

Theoretical framework

The theoretical and philosophical lens by which I conducted this research is best described as constructivist. As has been suggested, it is impossible to divest oneself as an interpreter of the research of the basic beliefs that will be used to construct the understanding (Lincoln & Guba, 2013). As such, it is my acceptance of the tenets of constructivism that framed the development of the research, the interpretation of the data, and the reporting of the findings.

Learner-centered education, such as project-based learning, falls most conveniently into line with the philosophical theory of constructivism as advocated by Dewey and von Glasersfeld, and founded in spirit by Jean Piaget (Emes & Cleveland-Innes, 2003; Doolittle & Camp, 1999). Modern teaching ideals favor constructivism and its espoused approaches (Bransford, Brown, & Cocking, 1999; McCaslin & Hickey, 2001)

Within the accepted tenets of constructivism, knowledge is most applicably gained through the interactions of existing perceptions and new experiences (Airasian & Walsh, 1997). Knowledge is constructed or changed through an ever increasing number of personal experiences had by the learner (Ackermann, 2001). This personal interaction with the information is what makes constructivism able to be generally applied to teaching, but most specifically to experience-based learning. According to von Glasersfeld (1989), knowledge is only “viable within the knowing subject’s range of experience” (p. 122). This context of experience is what I propose as one of the defining features of a successful experiential learning program.

One of the tenets of the philosophy of constructivism that has filtered into the greater practical model of learner-centered education is the idea that all knowledge is clarified through past experience and existing conceptions (Shymansky, 1992). These past experiences are thought to give credence to, or to discredit, all information gained afterwards. Knowledge and information are seen not as tangible entities to be traded back and forth, but as “experience to be constructed” (Ackerman, 1997, p. 7). The learners are believed to use the previous experiences as “both filter and facilitator of new ideas and experiences and themselves become transformed (or not) during learning” (Shymansky, 1992, p. 54). Put another way, no matter what students learn, even during a new experience, they approach learning with the prior knowledge they have accumulated up to the point they have the new experience. That prior experience will be the lens through which the students give credence or context to the new experience, and thus forever tint or in some cases taint the knowledge. Due to the way that constructivist theory views knowledge, knowledge building, and contextualization, it is natural and correct to understand constructivists as a limited form of pragmatism (von Glasersfeld, 1989).

Learners’ contact with the information is paramount to the learning process. Dewey (1938) stressed his view that “sound educational experience involves, above all, continuity and interaction between the learner and what is learned” (p. 10). “…While reality may exist separate from experience, it can only be known through experience, resulting in a personally unique reality” (Doolittle & Camp, 1999, p. 4).

Purpose of the study and research questions

The purpose of this quasi-experiment was to test the effect of the environmental determinant, level of authenticity, on academic achievement in physics. This study also examined whether students’ perceptions of the project’s difficulty and real-world relevance affect knowledge gains.

The following research questions were addressed in the study:

1. Does project authenticity affect change in science knowledge?
2. Do student's perceptions of projects affect change in science knowledge?
3. Does awareness of science and math competencies in agricultural contexts affect change in science knowledge?
4. Do students' experience levels, in agricultural education, affect change in science knowledge?
5. Does a student's perception of novelty with the project change science knowledge?

Limitations of the study

The following limitations of this study were considered when interpreting the data.

1. True random sampling was not used in the initial selection of testing sites. Therefore, the results of this study cannot be generalized beyond sites and the participants of this study.
2. This study was conducted in a school setting. There were potential outside variables that could have influenced the outcome. Examples of those factors were, but were not limited to, instructor involvement, environmental factors, unmeasured personal factors, learning styles, teaching styles, preexisting expectations towards education and learning, cultural and community norms, etc.
3. This study utilized intact cohort design. This design leads to uneven groups. No attempt was made to even out groups after the initial random group assignment.

4. Researchers have noted several demographic characteristics that should be taken into account when evaluating student learning. However, Texas A&M University's Institutional Review Board (IRB) and Human Research Protection Program did not approve collection of subjects' demographic information in this study, because the subjects were minor children. Therefore, I did not collect socioeconomic status, cultural background, familial makeup, educational attainment of parents, race or ethnicity, or special education status. Consequently, I was not able to account for variation that may have been explained by these variables.

Basic assumptions

The following assumptions were made in the performance of this study.

1. Students can all learn when experiential methods are used.
2. Science and math are appropriate to teach in the context of agricultural mechanics.
3. Students attempted to complete the assessment to the best of their ability.
4. Participants responded honestly and objectively to all instruments.
5. Students who have taken physics or physics related science courses would do better on the assessment than those who have not taken these courses.

CHAPTER II

REVIEW OF LITERATURE

Chapter II consists a review of relevant literature to the questions of this study as well as the variables of interest. This section contains information concerning agricultural education's relationship with science as both a field of study and a classification of educators, agricultural mechanics, and project-based methods.

Conceptual Framework

The increase of authentic experience in classroom instruction is in line with Carroll's (1963, 1989) model of school learning and Bandura's (1971) social learning theory. Carroll (1963) proposed students differ in the amount of time they need to learn, which he referred to as aptitude. Carroll (1963, 1989) proposed aptitude as the antecedent to academic achievement, in which the relationship between aptitude and academic achievement may be positively and/or negatively affected by four intermediary factors: (a) opportunity to learn, (b) ability to understand instruction, (c) quality of instruction, and (d) perseverance (Reeves & Reeves, 1997) (Figure 1). This study was situated in the quality of instruction subcategory of Carroll's 1989 model as I attempted to examine the effects of authenticity on the quality of instruction.

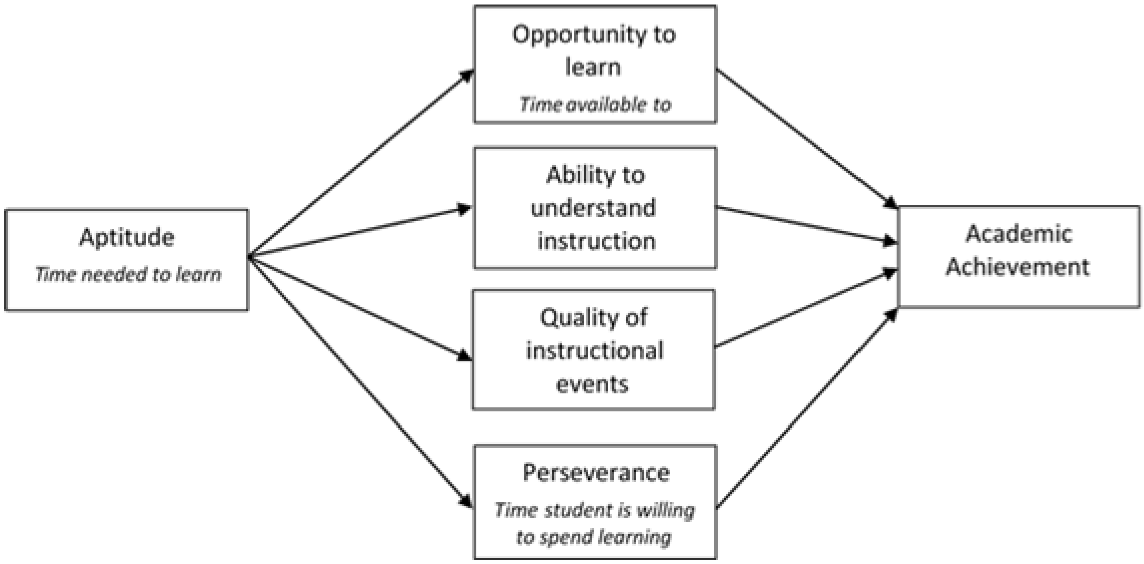

Figure 1. Carroll's model of school learning. This model shows the inputs that affect student academic achievement. Reprinted from (Carroll, 1963; 1989).

Carroll defined the terms in his model as the following:

Aptitude: "The amount of time a student needs to learn a given task, unit of instruction, or curriculum to an acceptable criterion of mastery under optimal conditions of instruction and student motivation" (Carroll, 1989, p. 26).

Opportunity to Learn: "The amount of time allowed for learning" (Carroll, 1989, p. 26). Carroll determined a lack of opportunity to learn, in the form of limited time, is one of the leading factors in students' inability to learn (1989, 1963). According to Carroll, "time on task" has been widely seen as a major limiting factor in the overall learning of a concept.

Perseverance: “The amount of time a student is willing to spend on learning the task or unit of instruction; in the sense, it becomes operational definition of motivation for learning” (Carroll, 1989, p. 26).

The final two variables as Carroll defined them pertain to achievement (1989).

Ability to Understand: Carroll and others have seen “ability to understand” as akin to the “general intelligence” and “verbal ability” of the students to whom the instruction is given. His postulation is that students are more apt to understand the instruction if the instructional design follows along with their own proclivity to use general intelligence or verbal ability (Carroll, 1963).

Quality of Instruction: The model is not specific regarding the characteristics of high quality instruction. However, students must be aware of what they are going to learn, that they are “put in adequate contact with learning materials, and that steps in learning must be carefully planned and ordered” (Carroll, 1989, p. 26).

Bandura (1971) theorized that learning is a cognitive process that occurs in a social setting, occurs through both observational and direct instruction, and is shaped by observing both positive and negative stimuli (1971). Bandura (1978) also proposed the reciprocal determinism model to provide an explanation of how relationships between the authenticity and the learning of the information occur. Purportedly, a student will interact with a stimulus, in the case of this study, classroom instruction. Depending on how that stimulus is designed, students will have varying levels of conditioned cognitive responses (Bandura, 1978). Bandura would call the conditioned cognitive responses learning.

Bandura (1978) described this learning process as a reciprocal interaction between the individual's environment and their understanding of that environment. Within the reciprocal relationship there is a triadic relationship of behavior (*B*), environment (*E*), and cognition (*P*). Any change in *E* will theoretically result in changes to *B* and/or *P*, or any combination thereof (Figure 2). Further, use of social learning theory allows researchers to predict that any change in the environment should result in a change in the cognition.

Using Bandura's model, I focused on the purposeful change of authenticity (*E*), measuring the resulting change in cognition (*P*) while using guided behaviors (*B*) within the framework of a hands-on lesson. The purpose of this study was to determine if the purposeful positioning of an educational experience along a continuum of authenticity (*E*) would result in changes in the cognition (*P*) of the individuals participating, as suggested by Bandura (1978). I manipulated environmental determinants (authenticity) in a manner that would elicit unknown behaviors (solutions). Success for those behaviors could only occur in a finite number of ways.

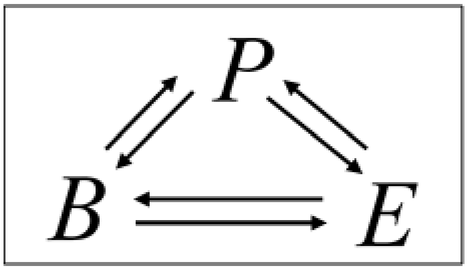

Figure 2. Graphic representation of the reciprocal triadic relationship of Bandura's social learning theory. B represents behavior, P cognition, and E environment. Reprinted from (Bandura, 1978).

Social learning theory and the school-learning model began with the same question: How does learning take place? Both models could be viewed with the same outcome, academic achievement, at their core. Carroll's factors contribute to learning as seen in Figure 1. Those factors can be used as inputs into the triad of Bandura's model (Figure 3). Academic achievement is the result of all inputs. Just as in social learning theory (Bandura, 1971; 1978), the model of school learning (Carroll, 1963, 1989) can be understood as a reciprocal relationship. Though not specifically stated in the work of Carroll, the intermediary factors affect each other. As quality of instruction is improved or diminished, the time needed to learn would likely be adjusted. As the quality of instruction increases, it is likely that time needed to learn that content would change. As learners need less time to learn they are likely to require a diminished quality of instruction (Carroll, 1963). By measuring the central outcome, academic achievement, we can determine the effectiveness of any specific changes made in the inputs of the model.

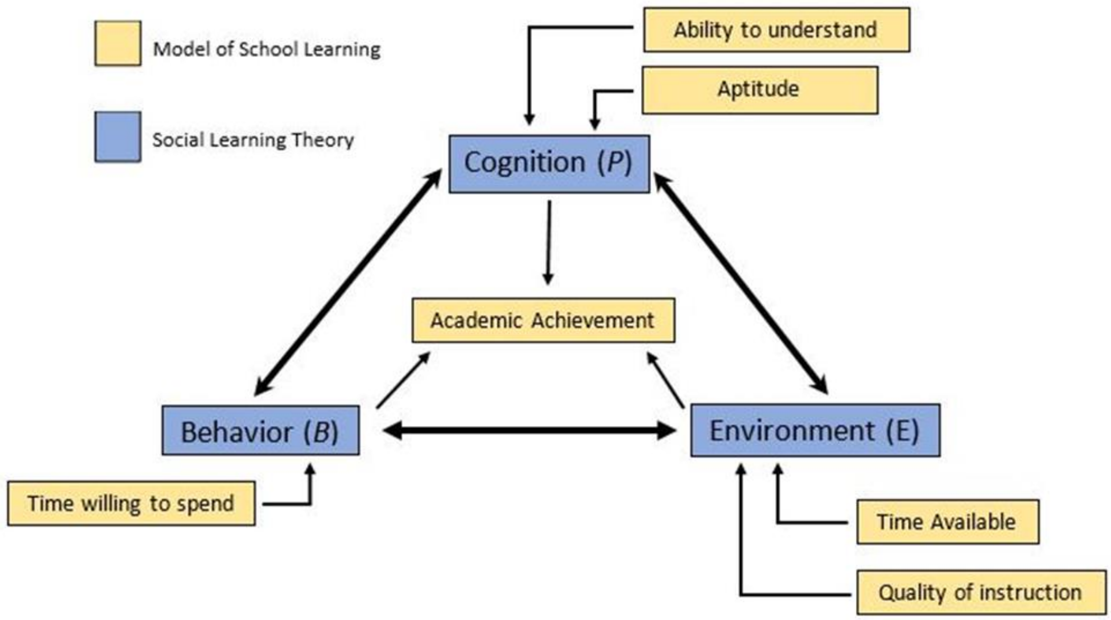

Figure 3. Carroll's model for school learning can be used as inputs into Social learning theory (Bandura, 1978). Academic achievement can be understood as the outcome for both models. Adapted from (Bandura, 1978; Carroll, 1989)

This study concentrated on the lesson's *quality of instruction*. More specifically, it examined the ideas that are within the heading of quality of instruction in that students must be put in adequate contact with the learning (Carroll, 1989). I used three models in this study; (1) the understanding postulated by Carroll, (2) the dynamic relationships suggested by Bandura, (3) and the model of project-based learning published by the Buck Institute. These models are intimately related. The essential elements of project-based learning model are housed within the "quality of instruction" section of the Carrol/model (Figure 4).

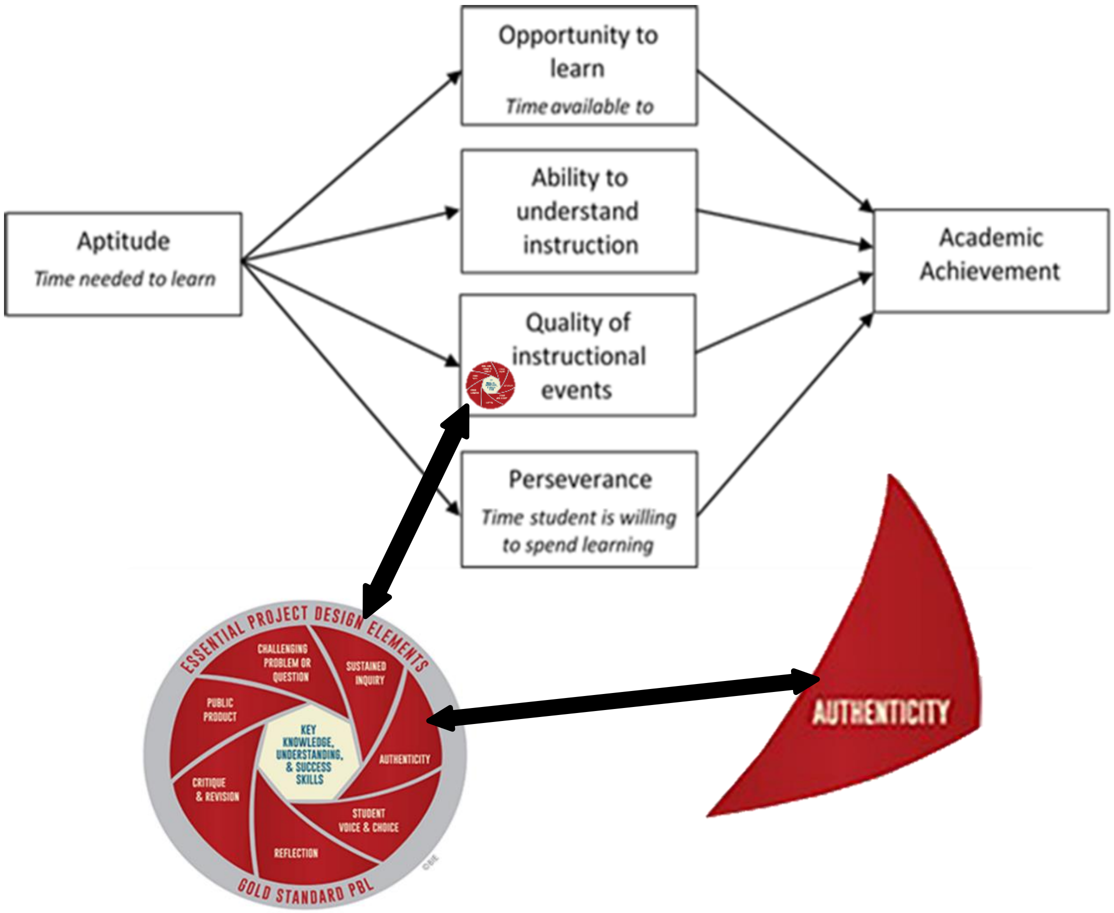

Figure 4. The model of project-based learning fits within the quality of instruction. Adapted from (Buck, 2015; Carroll, 1989)

Project-based learning

Practical Framework

Project-based learning in agricultural education is most often understood to begin with the Stimson Home Project Method (Moore, 1988). Stimson's method is predominately concerned with application projects taking place outside of the traditional day of learning, at home (Roberts & Harlin, 2007; Stimson, 1915, 1919). The research of agricultural education addressing project-based learning has been dominated by at home supervised agricultural experiences (SAE). The links between project-based learning and SAEs are clearly defined in literature, and extensive work has been done to highlight the importance of SAE in the total program model of agricultural education (Croom, 2008; Roberts & Harlin, 2007; Phipps & Osborne, 1988). In the early literature, projects were often advocated and prescribed for use both in and out of school (Roberts & Harlin, 2007). The focus of agricultural education in the intervening years has been on projects completed outside of the school day and away from the schoolhouse (Roberts & Harlin, 2007). There is a gap in the agricultural education literature concerning the use of projects within classrooms outside of SAE. In this study project-based learning methodology was used in classrooms, outside of SAE.

Project-based learning, as used in this study, is a classbased methodology of instruction advocated by modern experiential learning theorists (Krajcik & Blumenfeld, 2006). This method has many forms and frameworks that define how it is to be implemented. Those frameworks have a set of common themes; the use of a question, sustaining inquiry, student voice, product production, revision, reflection, and authenticity (Blumenfeld et al., 1994; Krajcik & Blumenfeld 2006; Krajcik, Blumenfeld, Marx & Soloway, 1994; Krajcik, Czerniak & Berger, 2002; Larmer & Mergendoller, 2015).

The structure of this study followed one of the most recent and widely promoted models of project-based learning. The practical framework used as the basis for this study was the “New Model for Gold Standard PBL” (project-based learning) published by the Buck Institute for Education (Figure 5). The framework prescribes seven primary elements for the project-based learning experience to be most effective. Those elements are challenging problem or question, sustained inquiry, authenticity, student voice or choice, reflection, critique and revision, and public product (Larmer & Mergendoller, 2015). Each of those primary elements will be discussed further.

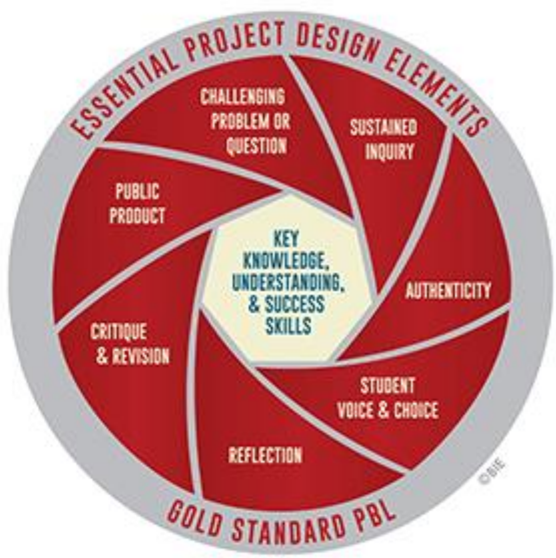

Figure 5. New model for gold standard PBL. Reprinted from (Buck, 2015).

The specific requirements and justifications for the seven elements of project design as proposed by Larmer and Mergendoller.

Challenging Problem or Question: The problem or question is the driving or organizing concept behind the lesson. According to the developers of the gold standard model, the problem/question is the reason students have to learn the information (Larmer & Mergendoller, 2015). A driving or focusing problem/question should be a challenging yet non-intimidating question that helps to point the student in the direction that they are going to be expected to go. (Larmer & Mergendoller, 2015)

Sustained Inquiry: When engaged in this version of project-based learning students are expected to identify their points of confusion and feel compelled to find the answer to that new question. This freedom to use the inquiry model to sense the problem, formulate the problem, search for the answer, and resolve the problem encourages students to achieve a deeper understanding (Shulman & Keisler, 1966; as cited in Ethridge & Rudnitsky, 2003).

Student Voice and Choice: A student's voice in the project is the perceived or actual ability of the student to develop a sense of ownership in the project (Larmer & Mergendoller, 2015). Ownership allows the student to use their own judgment to make decisions about the questions asked, how the driving question/problem will be answered, what resources or tools will be used to answer ancillary inquiries, the jobs or roles they will play within their team, and ultimately the product that they will create to answer the driving question or problem (Larmer & Mergendoller, 2015).

Reflection: A universally-required element housed within the overarching theme of student-centered learning, reflection is inherent in the system. John Dewey is widely quoted about the importance, to the point of primacy, of reflecting on learning to ensure that learning occurs. Reflection should be done continuously in an informal self-directed way, and more formally as a part of journaling, formative assessments, discussions, or presentations (Larmer & Mergendoller, 2015). Reflection is thought to help the student internalize the information and create concrete connections out of abstractions (Larmer

& Mergendoller, 2015). It is said that reflection helps students be able to continue to apply that information beyond the context of the project or situation (Larmer & Mergendoller, 2015).

Critique and Revision: Students are encouraged to engage in reflection to help deepen their understanding. Critique and revision is another form of reflection, albeit a more pointed and critical look at processes and understanding (Larmer & Mergendoller, 2015). Through thoughtful criticism and revision, students are able to increase their quality of work, identify the unknowns, and address erroneous assumptions (Larmer & Mergendoller, 2015). Utilizing thoughtful critique in a social setting allows students to increase authenticity of the project, and more closely creates a safe creative and inquisitive space that mimics the "real-world" point of view. This step emphasizes having evidence to back up the suppositions made by students, and highlights the importance of "formative evaluation" (Larmer & Mergendoller, 2015).

Public Product: the linchpin, to what has been labeled gold level project-based learning, is the creation of a tangible product of some kind. This production can take almost any form. Public presentation of the product increases the student's cultural pressure to perform, not wanting to be perceived as unintelligent or lacking in ability. Public displays play on cultural norms, and have been suggested to help increase the underlying understanding of the activity (Bandura, 1977). This motivation provides a "healthy motivator" through managed anxiety to the student (Larmer & Mergendoller, 2015).

Authenticity: The effect of the element known as authenticity is the focus of this study. Larmer and Mergendoller (2015) developed of this model. They advocate for “high levels of authenticity,” and define authenticity in terms of several qualifiers. A project can be authentic if it: involves a real-world process, has actual impact on others, is based in real performance standards, uses industry appropriate tasks or tools, involves the building or creation of something that will be used or experienced by others, is deemed personally important (based on culture, personal interest, identity or issues surrounding that student's life), or involves an authentic context (Larmer & Mergendoller, 2015). It is the use of the “or” in this definition that called the idea of authenticity into question. According to the leading advocates for the use of project-based learning and the developer of this model, a project can be any of the stated criteria and it is considered authentic. Which of these matters the most? Of these qualifiers, what makes the project fully “authentic”?

John Larmer, in a publication on the planning of authentic projects advocated for a four step approach to planning project authenticity. Larmer (2012) stated that projects must contain as much of the following as possible:

1) Represent a felt need in the world outside the classroom as perceived by the students.

2) Be directly relatable to students’ lives, “the more directly, the better.”

3) The situation surrounding the scenario must be realistic, even if the problem is manufactured.

4) Use the tools or processes that would be used by adults and professionals in the "real-world" setting.

Newmann, Bryk, and Nagaoka (2001) described the problems with typical school learning activities are that they seem "contrived and superficial" (p. 14). They further stated that an authentic lesson should be involved with "construction of knowledge, through the use of disciplined inquiry, to produce discourse, products, or performances that have value beyond school" (Newmann et al., 2001, p.14). Construction of knowledge being the adult-like development of new concepts from old ideas. Disciplined inquiry engages the construction of knowledge by involving prior learning, an internal desire to have a deep understanding of the topic, and a real expression of those new ideas and findings in a well thought out manner. Further, value beyond school relates to the intended audience.

Schoolwork has as a motivating factor the development of the internal for its own value. The adult world is externally focused and tries to "communicate ideas that have an impact on others" (Newmann et al., 2001, p. 15). To be concise, the goal of authenticity is an attempt to mimic the externally focused, deep development, with thoughtful communication of results.

Novelty

Mergendoller and Larmer suggested that students' lack of familiarity with the given method of instruction could be damaging to their educative outcomes due to the apprehension or uneasiness they feel with the different method (Personal communication

Mergendoller, October 15, 2015; Personal communication Larmer, October 12, 2015). However, Hedwig von Restorff (1933) demonstrated that students learned quicker and more deeply if the information they were expected to know was done in a way that was different from the rest of the information. Von Restorff (1933) and the subsequent iterations of her experiments used immediately known novelty to the individuals to highlight the different groups (Samuels, 1986). The von Restorff experiments were conducted by presenting small bits of information to young people printed in color while the bulk of information was printed in black (von Restorff, 1933). The colored information was retained at a much higher rate over the information printed in black (Samuels, 1986; von Restorff, 1933).

Summary

Agricultural education has had a long and well documented history with the use of project-based learning (Hillison, 1998; Roberts & Harlin, 2007; Moore, 1988). That connection to project-based learning has been explored in the context of supervised agricultural experience many times. The use of projects extends into the classroom, outside of the examined SAE context. Roberts and Harlin's (2007) work on the implementation of projects in agricultural education leads to the belief that, in the years since the founding of formal school-based agricultural education, project focus has shifted from a two faceted approach of school and home based projects to focusing exclusively on out-of-school projects. Krajcik and Blumenfeld (2006), as well as Grenno

(2006), advocated for the use of projects in the classroom as way to learn through situated perspectives in the general learning environment (Grenno, 2006).

The use of project-based learning outside of agricultural education is primarily focused on implementation within the school setting. Researchers have reported many criteria or elements to effectively implement projects in the classroom (Blumenfeld et al., 1994; Krajcik & Blumenfeld 2006; Krajcik, Czerniak & Berger, 2002; Larmer & Mergendoller, 2015; Krajcik, Blumenfeld, Marx & Soloway, 1994). Some of those elements have not been well defined or researched before they were suggested as necessary (Personal communication Mergendoller, October 15, 2015; Personal communications Larmer, October 12, 2015). One element lacking clarity is the element of authenticity.

Authenticity is said to pertain to the likelihood of that project being in the real-world (Larmer, 2012; Larmer & Mergendoller, 2015). Authenticity, as one of the project design elements, can be understood to affect the quality of instruction as defined by Carroll (1989). Quality of instruction, and the four other criterion that define the model of school learning as postulated by Carroll (1963, 1989), are understood to effect the levels of academic achievement. As such, any change in the quality of instruction, if all other things are kept constant, should consequently change academic achievement (Carroll, 1963, 1989).

If project design affects the quality of instruction as suggested by the advocates for project-based learning, and authenticity affects the design of the project, it could be postulated that changing the level of authenticity should change the level of academic achievement. However, with no evidence this change in academic achievement is only theoretical. Does authenticity indeed change academic achievement?

CHAPTER III

METHOD AND PROCEDURES

Purpose of the Study

The purpose of this quasi-experiment was to test the effect of the environmental determinant, level of authenticity, on academic achievement in physics. The purpose of this study was also to examine whether students' perceptions of the project's difficulty and real-world relevance affect knowledge gains.

The following research questions were addressed in the study:

1. Does project authenticity affect change in science knowledge?
2. Do students' perceptions of projects affect change in science knowledge?
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Population

The target population of this study were the students enrolled in agricultural science in the state of Texas. The total secondary agriculture, food, and natural resource student population according to the Legislative Budget Board was 211,838 in school year 2009/2010 (O'Brien, 2011). This represents an unrealistic population given the scope of this research. A convenience sample was developed of students enrolled in Principles of Agriculture Food and Natural Resources, Agricultural Mechanics and Metal Technology, and Agricultural Facilities Design and Fabrication. The rationale for this selection was to attempt to mitigate for experience in agricultural mechanics. These classes were chosen as predominantly freshman courses to mitigate for selection bias. Physics also contain these concepts, and is typically a course taken in the senior year of high school. These two courses were likely to have the lowest number of seniors enrolled.

Agricultural mechanics courses in Texas are traditionally populated with a disproportionate number of male students (Texas Education Agency, 2015). To more closely represent a more normal distribution of genders, both agricultural mechanics and principles of agriculture, food and natural resources were used as the population. Agricultural mechanics courses were used because of the appropriateness of the lesson. A lesson concerning direct current electricity is within the curricular requirements of agricultural mechanics, and very likely to be taught.

The accessible population for this study comprised students from six schools. Individual instructional periods were identified as cohorts, based on the label of the course (introduction to agriculture, food, and natural resources and introduction to agricultural mechanics). Sixteen class periods were identified as cohorts. Each class period cohort was assigned to one of the four treatments. This assignment was done using random selection for each class period cohort. The selection of introduction courses reduced the likelihood that students would be repeated across cohort groups. In addition, student number sheets were used to ensure no student was included in more than one cohort. Cohort-based nonequivalent comparison groups, notably those inside schools, are reliably more comparable, and thus return more accurate results (Shadish et al., 2002).

Sample

Subjects had to be able to complete the entire lesson, the treatment in this study, in a reliable and consistent manner across all cohort groups. To ensure treatment fidelity and adherence to study protocol I was not able to probabilistically select schools to include in this study. Therefore, I opted to use a purposive, non-probabilistic sample for this study. As such, the findings are not generalizable to a larger population. However, the findings may be applicable when similar situations exist. Instructors were contacted for participation. Using classes as intact groups, the researchers used multiple classes per treatment. Treatments were assigned to classes independent of the school, such that instructors with multiple sections of the courses could have been assigned multiple treatments.

Administrators from the selected test sites verbally committed, and were sent site authorization firms. Of the 10, eight returned the site authorizations. Of these eight, five sites were kept in the pool, due to administrative changes at the district level, health of the instructor (not related to the study), and educational factors not pertinent to this study. Those remaining represented various categories and demographic markers. As determined by the Institutional Review Board's (IRB) Human Research Protection Program (Appendix I) guidelines, I did not collect sensitive data (SES, reading level, scores on standardized testing, special needs status, etc.) from individual students or classes for this study. Any information regarding categorical classification or demographics was obtained from existing published data on the entire school population.

Following IRB guidelines, permission to conduct the research was sought from building or district administration (Appendix A). The outlines of the research were provided to the appropriate administrator. The outline contained the goals and questions addressed by the research. The administration had the right to cancel the continuation of the research at any point, and that right was exercised by one school represented in the eight that completed consent forms.

Consent from the students' guardians was sought via the IRB-approved form (Appendix B). These forms were sent to each student's guardians, collected by the teachers, and then mailed back to the research team.

Participating teachers were given a four column coding sheet that contained a column with a preprinted number the student would enter into the assent page of the web-based Qualtrics™ form (Appendix C). Additionally, the coding sheet contained three blank columns, one for the teachers to confirm the student had returned a signed consent form, one to record the class period the student was enrolled in the participating agriculture science class, and one for the student's name. This process allowed students to participate in the assessment and then be excluded from the study if they had not returned their consent form, or consent was not granted by the guardians. The same unique number was used by the students for both the pre and posttest to aid in the pairing of data. Any student not having both pre and posttest results was excluded. This allowed for the implementation of the projects and assessments while providing the least obstruction to daily operation of the classrooms. Reasons students did not have paired data were reported anecdotally to the researchers by the teachers. These reasons included, absence, athletic events, testing for other classes, CDE practices, in class illness, disruptions due to poor discipline, refusal to participate, students being banned from the use of school owned electronic devices by administration, etc.

The numbering system employed two techniques to ensure that students from separate schools could be kept separated within the same Qualtrics™ survey. The coding numbers began with a letter corresponding to the first name of their school, and the first digit of the three-digit numeric series began with a new number for each school. This double check aided in the organization of the data, and allowed data to be paired when students failed to the entire number or left off the beginning letter. This also aided in the cross checking of the consent forms to ensure non-consenting participants were not included in the analysis of the data.

The four column sheets were verified by the researchers, cross referencing students' names on the coding sheet with signed consent documents. Any discrepancies in the conformation of consent were corrected on the coding sheets. The researchers erred on the side of exclusion to ensure IRB regulations were followed to the letter. Once the coding sheets were crosschecked and confirmed, accurate student data were moved to a new digital spreadsheet containing only consented, paired data for analysis.

Validity and Reliability

Gall, Gall, and Borg (2003) outlined six criteria by which researchers should judge the quality of their tests or instruments: objectivity, standard conditions of administration and scoring, standards for interpretation, fairness, validity and reliability.

Objectivity and standard conditions were address by administering and scoring the assessment through the use of an online system.

Fairness is akin to reliability of the instrument. Fairness, according to Gall, Gall, and Borg, indicates how likely two individuals who have all things equal will achieve the same score on the assessment (2003). The use of a verified and qualified instrument from a reputable professional testing agency, the Massachusetts Department of Education (MDOE), was employed to fulfill this criterion for quality.

Mason and Bramble (1989) noted three kinds of validity content validity, construct validity, and criterion-related validity. Content validity is the amount of connection the items of an assessment have to the domain they are intended to measure (American Education Research Association, 1999; Fraenkel, Wallen, & Hyun, 2014; Gall, Gall, & Borg, 2003). Construct validity is important for the researchers to understand when no single measure has been identified as the proper method to quantify a certain area of interest. Criterion-related validity approaches the instrument by attempting to identify if one or more criteria exist that can be associated with a single trait or construct. Each of these approaches was used to ensure the selected tests measured what they were intended to measure.

The use of the Massachusetts Comprehensive Assessment System (MCAS) was intended to ensure the content validity with regards to physics learning. The MCAS was used because this exam is used to test the students who go on to perform well on nationally recognized assessments. The affective questions were evaluated by a panel of experts to ensure the construct validity of those items. That panel was selected from leaders in the fields of agricultural education, science education, and the implementation of the project-based method. To ensure that assertions of the results of the assessment were valid, the assessment was evaluated by experts in the field of agricultural education, agricultural mechanics, and secondary science education, which meets standard 1.7 of the *Standards for Education and Psychological Testing* (2014). This standard instructs researchers to ensure experts used to validate instruments are appropriate and qualified, and selected through systematic and reliable means (2014).

Reliability is the extent to which the assessment would yield the same or similar results when used again as a measure (Gall et al., 2003). The reliability of this instrument was estimated using the Cronbach's α test of internal consistency. Field (2009) suggested an alpha level of 0.80 or greater is considered sufficient reason for an instrument to be considered reliable (Field, 2009). The knowledge portion of the assessment has been determined by Hambleton, Zhau, Smith, Lam, and Deng (2008) to hold an internal consistency of .87 for the multiple choice items. This α coefficient is considered acceptable by current standards ($\alpha \geq .80$; Field, 2009). The internal consistency of the summated scale questions was calculated and reported according to the norms reported by Warmbrod (2014).

Metrics and Measures (Dependent Variables)

The purpose of this quasi-experimental study was to test the effect of the environmental determinant, level of authenticity, on academic achievement in physics. Academic achievement in the educational systems is often based on the results of a standardized test. Likewise, I used standardized testing to measure pre and post academic achievement. Questions taken from the MCAS were used to assess students' levels of science knowledge—more specifically, knowledge of electricity as tested in the physics portions of the MCAS exam. The 2009-2014 science and technology/engineering tests were downloaded. Questions from those exams determined to be covering the electricity were selected and aggregated into one assessment concerned only with electricity and its principles. The MCAS was selected due to the high percentage (63.6%) of Massachusetts students who scored four or above out of five on the physics electricity and magnetism advanced placement exam (College Board, 2014). The physics electricity and magnetism components of the advanced placement exam address the content of the lessons used as treatments in this study. The Advanced Placement (AP) exam is a national exam taken by thousands of students. As such, the AP exam would be the most appropriate norm-referenced assessment to use. However, rights to this exam could not be secured. The MCAS exam was available, and determined to be the next best assessment. This was due to the documented success of Massachusetts students on the AP exam, as well on the decreased likelihood students in Texas would have been exposed to the questions in the exam.

In this study, I used pretest (O_1) and posttest (O_2) measures of questions (Table 1) from the MCAS exam (Appendix D), with controlled environments (X) between the observations. The measured change (Δ) between the pretest and posttest observations ($O_2 - O_1$) is an indication of a change in the academic achievement (ΔO) of the participant as a result of the change in environment (X).

Table 1

Variable Description Table

Variable type	Description	Abbreviation(s)	Variable Reference
Independent	Treatment groups	X1, X2, X3, X4	Post_Q45
Independent	Project Perception	X1- X16	Postitive_Post36_1_2_3_37_4
Independent	STEM Perception	X1 – X18	STEM_Perception_in_AG
Independent	Experience	X1, X2, X3	POST_Q31_years_in_ag
Independent	Novelty	X1 – X5	POST_Q37_1_Have_you_done_this_before
Dependent	Change Scores	ΔO	CHANGE_SCORE
Covariates	Coursework	CV1	Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro
Covariates	Prescores	O1	PRE_PERCENT_DIFFERENCE_MC

Analyses

To compare the mean composite scores of the dependent variables across treatments, analysis of covariance (ANCOVA) was used. ANCOVA is a method of multiple regression that allows for the inclusion of continuous independent variables that are not being intentionally manipulated, but that have influence on the internal variability (Field, 2013). The use of ANCOVA strengthened the likelihood that any variability in the scores between groups was due to the grouping variables and not due to group differences outside the study. Even with the random assignment of cohort groups to treatments, there was a high likelihood that differences in ability and performance would be present in cohorts that were predominantly populated with older students or those with more advanced coursework. In addition, differences were apt to exist between cohorts' pretest scores. Therefore pretest scores, class year, and prior course work were used as covariates to allow for variances in change scores to be more clearly associated with treatments.

Statistical Assumptions and Analysis

Analysis of covariance (ANCOVA) is a statistical test, similar to an analysis of variance (ANOVA). However, ANCOVA allows the researcher to account for the variance that can be classified but not controlled. The variance being statistically controlled through the use of ANCOVA was grade in school, coursework in science, and pretest score. To complete the ANCOVA procedure with confidence in the results, the following assumptions needed to be meet (Coolidge, 2013):

1. The dependent variable is normally distributed throughout the population.
2. The scores associated with the independent variable are independent of group assignment.
3. The variances about each groups mean are not substantially different from each other, homogeneity of variance.
4. The effect of the covariate is the same on the dependent variable under all levels of the independent variable treatments.

Pretest scores were tested using ANCOVA methods against the treatment groups. This would reveal if significant differences existed in the treatment groups that could account for any future changes in test scores. Pretest scores were then used as covariates in the ANCOVA analysis. The use of the pretest as a covariate ensures that all variation seen in the change score is due to the effect of the treatment and not due to any residual variation caused by treatment selection (Field, 2013).

Omega square (ω^2) was reported as the effect size for each ANCOVA. Cohen's *f* and omega square are the most common measures of effect size in the agricultural education literature (Kotrlik, Williams, & Jabor, 2011). However, ω^2 is noted to be a less biased method of calculating the effect size, because it takes into account variance explained by the model (Field, 2013). Further, (ω^2) is more robust due to its estimate of the proportion of the variance as explained for the population rather than just the sample, as is done in Cohen's *f* (Kotrlik et al., 2011; Field, 2013).

Omega square (ω^2) was calculated as follows:

$$\omega^2 = \frac{\mathrm{SS_b} - (df_b)\,\mathrm{MS_R}}{\mathrm{SS_t} + \mathrm{MS_R}}$$

Where: SS_b = sums of squares contrast, *df* = degree of freedom between (*k* -1), MS_R = mean square error, SS_t = sums of squares total

Hair, Black, Babin, and Anderson (2010) recommend having a sample size that exceeds $n = 20$ to use ANCOVA. Given four treatments, each with an anticipated four cohort groups, and an average of 14 participants per cohort group, the analyses included appropriate representation $Y_{A\text{-}D}$ (n >22).

ANCOVA allows for the analysis of an independent variable with more than two cases (Field, 2013). For this study, the independent variable was the treatments applied Treatment A, paper packet (X_1); Treatment B, squishy circuit wiring, (X_2); Treatment C, drawing of a wiring diagram, (X_3); Treatment D, wire using wires, (X_4). The dependent or outcome variable was the change in score students achieve on the MCAS based exams.

Post hoc comparisons were conducted for significant differences. The alpha level for those comparisons was set *a priori* at (α = 05). Due to the multiple comparisons, a Bonferroni correction was used to correct for an inflated Type I error (α). A Bonferroni correction was calculated to account for all comparisons of the dependent variable using the following formula:

$$\alpha = \frac{\alpha}{k}$$

Hypotheses and Variable Identification

The main question of this quasi-experiment was does the environmental determinant, level of authenticity, effect academic achievement in physics? Six primary hypotheses were developed to answer that question.

H_{O1}: There will be no differences in academic achievement prescores O_1 among the groups.

$$X_1\ (O_1) = X_2\ (O_1) = X_3\ (O_1) = X_4\ (O_1)$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
Dependent Variable = Prescores (O_1)
Covariates: CV_1 = school grade,
CV_2 = prior course work

If differences exist, prescores (O_1) will be used as covariates in subsequent analyses.

H_{O2}: There will be no differences in academic achievement postscores O_2 among the groups.

$$X_1 (O_2) = X_2 (O_2) = X_3 (O_2) = X_4 (O_2)$$

H_{O3}: There will be no differences in academic achievement score changes ($\Delta = O_2 - O_1$) among the groups.

$$X_1 (\Delta) = X_2 (\Delta) = X_3 (\Delta) = X_4 (\Delta)$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
DV= Change Scores (Δ)
Covariates: CV_1 = school grade,
CV_2 = prior course work
CV_3 = prescores (O_1)

If differences exist, the following hypotheses will be tested in *post hoc* analyses

H_{A1}: The change (Δ) in X_1 pre (O_1) and post (O_2) academic achievement scores will be less than X_2 scores

$$\Delta OX_1 < \Delta OX_2$$

H_{A2}: The change (Δ) in X_2 pre (O_1) and post (O_2) academic achievement scores will be less than X_3 scores

$$\Delta OX_2 < \Delta OX_3$$

H_{A3}: The change (Δ) in X_3 pre (O_1) and post (O_2) academic achievement scores will be less than X_4 scores

$$\Delta OX_3 < \Delta OX_4$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
Dependent Variable = Change Scores (Δ)
Covariates: CV_1 = school grade,
CV_2 = prior course work
CV_3 = prescores (O_1)

Research design

To test the effects of authenticity on the knowledge gains of students participating in project-based learning, a quasi-experiment, using cohort-based nonequivalent comparison groups, was used. This design has been described as a quasi-experiment because it does not use full random sampling of the treatment groups. Experimental method is ideal for determining cause and effect (Campbell & Stanley, 1963). However, in some situations, including those presented in this document, an experiment is not practical or feasible. Quasi-experiments differ from true experiments because the independent variables are not wholly under the control of the researcher (Field & Hole, 2003). The design for this study can be found in Figure 6.

It was not feasible to randomly assign individual students to treatments in this study. Therefore, assignment of the treatments was not probabilistically determined. Because the individuals in each class are members of the same subpopulation (school), the individuals were arguably similar. Cohort based nonequivalent comparison groups, notably those inside schools, are reliably more comparable and, thus, return more accurate results (Shadish, Cook, & Campbell, 2002). The strength of a nonequivalent control group design is that pretesting the groups allowed for the testing of the similarity of the groups, based on performance scores (Campbell & Stanley, 1963).

Paper packets			Squishy Circuits			Drawing			Wiring		
Pre		Post	Pre		Post	Pre		Post	Pre		Post
O_1	X_1	O_2	O_1	X_2	O_2	O_1	X_3	O_2	O_1	X_4	O_2

Figure 6. Nonequivalent control group design. O_1 is the first observation and O_2 is the second observation. X_1, X_2, X_3, and X_4 represent treatments; in this case, treatments are environments changed by level of authenticity. If you are observing cognition before (O_1) and after (O_2), maturation effect (increased performance due to time, under normal circumstances) could positively contribute to an improvement between observations, which would be evident equally in all groups. Changes beyond maturation effect can be attributed to a difference of environments.

Levels of Treatment (X) and Assignment of Treatment to Cohorts (Independent Variable)

Four levels of authenticity were developed to test the effect of environmental elements of social learning theory (Appendix F): paper packets (X_1), squishy circuits (X_2), drawing of a circuit (X_3), and wiring of a circuit (X_4). Johnson, Wardlow, and Franklin (1997) reported paper packets, a non-hands-on teaching strategy, yielded the same academic achievement as hands-on methods when used to teach physics information in an agricultural class. This is in contrast to research on project-based learning done by Larmer and Mergendoller (2014). For this study, the paper-based, non-hands-on activity served as the control. Unlike the single hands-on activity of Johnson, Wardlow and Franklin (1997), I altered environmental determinants by adjusting the level of authenticity of several hands-on activities to determine if the resulting academic achievement can be varied based on the makeup of that hands-on activity, which is in line with the concepts proposed by Bandura (1978) and Carroll (1963, 1989).

Criteria Development for Each Level of Environment, Authenticity (X)

I used Larmer and Mergendoller's (2015) proposed model of *Gold Standard Project-based Learning: Essential Project Design Elements* in developing the levels of authenticity for this study. Larmer and Mergendoller (2015) outlined seven requirements for a project to be considered "authentic" (2015): (a) involve in a real-world process, (b) have actual impact on others, (c) be based in real performance standards, (d) use industry appropriate tools, (e) involve the building or creation of something that will be experienced by others, (f) be deemed personally important, and g) be involved in context. The four levels of the treatment fulfill differing requirements suggested by Larmer and Mergendoller (2015; see Table 2). The requirement labeled “personally important to participant” is not known at the onset of the research. The participants were asked to respond to questions regarding the level of personal importance they placed on the lesson to ascertain the amount of personal importance post hoc.

Table 2

Requirements for a Project to be Considered Authentic[a]

	a	b	c	d	e	f	g
Treatment A (X_1) Paper packet						U	
Treatment B (X_2) Squishy circuit wiring					S	U	S
Treatment C (X_3) Drawing of a wiring diagram	S	S			S	U	S
Treatment D (X_4) Wire using wires	S	S	S	S	S	U	S

Notes. [a] Larmer and Mergendoller (2015) outlined seven requirements for a project to be considered authentic: a) involve in a real-world process, b) have actual impact on others, c) be based in real performance standards, d) use industry appropriate tools, e) involve the building or creation of something that will be experienced by others, f) be deemed personally important, and g) be involved in context (Larmer & Mergendoller, 2015). S = Satisfying or exceeding the requirement. U = unknown beforehand. Blank cell = not meeting the requirement.

Treatment (levels of authenticity; X)

Paper packet (Treatment X_1) was a commercially available packet of information, readings, filling the blank questions, true/false questions, and short answer questions commonly used as curriculum support in Texas agricultural education. Squishy circuits (Treatment X_2) were a wiring proxy using electro conductive dough similar to Play-doh® and probe-based loads. The dough acted as a conductor and could be adjusted for conductivity by altering the mixture. Students were also given a power source and a selection of lights. The students were given the doughs, which are proxy for typical wiring materials, and instructed to construct a working series and parallel circuit. The students assigned to draw a diagram (Treatment X_3) were asked to draw out a diagram for a parallel and series circuit. Students were given markers and poster paper to ensure the materials available were the same, thus helping to ensure treatment fidelity. Those students assigned with wired circuits (Treatment X_4) were given materials to construct working series and parallel circuits. Those materials were lights, power sources, wires, and light terminals. In all hands-on projects, students explained how power would move through the circuit working the loads, during an oral presentation.

Public display of materials is one of the hallmarks of *Gold Standard Project-based Learning* (Larmer & Mergendoller, 2015). Due to regulations imposed by Texas A&M IRB (IRB2015-0500D), no portions of these presentations could be collected via photo, video, or description. Additional research will be needed to examine the effect of presenting the project on the outcome. For the purposes of this study, the requirement of public displaying the project was kept constant, as a best practice, according to advocates for the project-based method (Larmer & Mergendoller, 2015).

Instrumentation

All assessment instruments were administered in an online format using Qualtrics™. Students were given a number from a list corresponding to the student's name. That number was entered into the instrument. Student data were paired pre and post using this number.

All knowledge assessment items (Q1-Q23, Q41, Q42, Q43, Q44, and Q47) (Appendix H) were taken from The Massachusetts Comprehensive Assessment System (MCAS) (Appendix D). The Massachusetts Comprehensive Assessment System (MCAS) sample materials were included by permission of the Massachusetts Department of Elementary and Secondary Education (MDOE). "Inclusion of the MCAS instrument does not constitute endorsement of this dissertation or any other commercial publication" (J.A. Marcella, personal communication, June 29, 2015).

The assessment was comprised of 28 total items; 23 of these were multiple choice items (Q1-Q23). Two items with three single word responses, per question, in which participants were asked to provide a list three examples of items that could be either load or insulators within a circuit (Q41 a, b, c and Q47 a, b, c). Two items asked for single-statement answers regarding testing equipment used in electricity (Q42 and Q43). One item, asked students to describe the function of a selection of components common in DC electricity (Q44).

The MCAS was selected due to the high percentage of Massachusetts students who pass the physics electricity and magnetism advanced placement exam (College Board, 2014). I selected the MCAS exam because it is used to test the students at the state level, and students who score well on the MCAS score well on the national exam administered by the College Board. The belief was that this exams' assessment would resemble, though not be directly comparable to, the more nationally recognized exam.

The second part of the assessment collected perception information using a summated scale, 1-5 (Q36 through Q40; Appendix E) a mean score for each item was then calculated for each participant. Each question was composed of five statements that asked students to respond with specific aspects of, their experience in this study (Q36 and Q39), their history with projects (Q36 and Q39), their experiences in school outside of this experience (Q28 and Q40), their opinion about agriculture (Q38), and their "normal" day in agriculture class (Q37 and Q40). This section of the assessment was to determine students' perceptions of the experience of the project, project authenticity, frequency of project usage according to the students, and perceptions of relationship between; agriculture, math, and science.

Demographic items were also included in the questionnaire. Items to identify students' gender (Q26), class year (Q27), years of participation in agricultural science (Q29), number of agriculture courses taken and which course was taken (Q30 and Q31), career and technical education pathway information (Q32 and Q34), and number and level of science courses taken (Q28) were included. Demographic items were based on consultations with individuals in the fields of both agricultural education and project-based learning, and drawn from examples in the literature to identify covariates (Personal communication Mergendoller, October 15, 2015; Personal communications Larmer, October 12, 2015; Newman, Bryk, & Nagaoka, 2001).

The main purpose of this study was to determine the impact of authenticity on student score. The authenticity of the project was the main variable of interest however, as seen in Bandura (1971) and Carroll's (1963, 1989) models, emotional and internal determinants can also affect learning. Those emotional and internal determinants can be in reaction to the learning environment or task at hand (Bandura, 1971). It has also been shown that students' lack of familiarity with the given method of instruction can be detrimental to the educative outcomes due to the apprehension or uneasiness they feel with the different method (Personal communication Mergendoller, October 15, 2015; Personal communications Larmer, October 12, 2015). Thus, the assessment included perception questions to quantify participants' feelings about the task, encounter, or interaction (Gall et al., 2003).

The assessment contained questions assessing the students' perceptions about the frequency with which projects are typically used in class (Q37, Q39), as well the perceived novelty with the current project (Q32). There were questions to ascertain students' beliefs about agriculture's relationship to science and mathematics (Q38). Students were also asked about their experiences with science education (Q28), and their experiences with agricultural education (Q37 and Q40). To ensure valid responses, questions were asked with both negative and positive wording (Anastasi, 1976; Dillman, 2009; Nunnally, 1978; Scott, 1968).

Operational framework

All cohorts were unified for time following the same timeline as suggested by the model for school learning suggested by Carroll (1963, 1989). Pretesting was conducted before any instruction. Post testing was conducted four to five school days after the video-based direct instruction. (See Figure 7.)

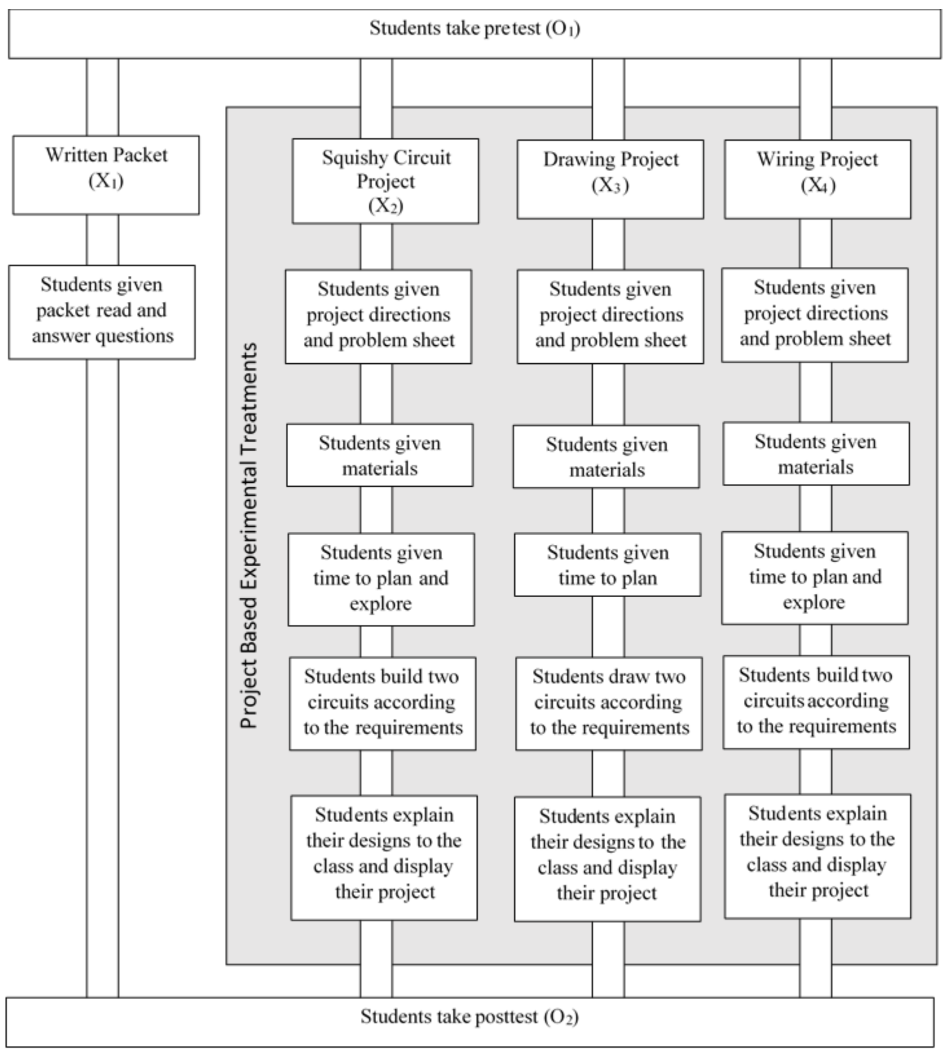

Figure 7. Operational research model.

Carroll identified a series of variables that affect academic achievement (Carroll, 1963, 1989). Carroll proposed aptitude as the precursor to academic achievement, in which the relationship between aptitude and academic achievement may be positively and/or negatively affected by four intermediary factors: (a) opportunity to learn, (b) ability to understand instruction, (c) quality of instruction, and (d) perseverance (Reeves & Reeves, 1997). This study held a consistent timeline across the treatment groups to assure fidelity of treatment and control for known variables.

Time line:

Day 1:

- Assign ID numbers to students
- Students take pretest

Day 2:

- View video and complete the note packet

Day 3:

- Assign the project or paper assignment
- Students are given time to explore the materials and testing equipment
- Students should have a basic design or idea by the end of the period

Day 4:

- Students finish up their projects

- Students are to test their projects
- Students work on their presentations

Day 4/5

- Students present their devices and evaluate each other's

Day 5:

- Students take posttest

CHAPTER IV

RESULTS

Introduction

Trends in agricultural education have been moving toward a more overt integration of STEM concepts into the curriculum for many years (Hillison, 1998; Myers & Dyer, 2006). It has been shown that agricultural mechanics is a direct link from the sciences (specifically, physics and engineering) to agriculture through hands-on application (Blackburn, 2013; Buriak, 1989; Edney, 2009; Scales et al., 2009). The use of project-based methods of instruction is common in agricultural education, however, a foundational understanding of certain tenets of this method of instruction is not clear. The purpose of this study was to determine the impact of a foundational tenet of the project-based method, authenticity, when integrating physics into secondary agriculture courses. This study also examined whether students' perceptions of the project's difficulty, real-world relevance, and project novelty affected knowledge gains.

The following research questions were addressed in the study:

1. Did project authenticity affect change in science knowledge as assessed by the MCAS instrument?
2. Did students' perceptions of projects affect change in science knowledge as assessed by the MCAS instrument?
3. Did awareness of science and math competencies in agricultural contexts affect change in science knowledge as assessed by the MCAS instrument?

4. Did students' experience levels in agricultural education affect change in science knowledge as assessed by the MCAS instrument?
5. Did a student's perception of the project novelty affect change in science knowledge as assessed by the MCAS instrument?

Variables used to address these questions are reported in Table 3.

Table 3

Description of Variables Table

Variable type	Description	Research question	Abbreviation (s)	Variable Reference
Independent	Treatment groups	1	X1, X2, X3, X4	Post_Q45
Independent	Project Perception	2	X1- X16	Postitive_Post36_1_2_3_37_4
Independent	STEM Perception	3	X1 – X18	STEM_Perception_in_AG
Independent	Experience level	4	X1, X2, X3	POST_Q31_years_in_ag
Independent	Novelty	5	X1 – X5	POST_Q37_1_Have_you_done_this_before
Dependent	Change Scores	1,2,3,4,5	ΔO	CHANGE_SCORE
Covariates	Course work	1,2,3,4,5	CV_1	Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro
Covariates	Prescores	1,2,3,4,5	O_1	PRE_PERCENT_DIFFERENCE_MC

I will report the findings as a brief description of the sample, which will be followed by sections dedicated to each of the objectives.

Description of the sample

Subjects had to be able to complete the entire lesson, the treatment in this study, in a reliable and consistent manner across all cohort groups. To ensure treatment fidelity and adherence to study protocol, I was not able to probabilistically select schools to include in this study. Therefore, I opted to use a purposive, non-probabilistic sample for this study. As such, the findings are not generalizable to a larger population. However, the findings may be applicable when similar situations exist. Instructors were contacted for participation. Using classes as intact groups, the researchers used multiple classes per treatment. Treatments were assigned to classes independent of the school, such that instructors with multiple sections of the courses could have been assigned multiple treatments. This purposive sample was made of students enrolled in Principles of Agriculture Food and Natural Resources, Agricultural Mechanics and Metal Technologies, and Agricultural Facilities Design and Fabrication. The purpose behind this selection was to attempt to mitigate for experience in agricultural mechanics. These classes were chosen as predominantly freshman courses to mitigate for selection bias. Physics would also contain these concepts, and is typically a course taken in the senior year of high school. These courses were likely to have the lowest number of seniors enrolled.

I used a convenient group of known agricultural science teachers to conduct this study. Those educators' abilities as educators were known and had a close, personal relationship with me. This was done to help ensure fidelity to the treatments and facilitate the successful collection of data. I approached ten sites for participation; eight completed the IRB-approved consent and authorization process at the beginning of the random treatment assignment. Due to administrative changes at the district level, health of an instructor (not related to the study), and educational factors beyond the control of the researcher, three sites were removed from the list. Five sites were kept in the pool.

At the five sites, fourteen classes were identified as cohorts. Table 4 represents the distribution of participants per testing site. Those intact cohorts were then randomly assigned one of the four treatments. A total of 219 students participated in either the pretest or the posttest phase of the study. Of those 219, (n = 159) students provided both pre and posttest data and a signed parent consent form. Data in

Table 5 show the resulting distribution of individuals (n) for each treatment group.

Table 4

Participants

School	*n*	%
School 1	7	4.40
School 2	30	18.90
School 3	85	53.50
School 4	18	11.30
School 5	19	11.90
Total (*N*)	159	100.00

Table 5

Treatment Assignment

	Treatment	*n*	%
1	Wiring	50	31.45
2	Squishy	61	38.36
3	Drawing	25	15.72
4	Paper Packet	23	14.47
Total		159	100.00

Research question one

Research question one: Did project authenticity affect change in science knowledge as assessed by the MCAS instrument? To assess this question, the following null hypotheses were developed *a priori* and tested.

Hypotheses and variable identification

H_{O1}: There are no differences in academic achievement prescores O_1 among the groups.

$$X_1 (O_1) = X_2 (O_1) = X_3 (O_1) = X_4 (O_1)$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
Dependent Variable = Prescores (O_1)
Covariates: CV_1 = school grade,
CV_2 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)

If differences exist, prescores (O_1) will be used as covariates in subsequent analyses.

H_{O2}: There are no differences in academic achievement postscores O_2 among the groups.

$$X_1 (O_2) = X_2 (O_2) = X_3 (O_2) = X_4 (O_2)$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
Dependent Variable= Postscores (O_2)
Covariates: CV_1 = school grade,
CV_2 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_3 = prescores (O_1)

H_{O3}: There are no differences in academic achievement score changes ($\Delta = O_2 - O_1$) among the groups.

$$X_1 (\Delta) = X_2 (\Delta) = X_3 (\Delta) = X_4 (\Delta)$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
DV= Change Scores (Δ)
Covariates: CV_1 = school grade,

CV_2 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_3 = prescores (O_1)

If differences existed, the following hypothesis would be tested in *post hoc* analyses

H_{A1}: The change (Δ) in X_1 pre (O_1) and post (O_2) academic achievement scores are less than X_2 scores

$$\Delta\, OX_1 < \Delta\, OX_2$$

H_{A2}: The change (Δ) in X_2 pre (O_1) and post (O_2) academic achievement scores are less than X_3 scores

$$\Delta\, OX_2 < \Delta\, OX_3$$

H_{A3}: The change (Δ) in X_3 pre (O_1) and post (O_2) academic achievement scores are less than X_4 scores

$$\Delta\, OX_3 < \Delta\, OX_4$$

Variables: Independent Variable = Treatments (X_1, X_2, X_3, X_4)
Dependent Variable = Change Scores (Δ)
Covariates: CV_1 = school grade,
CV_2 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_3 = prescores (O_1)

Statistical Assumptions and Analysis

An analysis of co-variance (ANCOVA) was performed to test each hypotheses. ANCOVA is a statistical test, similar to an analysis of variance (ANOVA), but allows the researcher to account for the variance that can be classified but not controlled (Field, 2013). The variances statistically controlled through the use of ANCOVA were grade in school, coursework in science, and pretest score. To complete the ANCOVA procedure with confidence in the results, the following assumptions needed to be meet (Coolidge, 2013):

1. The dependent variable is normally distributed throughout the population.
2. The scores associated with the independent variable were independent of group assignment.
3. The variances about each group's mean were not substantially different from each other (homogeneity of variance).
4. The effect of the covariate is the same on the dependent variable under all levels of the independent variable.

Assumption one: The first step was to test for the assumption of normally distributed data, including pretest, posttest, and change scores. Pretest scores (*M* = 11.11; *SD* = 3.39; *SE* = .19; skewness = .36) were normally distributed (Table 6 and Figure 8 displays the graphic representation of the distribution of the pretest data across all participants.) Posttest scores (*M* = 11.70; *SD* = 3.69; SE = .19; Skewness = .04) were normally distributed (Table 6). Change scores (*M* = 12; *SD* = 2.57; *SE* = .19; Skewness = .07) were normally distributed (Table 6 and Figure 9).

Table 6

Distribution of Pretest, Posttest, and Change Score (n = 159)

	M	*SD*	*SE*	Skewness
Pretest	11.11	3.39	.19	.36
Posttest	11.70	3.69	.19	.04
Change	0.59	3.22	.19	.07

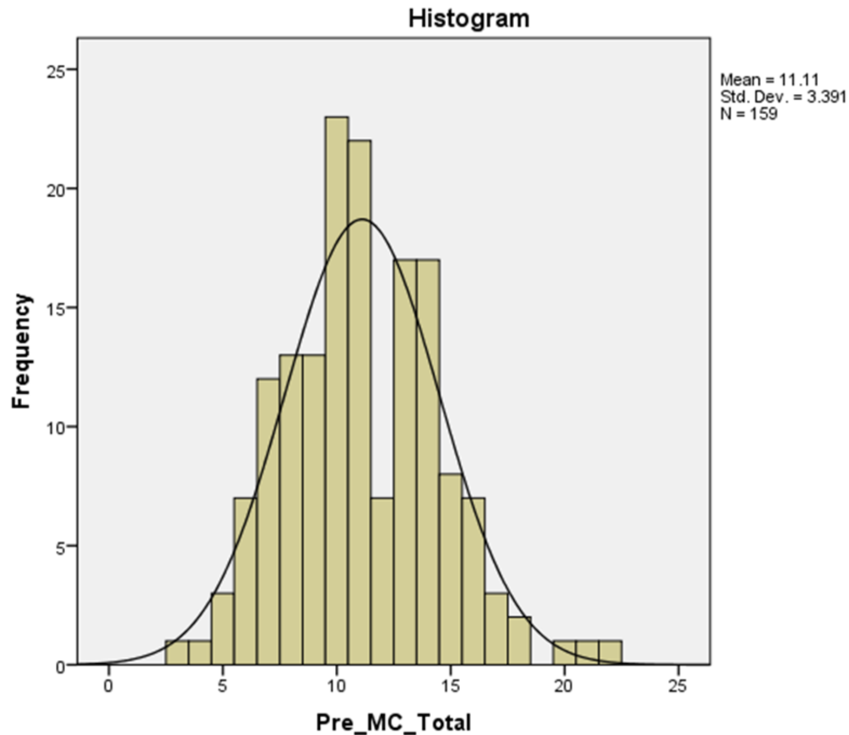

Figure 8. Histogram of distribution of pretest.

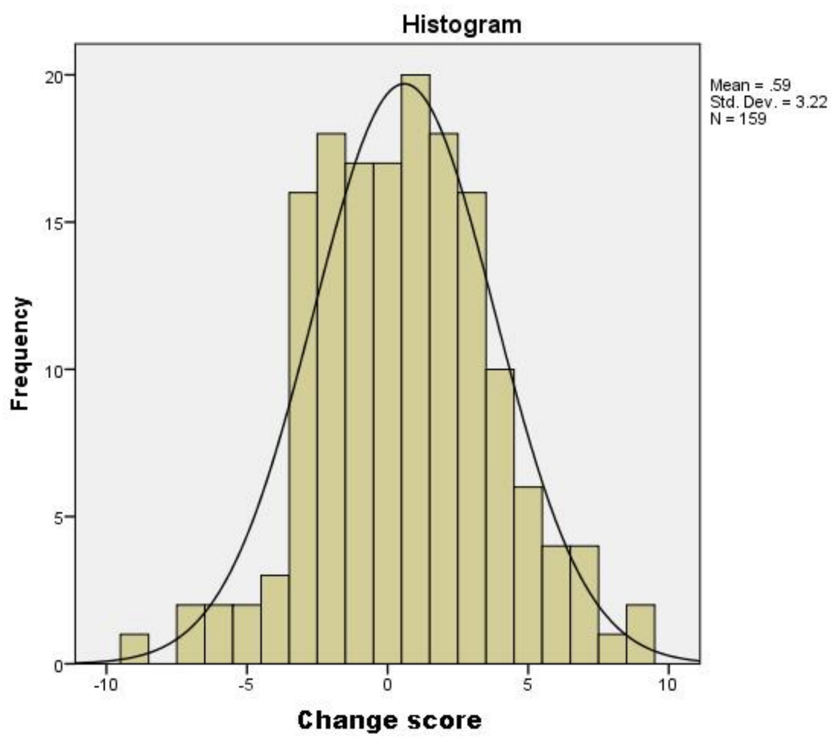

Figure 9. Histogram of distribution of change score.

Assumption two: The assumption that the independent variable was independent of group assignment (Coolidge, 2013) was upheld via the use of role and assent sheets given to the instructor. Students did not repeat in multiple treatment groups. Table 7 displays the descriptive statistics for each treatment. To ensure this beyond group assignment, ANCOVA was used to test for significant differences in the pretest scores based on group (Table 9). No significant differences were detected in the pretest scores at ($\alpha = .05$) level, (F (3,159) = 1.778, p = 0.152, $1 - \beta = .49$).

Table 7

Descriptive Statistics for Pretest by Treatment

	M	*SD*	*n*
Wiring	11.66	3.35	50
Squishy	11.16	3.46	61
Drawing	10.32	3.58	25
Paper Packet	10.61	3.01	23
Total	11.11	3.40	159

Assumption three: The variances about each group's mean were not substantially different from each other; homogeneity of variance was tested using Levene's test for the homogeneity of variances (Field, 2013; Coolidge, 2013). Data in Table 8 show no significant differences among the variance of the dependent variable (posttest) across treatment groups, ($p = .342$). I upheld assumption three until further analysis can be performed.

Table 8

Levene's Test of Equality of Error Variances[a] for Treatment Variable (IV)

F	*df1*	*df2*	*p*
1.12	3	155	.342

Tests the null hypothesis that the error variance of the DV is equal across groups.
[a.] Design: Intercept + Class year + Chem + Phy_Sci + Bio + Physics + IPC + Astron + E_and_S + Enviro + Pretest + Treatment

Assumption four: The effect of the covariate is the same on the dependent variable under all levels of the independent variable. Field (2013) suggests that independence of covariates and treatment variables ensures easy of interpretation of data. To test this assumption, the covariates were entered into an omnibus ANOVA as dependent variables, holding the treatment variable as independent. The variable, grade level, proved not fully independent of the treatment variable ($F(1,159) = 3.97$, $p = 0.048$, $\omega^2 = 0.03$). Table 9 displays the results of those analyses. As such, class year was removed from the covariance list in all further statistical tests.

Table 9

ANCOVA Table Testing of Independence of the Treatment Variable (IV) and Covariate by Pretest (DV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	297.13[a]	13	22.86	.013	2.18	*.16*	.95
Class Year[b]	41.61	1	41.61	.048*	3.97	.03	.51
Chemistry	14.48	1	14.48	.242	1.39	.01	.22
Physical Science	13.77	1	13.77	.254	1.31	.00	.21
Biology	4.96	1	4.96	.493	0.47	.01	.11
Physics	16.49	1	16.49	.212	1.57	.01	.24
IPC	13.36	1	13.36	.261	1.28	.01	.20
None	37.45	1	37.45	.061	3.57	.02	.47
Astronomy	3.83	1	3.83	.547	0.37	.01	.09
Earth and Space	6.78	1	6.78	.423	0.65	.00	.13
Environ. Systems	.01	1	0.01	.983	0.00	.00	.05
Pretest	56.23	3	18.74	.152	1.79	.04	.46
Error	1520.05	145	10.48				
Corrected Total	1817.18	158					

Note. All dependent variables were tested against treatment for the independent variable; results were of that independent variable (treatment).

[a] R^2 = .164 (Adjusted R^2 = .089); [b] 9th grade *n=103*, 10th grade *n=37*, 11th grade *n=13*, 12th grade *n=6*.

*significant at the .05 level.

Results related to pretest differences across all groups

Before addressing the set research questions, I compared the mean pretest scores of the treatment groups to determine if there were significant differences in the scores of those groups before any treatment was applied. Many factors could have affected the outcome of the study. Those could be quality of instructor, school situation, and exposure to concepts, among others. For this reason, a pretest was used to gauge the prior knowledge of the participants and test for independence of the treatment assignment. The use of the pretest as dependent variable also allowed for the examination of any variation introduced through group assignment.

Pretest comparison of sites

An ANCOVA was calculated to determine if statistical differences existed in the assigned groups (IV = Treatment, DV = Pretest, Covariates = Course work) before the application of any treatment. Levene's test of homogeneity of variances did not detect differences in the variances ($p = .433$; Table 10). Because the test for homogeneity of variances was not significant, an ANCOVA test was conducted. No significant differences ($F(3,159) = 1.18$, $p = 0.318$, $1 - \beta = .31$) were found in the pretest scores across all groups when the predetermined covariance were taken into account, as shown in Table 11 and Table 12The absence of significant differences across any group allows for further analysis of these data using *a priori* determined methods.

Table 10

Levene's Test of Equality of Error Variances[a] for Pretests

F	*df1*	*df2*	*p*
.92	3	155	.433

Tests the null hypothesis that the error variance of the DV is equal across groups.
[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + POST_Q45

Table 11

Descriptive Statistics for Pretest (DV) by Treatment (IV)

	M	*SD*	*n*
Wiring	50.70	14.56	50
Squishy	48.54	15.02	61
Drawing	44.87	15.56	25
Paper Packet	46.12	13.35	23
Total	48.29	14.74	159

Table 12

ANCOVA Table Testing Pretests (DV) by Treatments (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	4830.14a	12	402.51	.029	1.99	.01	.91
Course Chem	73.57	1	73.57	.547	.364	.00	.09
Course PhySci	345.30	1	345.30	.193	1.70	.00	.26
Course Bio	127.01	1	127.01	.429	.63	.00	.12
Course Phy	1923.55	1	1923.55	.002	9.51	.00	.87
Course IPC	51.72	1	51.72	.614	.26	.00	.08
Course None	576.66	1	576.66	.093	2.85	.00	.39
Course Astro	123.31	1	123.31	.436	.610	.00	.12
Course Earth	228.20	1	228.20	.290	1.13	.00	.18
Course Enviro	34.47	1	34.47	.680	.17	.00	.07
Treatment	717.67	3	239.22	.318	1.18	.00	.31
Error	29521.137	146	202.20				
Corrected Total	34351.27	158					

Note. [a.] R^2 = .14 (Adjusted R^2 = .07)

When accounting for pretest scores, no significant differences existed among the treatment groups, I accepted H_{O1} as true. Pretest scores were used as a covariate in further analysis of the change score. H_{O2} was therefore not considered.

Posttest comparison of treatment

Student participants were asked to complete a posttest examination that measured their knowledge at the end of the project-based lesson. The posttest (O_2), as well the pretest (O_1), was taken from the MCAS system described in chapter three. A change score (Δ) was calculated based on the differences between the prescore and postscore ($\Delta = O_2 - O_1$).

H_{O3}: There were no differences in academic achievement score changes ($\Delta = O_2 - O_1$) among the groups. That can be expressed as $X_1 (\Delta) = X_2 (\Delta) = X_3 (\Delta) = X_4 (\Delta)$. To test this, ANCOVA was calculated. As with other analysis, science class participation was used as a covariate in the analysis. In addition, as was stated *a priori* with no significant differences in the pretest scores across treatment groups, the pretest score was used as a covariate.

There is a risk of a rising alpha level (α), and thus an inflated risk of making a Type I Error, with an increased number of tests, two in this case. Consequently, the Bonferroni correction was made. Bonferroni correction is thus made by dividing the current alpha (α) by the number of tests (k) to be made ($(Pcrit) = \frac{\alpha}{k}$; Field, 2013). In this hypothesis, two tests were conducted, one for H_{O1} and one for H_{O3}. Alpha was adjusted to the ($\alpha = .025$) level.

An ANCOVA was conducted to compare the change in score across the treatments (IV = Treatment, DV = ΔO, Covariates = Course work). Levene's test of homogeneity of variances was not statistically significant ($p = .433$; Table 13). Since the test for homogeneity of variances was not significant, an ANCOVA test was conducted. The ANCOVA revealed significant differences in the independent variable ($F(3,145) = 3.59$ $p = .015$, $\omega^2 = .04$). I rejected H_{O3} because of these results. Field (2013) suggested standards for levels of effect size (ω^2). An effect size of ($\omega^2 = .04$) falls between the small ($\omega^2 < .01$) and medium ($\omega^2 = .06$) Tables 13, 14, 15 and 16 are provided to support these statements.

Table 13

Levene's Test of Equality of Error Variances[a] for Treatment (IV)

F	*df1*	*df2*	*p*
1.47	3	155	.226

Tests the null hypothesis that the error variance of the DV is equal across groups.
[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + Pre_MC_Percentage + POST_Q45

Table 14

Descriptive Statistics for Change Score (DV) by Treatment (IV)

Treatment	M	SD	*n*
Wiring	0.00	14.03	50.00
Squishy	5.77	14.08	61.00
Drawing	4.52	12.46	25.00
Paper Packet	-2.46	13.61	23.00
Total	2.57	14.00	159.00

Table 15

Estimated Mean Differences with Covariate Adjustments of Change Score

			95% Confidence Interval	
Treatment	*M*	*SE*	*Lower bound*	*Upper Bound*
Wiring	.843[a]	1.81	-2.72	50
Squishy	6.03[a]	1.64	2.79	61
Drawing	3.53[a]	2.55	-1.51	25
Paper Packet	-3.90[a]	2.68	-9.20	23

[a.] Covariates appearing in the model are evaluated at the following values: Chem = .30, PhySci = .08, Bio = .92, Phy = .13, IPC = .09, None = .02, Astro = .03, Earth = .05, Enviro = .04, Pretest = 48.29

Table 16

ANCOVA Table for the Change Scores (DV) by Treatment (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	8193.03[a]	13	630.23	.000	4.01	.19	.99
Course Chem	19.52	1	19.52	.725	.12	.00	.06
Course PhySci	130.74	1	130.74	.363	.83	.00	.15
Course Bio	525.00	1	525.00	.070	3.34	.01	.44
Course Phy	83.43	1	83.43	.467	.53	.00	.11
Course IPC	150.28	1	150.28	.330	.96	.00	.16
Course None	483.58	1	483.58	.081	3.08	.01	.41
Course Astro	42.03	1	42.02	.606	.27	.00	.08
Course Earth	.03	1	.03	.989	.00	.00	.05
Course Enviro	2.07	1	2.07	.909	.01	.00	.05
Pretest	3856.80	1	3856.80	.000	24.55	.11	.99

(continued)

Table 16 **(continued)**

ANCOVA Table for the Change Scores (DV) by Treatment (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Treatment	1691.20	3	563.73	.015*	3.59	.04	.78
Error	22779.14	145	157.10				
Corrected Total	30972.168	13					

Note. [a.] R^2 = .265 (Adjusted R^2 = .199)
*significant at p = .025

Further analysis using pairwise comparisons helped identify where the specific differences lay within the larger set of four treatments. The results of the pairwise comparisons of each treatments is shown in Table 17

Table 17

Pairwise Comparison of Change Score (DV) by Treatments (IV)

(I) Treatment	*(J) Treatment*	*Mean Difference (I-J)*	*Std. Error*	*p*	*95% Confidence Interval for Difference* Lower bound	*95% Confidence Interval for Difference* Upper bound
Wiring	Squishy	-5.19	2.47	.038*	-10.08	-.30
	Drawing	-2.69	3.15	.395	-8.92	3.54
	Paper Packet	4.74	3.21	.142	-1.61	11.09
Squishy	Drawing	2.50	3.02	.410	-3.48	8.47
	Paper Packet	9.93	3.19	.002*	3.62	16.24
Drawing	Paper Packet	7.43	3.74	.049*	.04	14.82

Note. Duplicate comparisons have been removed.
*significant at the p = .05 alpha level.

Statistically significant differences were detected at the ($\alpha = .05$) level for treatments; Squishy at Wiring ($p = .038$) with a mean difference of 5.19 positive toward the Squishy treatment, Squishy at Paper Packet ($p = .002$) with a mean difference of 9.93 positive toward the Squishy treatment, and Drawing at Paper Packet ($p = .049$) with a mean difference of 7.43 positive toward the Drawing treatment.

The purpose of research question one was to test for the effects of project authenticity on the learning of physics information within an agricultural mechanics context. I concluded that project authenticity has an effect on learning as measured in this study. Chapter Five will contain further discussion of this finding.

Research question two

Research question two: did participants' perceptions of projects affect change in science knowledge? To assess this question, the pre to posttest change score was used as a dependent variable and an ANCOVA was calculated as previously described, holding the same requirements for the completion of robust statistical tests.

$H_{O2\text{-}1}$: There are no differences in academic achievement Change scores $O\Delta$ among the perception score groups.

$$X_1\,(O\Delta) = X_2\,(O\Delta) = X_3\,(O\Delta) = X_4\,(O\Delta)\ \ldots = X_{16}\,(O\Delta)$$

Variables: Independent Variable = Perception scores ($X_{1\text{-}16}$)
Dependent Variable= Change scores ($O\Delta$)
Covariates:
CV_1 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_2 = prescores (O_2)

Calculation of student perception

Students' perceptions of the project were assessed by asking both negative and positive versions of the same questions, as is common in literature (Anastasi, 1976; Dillman, Smyth, & Christianson, 2014; Nunnally, 1978). However, it has been shown that negatively worded items often negatively skew data (Colosi, 2013; Schriesheim & Hill, 1981). To test the relationship between the two questions, bivariate Pearsonian correlations were performed (Field, 2013). The two questions (Post_Q36_1 and Post_Q39_1recode) were highly negatively correlated, ($r(152) = -.50$, $p < .001$). These questions asked students about their opinions regarding their perception of learning from the project. The two questions (Post_Q36_3 and Post_Q39_3_recode) were highly negatively correlated, ($r(154) = -.49$, $p < .001$). These questions asked students about their feeling of preparation to complete the project successfully. The two questions (Post_Q36_2 and Post_Q39_2_recode) were highly negatively correlated, ($r(154) = -.52$, $p < .001$). These questions asked students about their feeling of preparation to complete the project successfully. The two questions (Post_Q37_4 and Post_Q39_5_recode) were highly negatively correlated, ($r(149) = -.38$, $p < .001$). These questions asked students about their feeling of the project's proximity to "the real-world." Given this significant negative correlation, the inclusion of a negatively worded question in the instrument decreases the validity of the questionnaire. This is consistent with predictions by Schreesheim and Hill (1981). As is recommended in this instance the negatively worded questions were removed from analysis (Schriesheim & Hill, 1981). Positively worded questions (Post_Q36_1, Post_Q36_2, Post_Q36_3, and Post_Q37_4) were compiled into a composite score of the perception of the project (Positive_Post36_1_2_3_37_4). A strong correlation between the individual questions and the composite variable was seen of the variables was observed (Table 8). The resulting composite variable had a Cronbach's alpha of .90. Exceeding recommended $\alpha \geq .80$ for internal consistency (Field, 2013).

Table 18

Correlations of Composite Variable On Project Perceptions

					Composite Variable		
	1	2	3	4	*df*	*r*	*p*
1	--	.68*	.73*	.36*	148	.871	<.001*
2	.68*	--	.59*	.29*	148	.814	<.001*
3	.73*	.59*	--	.42*	148	.857	<.001*
4	.36*	.29*	.42*	--	148	.636	<.001*

Note. *correlation is significant at the .01 level (1-tailed)

1 = Post_Q36_1, 2 = Post_Q36_2, 3 = Post_Q36_3, 4 = Post_Q37_4

Student perception effect on MCAS score

Student perception scores were assigned by calculating a mean score on the items for each participant. Levene's test of homogeneity of variances was not significantly different (p = .333, Table 19). Since the test for homogeneity of variances was not significant, an ANCOVA test was conducted. After ANCOVA (IV = Project Perception, DV = ΔO, Covariates = Course work) analysis, a statistically significant difference was seen between students of various perception levels of the project (F(15,149) = 1.82, p = .036, ω^2 = .06; Table 20). I rejected $H_{O2\text{-}1}$ because of these results. Field (2013) suggested standards for levels of effect size (ω^2). An effect size of (ω^2 = .06) falls in the medium range of effect size (ω^2 = .06).

Table 19

Levene's Test of Equality of Error Variances[a] for Project Perception (IV)

F	*df1*	*df2*	*p*
1.13	15	134	.333

Tests the null hypothesis that the error variance of the DV is equal across groups.

[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + Pre_MC_Percentage + Postitive_Post36_1_2_3_37_4

Table 20

ANCOVA Table for the Change Scores (DV) By Perception of the Project (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	10090.63[a]	25	403.63	.000	2.68	.21	.99
Q28_1_Chem	342.56	1	342.56	.134	2.27	.00	.32
Q28_2_Phy_Sci	3.06	1	3.06	.887	.02	.00	.05
Q28_3_Bio	260.43	1	260.43	.191	1.73	.00	.26
Q28_4_Physics	46.70	1	46.69	.579	.31	.00	.09
Q28_5_IPC	212.42	1	212.42	.237	1.41	.00	.22
Q28_6_None	521.43	1	521.43	.065	3.46	.01	.46
Q28_7_Astron	47.78	1	47.78	.574	.32	.00	.09
Q28_8_E_and_S	43.55	1	43.55	.592	.29	.00	.08
Q28_9_Enviro	39.91	1	39.91	.608	.27	.00	.08
Pretest	4199.12	1	4199.12	.000	27.87	.14	.99
Perception score	4108.78	15	273.92	.039*	1.82	.06	.92
Error	18680.13	124	150.65				
Corrected Total	28770.76	149					

Note. [a] R^2 = .351 (Adjusted R^2 = .220) *significant at the p = .05 level.

A pairwise comparison was done to compare levels of perception to determine where the variation exists within the variable labeled perception. Those instances, as well as the mean and standard deviations for each reported instance, are recorded in Table 21. The results of the pairwise comparisons of each perception score, comparing to each other perception score, are shown in Appendix G.

Table 21

Perception Scores of the Project Mean and Standard Deviation

Perception score	*M*	*SD*	*n*
1.00	2.68	12.37	13
1.25	-6.52	16.76	8
1.50	8.21	11.80	9
1.75	1.93	9.75	9
2.00	6.67	11.37	15
2.25	9.94	16.57	14
2.50	3.48	19.04	15
2.75	3.19	11.79	15
3.00	0.51	14.08	17
3.25	-0.79	14.66	11
3.50	8.70	12.80	4
3.75	0.87	9.43	5
4.00	-2.90	7.10	6
4.25	6.52	3.07	2
4.50	7.25	17.57	3
5.00	-10.87	10.35	4

Table 22 represents the comparisons of a score of 5 with all other scores. A whisker plot is provided (Figure 10) to graphically represent the perception scores as they relate to the change scores.

Table 22

Pairwise Comparisons of Perception Scores (IV) and Change Score (DV)

(I) Perception score	*(J) Perception score*	*Mean Difference (I-J)*	*Std. Error*	*p*	*95% Confidence Interval for Difference*	
					Lower bound	*Upper bound*
5.00	1.00	-26.56	7.37	.000*	-41.14	-11.98
	1.25	-12.85	7.65	.096	-28.00	2.30
	1.50	-25.45	7.56	.001*	-40.41	-10.50
	1.75	-24.36	7.72	.002*	-39.64	-9.07
	2.00	-26.12	7.19	.000*	-40.35	-11.88
	2.25	-25.19	7.21	.001*	-39.47	-10.92
	2.50	-23.87	7.15	.001*	-38.02	-9.71
	2.75	-23.60	7.13	.001*	-37.72	-9.49
	3.00	-20.04	6.99	.005*	-33.88	-6.21
	3.25	-18.27	7.33	.014*	-32.77	-3.78
	3.50	-28.03	9.18	.003*	-46.19	-9.87
	3.75	-16.62	8.31	.048*	-33.06	-.19
	4.00	-13.05	8.22	.115	-29.32	3.23
	4.25	-24.65	10.77	.024*	-45.96	-3.34
	4.50	-22.73	9.48	.018*	-41.50	-3.96

Note. Only significant findings reported. Full chart can be found in Appendix
* Significant at the .05 level.

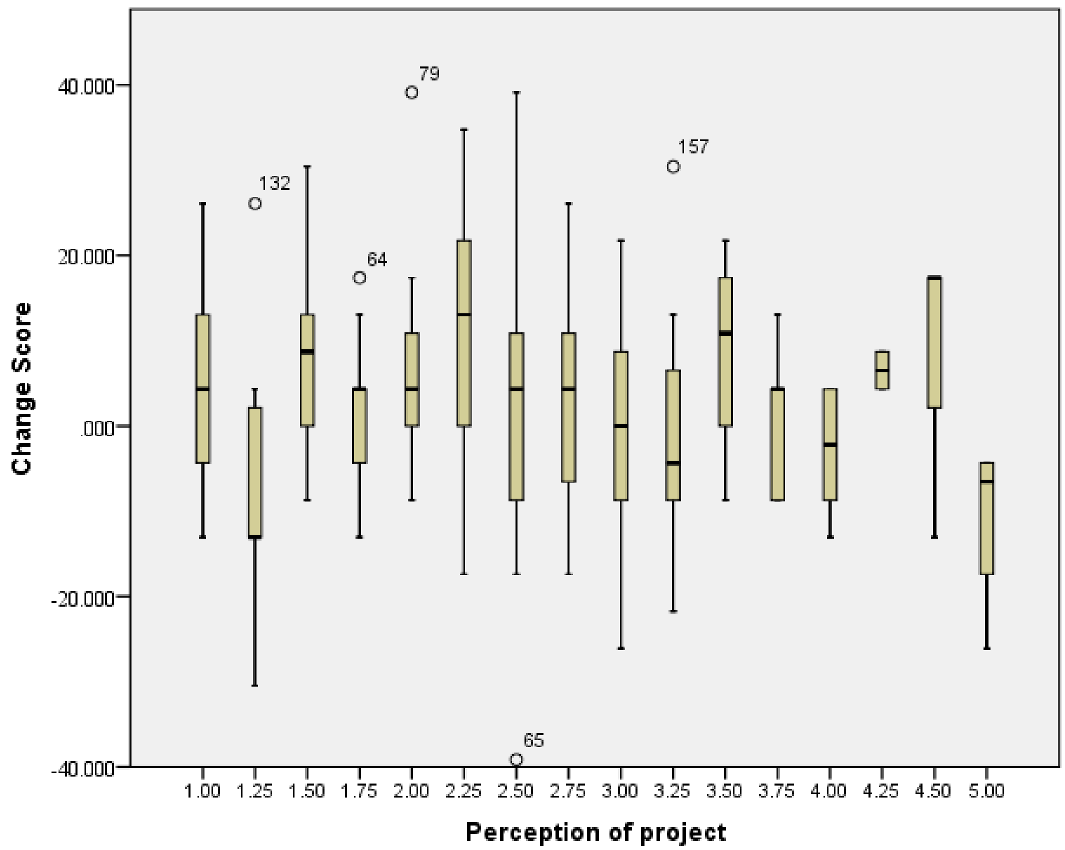

Figure 10. Whisker plot of perception of project to change score.

Students with a composite score of 5 in perception of the project, indicating they had highly negative feelings about the project, had statistically significantly lower change scores than students who indicated moderate to highly positive (3.50, 2.75, 2.50, 2.25, 2.00, 1.75, 1.50, 1.00) perceptions of the project.

The purpose of research Question Two was to test for the effects of project perception on the learning of physics information within an agricultural mechanics context. I concluded that project perception has an effect on learning as measured in this study. Chapter Five will contain further discussion of this finding.

Research question three

Research question three: did awareness of science and math competencies in agricultural contexts affect change in science knowledge as assessed by the MCAS instrument?

$H_{O3\text{-}1}$: There are no differences in academic achievement Change scores $O\Delta$ among the STEM perception score groups.

$$X_1\,(O\Delta) = X_2\,(O\Delta) = X_3\,(O\Delta) = X_4\,(O\Delta) \ldots = X_{18}\,(O\Delta)$$

Variables: Independent Variable = Perception scores ($X_{1\text{-}18}$)
Dependent Variable= Change scores ($O\Delta$)
Covariates:
CV_1 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_2 = prescores (O_2)

To quantify this awareness, student participants were asked a series of questions pertaining to their beliefs about the interrelationships between science and agriculture and math and agriculture. A mean score on the items for each participant was then calculated. Six questions asked students to rank their beliefs 1-5 (one indicating high belief, and five indicating low belief). Bivariate, single tailed, Pearsonian correlations were performed to test the relationship between the items (Field, 2013). Questions (Post_Q38_1, Post_Q38_2, Post_Q38_3, Post_Q38_4, Post_Q38_5, and Post_Q38_6) were compiled into a composite score of the perception of STEM concepts in agriculture. Each variable's correlation value is shown in Table 23. A strong correlation between the individual questions and the composite variable was seen (Table 23). The composite variable had a Cronbach's alpha of .81 exceeding the recommended $\alpha \geq .80$ for internal consistency (Field, 2013).

Table 23

Correlations: Composite Variable to Individual Questions Regarding STEM Perceptions

	1	2	3	4	5	*6*	*df*	*r*	*p*
1	--	.60*	.62*	.48*	.42*	.56*	158	.74	<.001*
2	.60*	--	.59*	.65*	.56*	.42*	158	.78	<.001*
3	.62*	.57*	--	.79*	.56*	.73*	158	.85	<.001*
4	.48*	.65*	.79*	--	.65*	.65*	158	.86	<.001*
5	.42*	.56*	.56*	.65*	--	.74*	158	.82	<.001*
6	.56*	.42*	.73*	.65*	.74*	--	158	.84	<.001*

Note. 1 = Post_Q38_1, 2 = Post_Q38_2, 3 = Post_Q38_3,4 =Post_Q38_4, 5 =Post_Q38_5, 6 = Post_Q38_6
*correlation is significant at the .01 level (1-tailed)

Student STEM perception effect on MCAS score

Student STEM perception scores were calculated. Frequencies, means, and standard deviations can be found in Table 24. Levene's test of homogeneity of variances was not significantly different (*p* = .494; Table 25). Since the test for homogeneity of variances was not significant, an ANCOVA test was conducted. After ANCOVA analysis (IV = STEM Perception, DV = ΔO, Covariates = Course work), no statistically significant differences were seen between students of various perception levels of the project. ($F(17,158) = 1.30$, $p = .201$; Table 26).

Table 24

STEM Perception Score Means, Standard Deviations, and Frequencies

STEM Perception score[a]	*M*	*SD*	*f*
1.00	1.98	13.60	60
1.17	-4.35	8.70	4
1.33	11.41	10.89	8
1.50	-5.07	8.88	6
1.67	1.24	18.05	7
1.83	8.15	14.78	8
2.00	3.66	14.29	19
2.17	2.17	3.07	2
2.33	0.00	11.09	9
2.50	7.83	11.25	5
2.67	11.59	17.57	3
2.83	2.17	9.22	2
3.00	-5.16	17.34	16
3.33	15.22	15.37	2
3.50	-1.45	13.28	3
3.67	13.04	--	1
4.17	13.04	--	1
5.00	19.57	3.07	2
Total	2.50	14.02	158

Note: perceptions are rated 1 – 5. One being fully positive five being fully negative.

Table 25

Levene's Test of Equality of Error Variances[a] *for STEM (IV)*

F	*df1*	*df2*	*p*
.97	17	140	.494

Tests the null hypothesis that the error variance of the DV is equal across groups.

[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + Pre_MC_Percentage + STEM_Perception_in_AG

Table 26

ANCOVA Table for the Change Scores (DV) by STEM Perception (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	10058.70[a]	27	372.55	.001	2.33	.18	.99
Course Chem	97.92	1	97.92	.435	.61	.00	.12
Course PhySci	80.05	1	80.05	.481	.50	.00	.19
Course Bio	491.66	1	491.66	.082	3.07	.01	.42
Course Phy	8.24	1	8.24	.821	.05	.00	.06
Course IPC	22.36	1	22.36	.709	.14	.00	.07
Course Astro	355.75	1	355.75	.138	2.22	.01	.32
Course None	36.51	1	36.51	.634	.23	.00	.08
Course Earth	76.47	1	76.47	.491	.48	.00	.11
Course Enviro	36.88	1	36.88	.632	.23	.00	.08
Pretest	4037.82	1	4037.82	.000	25.23	.12	.99
STEM Perception Score	3541.62	17	208.33	.201	1.30	.03	.81
Error	20803.09	130	160.02				
Corrected Total	30861.79	157					

Note. [a] R^2 = .326 (Adjusted R^2 = .186)

The purpose of research question three was to test the effects of awareness of science and math competencies in agricultural contexts on the learning of physics information within agricultural mechanics. I concluded that awareness has no effect on learning as measured in this study. Chapter five will contain further discussion of this finding.

Research question four

Research question four: did student participants' experience levels in agricultural education affect change in science knowledge as assessed by the MCAS instrument?

Students were asked to answer questions regarding their experience level in agricultural education up to the point of the study. Table 27 records the years of agricultural education taken up to that point. Table 28 records the course work in agricultural education by the student participants.

$H_{O4\text{-}1}$: There are no differences in academic achievement Change scores $O\Delta$ among the experience level groups.

$$X_1\,(O\Delta) = X_2\,(O\Delta) = X_3\,(O\Delta)$$

Variables: Independent Variable = Years of agricultural education ($X_{1\text{-}3}$)
Dependent Variable= Change scores ($O\Delta$)
Covariates:
CV_1 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)
CV_2 = prescores (O_2)

Table 27

Years Involved in Agricultural Education of Student Participant

Years	*MS*	*SD*	*f*
1	2.28	13.96	143
2	9.66	12.63	9
3	8.70	--	1
Total	2.76	13.92	153

Note. Years of participation included the current year of the study.

Table 28

Frequency of Reported Coursework in Agriculture/CTE

Course	*f*
Hort	0
Mech and Metal	10
Principles of AFNR	85
Practica	0
Ag Math	0
Floral Design	5
Welding	6
Wildlife	4
Food Tech	2
Range	0
Forestry	1
Advanced plant	0
Ag Power	0
Equine	1
Small Animal	3
Advanced Animal	1
Concepts of Engineering*	15
Small Engine	2
Middle School Exploring Careers	10
Middle School Career Portals	18
Advanced Welding	3
Vet Med Applications	1
N	167**

Note. *course from another cluster taught by an agriculture science teacher
**students were possibly in multiple classes.

Levene's test of homogeneity of variances was not significantly different (p = .493; Table 29) further analysis were made. ANCOVA tests of the mean change scores were conducted to test for the effect of involvement in agricultural education on student performance on the MCAS assessment (IV = Experience, DV = ΔO, Covariates = Course work; Table 30). No statistically significant results were noted based on students' years of involvement in agricultural education ($F(2,152) = .568$, $p = .568$). I accepted H_{O4-1} because of these results.

Table 29

Levene's Test of Equality of Error Variances[a] for Years in Agriculture (IV)

F	*df1*	*df2*	*p*
.77	2	150	.463

Tests the null hypothesis that the error variance of the DV is equal across groups.
[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + Pre_MC_Percentage + POST_Q31_years_in_ag

Table 30

ANCOVA Table for the Change Scores (DV) by Years in Agriculture Courses (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	6316.68[a]	12	526.39	.000	3.19	.14	.99
Course Chem	5.61	1	5.61	.854	.03	.00	.05
Course PhySci	40.91	1	40.91	.620	.25	.00	.08
Course Bio	605.07	1	605.07	.058	3.66	.01	.48
Course Phy	.35	1	.35	.963	.00	.00	.05
Course IPC	40.90	1	40.90	.620	.25	.00	.08
Course Astro	635.85	1	635.85	.052	3.85	.02	.50
Course None	18.35	1	18.35	.739	.11	.00	.06
Course Earth	67.59	1	67.59	.523	.41	.00	.10
Course Enviro	28.93	1	28.93	.676	.18	.00	.07
Pretest	3201.10	1	3201.10	.000	19.38	.10	.99
Years in AGED	187.68	2	93.84	.568	.57	.00	.14
Error	23125.72	140	165.18				
Corrected Total	29442.41	152					

Note. [a] R^2 = .215 (Adjusted R^2 = .147)

The purpose of research question four was to test the effects of experience level in agricultural education on the learning of physics information within agricultural mechanics. I concluded that experience level in agricultural education has no effect on learning as measured in this study. Chapter five will contain further discussion of this finding.

Research question five

Research question five: Did a student's perception of novelty with the project affect change in science knowledge as assessed by the MCAS instrument?

Students were asked if they had completed a project similar to the one they completed in this study. Table 31 represents the frequency of responses and corresponding mean and standard deviation of the MCAS change score. Table 32 represents the reported novelty of the project based on the individual projects being performed. Participants were asked if they had ever performed a project like the one they had, the more negative the response the more novel the experience.

Table 31

Novelty Responses

	M	*SD*	*n*
1	.54	14.18	24
2	-3.66	13.92	19
3	2.42	11.96	27
4	9.10	13.5	33
5	1.69	14.39	49
Total	2.57	14.08	152

Note. 1 = Definitely yes, 2 = Probably yes, 3 = Maybe, 4 = Probably not, 5 = Definitely not

Table 32

Reported Novelty of the Project

Have you ever participated in a project like this before?		Wiring	Squishy	Drawing	Paper	Total
Definitely Yes	*n*	10	4	6	4	24
	% of treatment	21.70	6.70	24.00	19.00	15.80
Probably Yes	*n*	7	6	1	5	19
	% of treatment	15.20	10.0	4.00	23.80	12.50
Maybe	*n*	9	11	5	2	27
	% of treatment	19.60	18.30	20.00	9.50	17.80
Probably Not	*n*	14	14	3	2	33
	% of treatment	30.40	23.30	12.00	9.50	21.70
Definitely Not	*n*	6	25	10	8	49
	% of treatment	13.00	41.70	40.00	38.10	32.20
Total	*n*	46	60	25	21	152
	% of treatment	30.30	39.50	16.40	13.80	100

Note. Participants were asked if they had ever performed a project like the one they had. The more negative the response the more novel the experience.

$H_{O5\text{-}1}$: There are no differences in academic achievement change scores $O\Delta$ among the level of novelty with the project.

$$X_1\ (O\Delta) = X_2\ (O\Delta) = X_3\ (O\Delta)$$

Variables: Independent Variable = Reported level of novelty with the project ($X_{1\text{-}5}$)
Dependent Variable= Change scores ($O\Delta$)
Covariates:
CV_1 = prior course work (Course Chem, Course PhySci, Course Bio, Course Phy, Course IPC, Course Astro, Course None, Course Earth, Course Enviro)

Levene's test of homogeneity of variances was not significantly different (p = .853; Table 33). Since the test for homogeneity of variances was not significant, an ANCOVA test was conducted. An ANCOVA test of the mean change scores was calculated to test for the effect of novelty on student performance on the MCAS assessment (IV = Novelty, DV = ΔO, Covariates = Course work; Table 34). Statistically significant results were noted based on student's perception of novelty (F(4,138) = 2.56, p = .041, ω^2 = .04). I rejected H_{O5} because of these results. Field (2013) suggested standards for levels of effect size (ω^2). An effect size of (ω^2 =.04) falls between the small (ω^2 < .01) and medium (ω^2 = .06).

Table 33

Levene's Test of Equality of Error Variances[a] for Novelty (IV)

F	*df1*	*df2*	*p*
.34	4	147	.853

Tests the null hypothesis that the error variance of the DV is equal across groups.
[a.] Design: Intercept + Q28_1_Chem + Q28_2_Phy_Sci + Q28_3_Bio + Q28_4_Physics + Q28_5_IPC + Q28_6_None + Q28_7_Astron + Q28_8_E_and_S + Q28_9_Enviro + POST_Q37_1_Have_you_done_this_before

Table 34

ANCOVA Table for the Change Score (DV) by Reported Novelty (IV)

	SS	*df*	*MS*	*p*	*F*	ω^2	$1 - \beta$
Corrected Model	4464.44[a]	13	343.42	.066	1.86	.14	.90
Q28_1_Chem	66.22	1	66.22	.550	.36	.00	.09
Q28_2_Phy_Sci	188.76	1	188.76	.314	1.02	.00	.17
Q28_3_Bio	144.27	1	144.28	.378	.78	.00	.14
Q28_4_Physics	405.79	1	405.79	.140	2.20	.04	.31
Q28_5_IPC	145.57	1	145.57	.376	.79	.00	.14
Q28_6_None	931.56	1	931.56	.026	5.05	.02	.61
Q28_7_Astron	17.69	1	17.68	.757	.10	.00	.06
Q28_8_E_and_S	51.65	1	51.61	.598	.28	.00	.08
Q28_9_Enviro	41.02	1	41.02	.638	.22	.00	.08
POST_Q37_1_Have_ you_done_this_before	1889.70	4	472.43	.041*	2.56	.04	.71
Error	25454.50	138	184.45				
Corrected Total	29918.91	151					

Note. [a] R^2 = .149 (Adjusted R^2 = .069)
*significant at the p = .05 level.

A pairwise comparison was calculated to compare levels of novelty to determine where the variation exists within the variable reported novelty levels. Those instances, as well as the mean and standard deviations for each reported instance, are recorded in Table 35. Statistically significant differences were noted. Students with novelty level 4 had statistically different change scores than those at novelty level 2 (p =*.006)* and students with novelty level 4 were different than those with a novelty level 5 *(*p *= .012*).

Table 35

Pairwise Comparison of Change Score (DV) by Novelty of Project (IV)

(I)Novelty	*(J) Novelty*	*Mean Difference (I-J)*	*Std. Error*	*p*	*95% Confidence Interval for Difference*	
					Lower bound	*Upper bound*
1	2	4.31	4.40	.329	-4.39	13.00
	3	-1.75	3.95	.658	-9.55	6.06
	4	-6.98	3.75	.065	-14.39	.43
	5	.89	3.52	.800	-6.06	7.85
2	3	-6.06	4.13	.145	-14.22	2.11
	4	-11.29*	4.02	.006	-19.25	-3.33
	5	-3.41	3.84	.376	-11.01	4.18
3	4	-5.23	3.57	.145	-12.30	1.83
	5	2.64	3.33	.429	-3.94	9.22
4	5	7.88*	3.09	.012	1.76	13.99

Note: 1 = Definitely yes, 2 = Probably yes, 3 = Maybe, 4 = Probably not, 5 = Definitely not
Duplicate comparisons have been removed.
* The mean difference is significant at the .05 level.

Additionally, a Pearson Chi Square analysis was run to determine if a relationship between novelty and project type existed. The relationship between these two variables was determined to be significant, X^2 (12, N=152) = 22.35, p = .034.

The purpose of research question five was to test the effects of project novelty on the learning of physics information within an agricultural mechanics context. I concluded that project novelty has an effect on learning as measured in this study. Chapter five will contain further discussion of this finding.

Summary of findings

This chapter included the analysis of data as related to the testing of hypotheses related to the research questions. From those analyses, there were five findings:

1. Statistically significant differences were found between treatment groups.
    a. Between squishy circuits and wiring.
    b. Between squishy circuits and paper packets.
    c. Between drawing and paper packets.
2. Statically significant differences were found between student perception scores. Students with the most negative reported perception of the project were significantly lower in their change score than students who had almost every other perception score.
3. Statistically, no differences existed between students' various perceptions about science and mathematics in agricultural education.
4. Statistically, no differences existed between students with different years of experience.
5. Statistically significant differences were found between students' perceived novelty scores. Students who reported having higher novelty with the project type had significantly higher change scores pretest to posttest than students who had lower levels of novelty.

These findings provide opportunity for discussion about the practices of teaching, learning, and the development of future educators. These findings also yield questions that cannot be answered using the data collected. As such, I suggest more research to answer these questions.

CHAPTER V

DISCUSSIONS AND CONCLUSIONS

Introduction

In the four preceding chapters, I have attempted to provide evidence as to the role that agricultural education plays in the world of (core) STEM subject teaching and learning, most specifically science. I presented information to show that in the history of agricultural education, the direction and function of the discipline have been unclear. I attempted to show that the hands-on, or student-centered, nature of agricultural education provides fertile ground for the application of abstract concepts typically seen in the STEM disciplines. Arguably, that agricultural education was at one point, and can be again, not only a partner with the STEM disciplines but itself an integral part of STEM.

At the core of this study was an examination of how one of the foundations of agricultural education, project work (Dewey, 1916, 1938; Hummel & Hummel, 1913; Kilpatrick, 1918, 1925; Stimson, 1915, 1919), can affect the integration of STEM concepts. It is my hope that those who understand what it takes to integrate STEM (using our foundational methodologies) can better serve their students. This section includes a summary of the study as it was performed, draw conclusions based on the evidence, provide discussion about the implications of those conclusions, and present recommendations to inform best practice. A discussion flaws and setbacks of this study to provide starting points for future research.

Summary

The prevalence of STEM in agricultural education has waxed and waned over the many years since the formal beginnings (Chaisson & Burnett, 2001; Enderlin & Osborne, 1992; Hillison, 1998; Lee, 1994; Myers & Dyer, 2006; Myers & Thompson, 2009; Thompson & Balshweid, 1998; 2000; Rickets et al., 2006). Agricultural mechanics has been shown to provide a link between the practical or hands-on application of skills and the theoretical sciences, specifically, physics and engineering (Blackburn, 2013; Buriak, 1989; Edney, 2009; Scales et al., 2009). The use of project methods of instruction is common in agricultural education (Buriak, 1989; Moore, 1988; Parr & Edwards, 2004; Roberts & Harlin, 2007). However, a foundational understanding of certain tenets of the project-based method is not clear.

This study was conducted using quasi-experimental design with intact cohort groups. It examined the effects of project authenticity to determine its impact on the effectiveness of the project-based learning when integrating physics into secondary agriculture courses. In this study I also examined whether students' perceptions of the project's difficulty and real-world relevance affected knowledge gains. In addition, I explored the effect students' perceived novelty with the project had on scores.

The dependent variable in this study was the change in score from the pretest to the posttest on a composite exam taken from the Massachusetts Comprehensive Assessment System (MCAS). The MCAS was chosen as a standardized test developed by the same organization that develops national standardized tests. The Massachusetts students tend to perform well on the national standardized tests and those national tests were not feasibly accessible. The MCAS test was also not likely to have been seen by the participants and thus decreased this threat to external validity (Shadish et al., 2002). The independent variables in this study were the level of authenticity of the project, student perception of the project, student perceptions about the presence of science and mathematics within agriculture courses, the experience level of students in agricultural education, and students reported novelty with the type of project in which they participated.

The following research questions were addressed in the study:

1. Did project authenticity affect change in science knowledge as assessed by the MCAS instrument?
2. Did students' perceptions of projects affect change in science knowledge as assessed by the MCAS instrument?
3. Did awareness of science and math competencies in agricultural contexts affect change in science knowledge as assessed by the MCAS instrument?
4. Did students' experience levels, in agricultural education affect change in science knowledge as assessed by the MCAS instrument?
5. Did a student's perceived novelty with the project affect change in science knowledge as assessed by the MCAS instrument?

Students enrolled in agricultural education classes at five Texas High Schools served as the participants in the research (N = 219). At the conclusion of the study (n = 159), participants' change scores were usable for analysis. The 60 participant loss was due to a number of factors: lack of completion of both pre and posttests, lack of return of parental consent forms, not inputting the ID number into the exam properly, or absence (s) for any day of the treatment process. Four treatments with increasing levels of authenticity were designed to test the effect of authenticity. Increasing levels of authenticity were based on the recommendations by Larmer & Mergendoller (2015): paper packet (least authentic), squishy circuit, drawing a circuit, and wiring a circuit (most authentic). (See Table 1)

Fourteen cohort groups were identified in the five sites. These fourteen cohort groups were assigned randomly to one of the four treatments. Participants in each treatment progressed through the experience at the same pace, using the same support materials, and scenario, with the same direct instruction piece by use of an instructional video. The experimental variation was solely in the project conducted by the participants.

Participants began the process by completing the computer-delivered pretest. The participants then completed the protocol according to their assigned treatment group; they ended by completing the computer delivered posttest. During testing, I also collected perception, coursework, and experience data. I analyzed all data using IBM SPSS© version 24. I tested pretest scores for independence by calculating an analysis of covariance with treatment as the independent variable and class year, chemistry, physical science, biology, physics, integrated physics and chemistry (IPC), none, astronomy, earth and space, and environmental systems as covariates. Class year was the only variable found to be significantly. Thus, class year was removed from the covariate list as a violation of assumptions (Field, 2013; Coolidge, 2013).

Summary of findings

Statistically significant differences were found between several of the treatment groups. I saw differences between: (a) squishy circuits and wiring, (b) between squishy circuits and paper packets and (c) between drawing and paper packets. Additionally I noted statically significant differences between student perception scores. Specifically students with the most negative reported perception of the project were significantly lower in their change score than students who had almost every other perception score. There were no statistical differences detected between students' various perceptions about science and mathematics in agricultural education, or between students with different years of experience. However, I did find statistically significant differences between students' perceived novelty scores. Particularly students who reported having higher perceived novelty with the project type had significantly higher change scores pretest to posttest.

Finding one

The first finding of this study was that there were statistical differences found between the treatment groups. Tested at the ($\alpha = .025$) level to guard against rising change of Type I error due to an increase in number of tests, the results of a calculated ANCOVA would indicate that statistical differences do exist when different levels of authenticity are applied to the project-based methods ($F(3,145) = 3.59$. $p = .015$). However, this finding has a low to medium effect size ($\omega^2 = .04$).

Differences between treatments were tested using pairwise comparisons. Statistically significant differences were detected at the ($\alpha = .05$) level for treatments: squishy circuit at wiring ($p = .038$) with a mean difference of 5.19 positive toward the squishy treatment, squishy circuit at paper packet ($p = .002$) with a mean difference of 9.93 positive toward the squishy circuit treatment, and drawing at paper packet ($p = .049$) with a mean difference of 7.43 positive toward the drawing treatment. It should be noted that the wiring treatment, the most authentic, did not yield significantly higher scores than any of the treatments.

Finding two

The second finding was that statistical differences were seen between participants' scores when they varied in perceptions of the projects ($F(15,149) = 1.82$, $p = .036$). This finding has medium effect size ($\omega^2 = .06$). Using pairwise comparisons it was found that the highest perception score (5), and thus the worst opinion of the project, were statically different than 14 of the other perception scores. All participants with lower perception scores (better opinions of the project) had statically significantly higher change scores than the participants who reported a very low or negative opinion of the project.

Finding three

The third finding of this study concerned the perceptions of agricultural education's involvement with STEM most notably science and mathematics. No significant differences in change scores were found ($F(17,158) = 1.30$, $p = .201$) across perceptions of STEM in agricultural education. However, 59% felt very strongly in the positive that agriculture was part of STEM (1.00-1.59), 26% felt strongly in the positive (2.00-2.59), and 1.9% felt that agriculture was not part of STEM (4.00- 5.00).

Finding four

Finding four of this study was that no statistical differences existed in change scores between students with different years of experience in agricultural education ($F(2,152) = .57$, $p = .568$). One year of participation in agricultural education was the most common reported answer ($n = 143$).

Finding five

The fifth finding of this study was that statistical differences were found between students' perceived novelty scores ($F(4,152) = 2.56$, $p = .041$). An effect size ($\omega^2 = .04$) which falls between the small ($\omega^2 < .01$) and medium ($\omega^2 = .06$) was calculated. Calculating pairwise comparisons it was found that the students who reported having had previous experience with a project similar to the one they performed, performed worse than those who reported not having a similar project experience (ΔO mean difference = 11.29). Students who reported they had never performed a project like the one they participated in performed significantly worse than those who reported less novelty (ΔO mean difference = -7.88). A Chi Square analysis was run and a relationship was determent to exist between project and perceived novelty X^2 (12, N=152) = 22.35, p = .034.

Conclusions

Considering the findings in the context of the limitations of the study, I made four conclusions. These conclusions will inform the discussion later in this chapter.

1. Authenticity did play a part in the effectiveness of project-based learning; however, projects with the highest level of authenticity (wiring a circuit) did not lead to the highest levels of learning. That high-level authentic project yielded the same results as the least authentic project (paper packet). Projects with medium levels of authenticity, squishy circuits and drawing circuits provided more learning than did either low authenticity (paper packet) or highest authenticity (wiring a circuit).
2. Students' perceptions about the project interacted with student learning. Students who had a negative option of the experience did poorly.
3. Students' perceptions about STEM had no bearing on their learning of STEM concepts in the context of agricultural education. Students who were negative about STEM in agriculture did just as well as students who were positive.
4. A student's tenure in agricultural education played no part in STEM learning in agricultural education. There is no difference between a freshman and a senior in their potential to learn STEM in agriculture.

5. Student perceptions of novelty of the project system played a part in the effectiveness of a project in a project-based learning lesson. Higher perceptions of novelty lead to higher levels of learning and project assignment is related to that perception of novelty.

Discussion

Hands-on skill building in agricultural mechanics courses has shown to be a positive link to the hard or bench sciences such as physics and biology (Blackburn, 2013; Buriak, 1989; Edney, 2009; Scales et al., 2009). Project-based learning methods are ubiquitous in these agriculture courses (Buriak, 1989; Moore, 1988; Parr & Edwards, 2004; Roberts & Harlin, 2007). However, a foundational understanding of certain tenets of the project-based method of instruction is not clear. As agricultural education moves to an overt inclusion of the STEM discipline concepts into the curriculum (Hillison, 1998; Myers & Dyer, 2004) a clearer understanding of how to properly implement projects would be helpful to better inform practice. This study was designed to begin understanding the proposed relationship between project authenticity (Larmer & Mergendoller, 2015) and learning in an attempt to bridge the gap between what has been proposed and what has been tested. I will make and attempt to advance understanding of the role “authenticity” played in this instance of project-based learning.

Conclusion one: Authenticity did play a part in the effectiveness of project-based learning; however, projects with the highest level of authenticity did not lead to the highest levels of learning.

Larmer and Mergendoller said that to properly implement projects in the frame of project-based learning, projects must have “high levels of authenticity” (2015). However, little research supports those claims (Personal communication Mergendoller, October 15, 2015; Personal communications Larmer, October 12, 2015). I found in this study that authenticity did indeed play a part in educational gains of students, thus concurring with Larmer and Mergendoller (2015). However, those gains were not directly related to the authenticity of a project. Gains for students engaged in the most authentic project, a hands-on activity, and gains for students engaged in the least authentic, a non-hands-on activity, were not significantly different. This is consistent with the Johnson et al. (1997) findings that traditional paper and pencil activities yield the same academic results as hands-on activities to teach physics in agricultural mechanics. Johnson et al. (1997) noted that their projects, while hands-on, did not stimulate interest. The results of this study reflect that the stimulation of interest in the learning process is more likely to present itself using projects with medium levels of authenticity.

My first statement about individual projects is, that according to results presented in this study, fully authentic projects did not appear to provide any better opportunities for students to learn STEM concepts than reading a paper packet and answering questions. This is consistent with previous research. The differences appeared when I discuss the two projects with medium levels of authenticity. The second most authentic project involved participants drawing wiring diagrams. This project group yielded statistically better results than the paper packet group but not statistically different results than the wiring group. The least authentic project that was still hands-on, squishy circuit had a statistically higher change score than both wiring, the most authentic, and paper packet, the least. These two mid-level authenticity projects were not statistically different from each other.

What did these two mid-level authenticity projects have in common with each other, not seen in the other projects? Using the definitions set forth at other points of this document, the answer is nothing. None of the requirements suggested by Larmer and Mergendoller (2015), as seen in Table 2, were in the mid-level authenticity projects that were not also present in the fully authentic wiring project. To explain the difference, we must examine what else was different about the projects. The main difference between the squishy project and drawing project groups and the wiring and the paper packet groups were perceptions of novelty with the project type, which will be discussed at greater length in conclusion five.

Conclusion two: Participant perceptions of the project played a part in predicting the change score.

According to the Buck Institute for Education, a project-based learning training, research, and advocacy organization, students need to have a voice or choice in the project (Larmer & Mergendoller, 2015). Constructivist theory informs educators that learning should be internally motivated, not extrinsically motivated (von Glasersfeld, 1989; 1991). Intrinsic motivation allows students to push themselves through difficulty without need for praise or prodding. This intrinsic versus extrinsic argument goes back to the same base argument between the two main parties about vocational education. Georg Kershnesteiner, Charles Prosser, and David Snedden promoted the idea that; extrinsic motivation leads to more obedient workers, whereas intrinsic motivation leads to more independent abilities that are outside of the control of overseers (Gonon, 2009).

In an attempt to measure the intrinsic motivation of the student, I asked student participants at the end of the project how they felt about that project. They were asked several questions coalesced around whether they felt like they learned anything via the project. The findings led me to conclude that indeed, students' internal perceptions do lead to differing results. However, this finding appears to be most evident in students who have the least positive feelings. Students who felt with certainty that they did not like or learn from the project did not show noteworthy gains in understanding.

Students' feelings could very well have seen associated with the project itself. However, the only project not represented in the lowest perception category was the drawing project. The rest of the projects had at least one individual report in the lowest perception category. While philosophy leads us to believe that intrinsic motivations lead to better learning environments (von Galsersfeld, 2001, 1989) I hesitate to point to this conclusion as definitive. The students reporting a poor perception of the project (n = 4) also had unusually low scores on the posttest. This group lost an average of 10.8 points from the pre to the posttest. These results lead me to conclude that these four participants could have been less than truthful about their perceptions and thus have been sources of potentially unreliable data.

Conclusion three: Students' perceptions about STEM have no bearing on their learning of STEM concepts in the context of agricultural education.

STEM are on the forefront of education. As has been argued in this document, career and technical education is a prime spot to teach those STEM concepts (Blackburn, 2013; Buriak, 1989; Chaisson & Burnett, 2001; Conroy & Walker, 1998; Edney, 2009; Enderlin & Osborne, 1992; Myers & Dyer, 2006; Myers & Thompson, 2009; Rickets et al., 2006; Scales et al., 2009; Thompson & Balschweid, 1998). However, little is known about the effects of the agricultural education method of teaching on STEM education (Stone, 2011). Considerable research has been conducted to ascertain teachers' opinions about the integration of STEM concepts in agricultural education (Brister & Swortzel, 2009; Scales et al., 2009; Smith, Rayfield, & McKim; 2015; Thompson & Balschweid, 2000). Little research has been conducted however to determine if students' perceptions about STEM play a part in the learning of STEM concepts in agriculture.

Perceptions about the learning environments play a part in the potential for learning (Bandura, 1971; 1978; Carroll, 1963, 1989). If students perceived that agricultural education was not part of STEM, does this affect their ability to learn overtly STEM concepts in the context of agricultural education? Likewise, if students believe agriculture is part of the STEM disciplines, does that perception lead them to learning more science or mathematics in agriculture. There is no evidence in the responses of this study's (n = 159) participants that students' perceptions about agriculture's position in or out of the STEM disciplines plays any part in their ability to learn STEM concepts. However, in this sample the participants did believe that agriculture was part of STEM; 59% felt very strongly in the positive that agriculture was part of STEM (1.00-1.59); 26% felt strongly in the positive (2.00-2.59); 1.9% felt that agriculture was not part of STEM (4.00- 5.00).

Conclusion four: A student's tenure in agricultural education plays no part in STEM learning in agricultural education.

This study highlighted the importance of STEM concepts within agricultural education. This is not a new nor novel aim. As discussed, what is now called STEM is at the foundation of what agricultural education was built to do before the discipline became overtly vocational. Agricultural education has a particular method of teaching that typically highlights the hands-on and experiential (Newcomb et al., 1993; Phipps & Osborn, 1988). Many other have also said that participating in agricultural sciences increases the science scores of students more than science courses in isolation (e.g., Clark et al., 2013; Myers & Dyer, 2004; Stone, 2011; Rickets et al., 2005).

Agricultural education is a holistic discipline that highlights student involvement through classroom-based education, application-based projects that are related to classroom work, and leadership opportunities that are related to the former two. The three-circle diagram of the "total program" as promoted by most agricultural education dogma (Figure 11), pushed by Phipps and Osborne (1988) and fully realized by Croom

(2008), is held up as unique to the field and lauded as the key to the success of agricultural education. Research in agricultural education has declared that activities done in context are an integral part of the agricultural education curriculum (Cheek, Arrington, Carter, & Randall, 1994; Conroy, Trumbull, & Johnson, 1999; Johnson, 1991; Noxel & Cheek, 1988; Roegge & Russell, 1990). Others have established that students learn best when taught within context (Balschweid, 2001; Conroy et al., 1999; Darling-Hammond & Falk, 1997; Shelley-Tolbert et al., 2000).

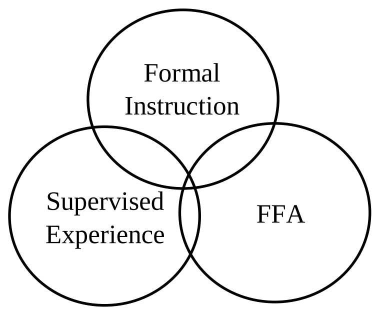

Figure 11 Total program model. Reprinted from (Croom, 2008).

If this contextualization is relatively important to education, does the familiarity with this system of education play a part in learning? The data present in this study suggest that familiarity does not play a role. In this situation, a student with only one year of experience (n = 143) was no more or less likely to perform better in the context of agriculture than a student with two or three years of experience. This finding supports studies that show students do better in science courses when they also participate in agriculture (Clark et al., 2013; Myers & Dyer, 2004; Stone, 2011; Rickets et al., 2005). These studies identified differences in the immediacy of agricultural educational methods. Those differences were not dependent on extended acculturation and were not exclusive to those who had continued to self-select to participate in the agricultural education program.

One problem with an interpretation of these data is the very unequal sample resulting from the selection methods. In an attempt to limit the effects of coursework, namely science course work, the sample contained a disproportionate number of younger students in introductory agriculture courses. Younger students were less likely to have taken science courses that could have confounded change in the pre to posttest scores. This would have not been due to the treatments, but rather due to an existing understanding of the concepts. The selection method also led to a very large group of students who had not been in agricultural education courses previously, primarily due to the very few number of school districts in Texas that offer agriculture at the middle school level. An unequal sample size does violate one of the rules of analysis of covariance (Field, 2013).

Conclusion Five: Student perception of novelty with the project system plays a part in the effectiveness of a project in a project-based learning lesson. However, the overall effect is very small.

According to Larmer and Mergendoller, students need to be familiar with the project type to perform in a project-based system (2015). The findings of this study run contrary to what was said by Larmer and Mergendoller. Students did not have to be familiar with the project type to be successful. It was found in this study that students who reported higher levels of novelty with the project type performed best of all.

Hedwig von Restorff demonstrated that students learned quicker and more deeply if the information they were expected to know was presented in a way that was different from the rest of the information (von Restorff, 1933). Von Restorff and the subsequent iterations of her experiments used immediately known novelty to the individuals to highlight the different groups (Samuels, 1986). The von Restorff experiments were conducted by presenting small bits of information to young people printed in color while the bulk of information was printed in black (von Restorff, 1933). The colored information was retained at a much higher rate than the information printed in black (Samuels, 1986; von Restorff, 1933). Applying the theory of novelty across time, I can draw parallels about the effect of novelty on this study. Rather than students needing to see items that are immediately different, as was done in von Restorff's experiments, the differences could be over time. The change is less immediate; students see something they learned previously operated in a certain way operate in a new or novel way.

I saw novelty in this study in two ways. The novelty of drawing a circuit is something that is done in engineering but is not often done in high school agriculture classes. Students also have likely not participated in the squishy circuit activity. The drawing and squishy treatments have the highest reported novelty with 67% of the Squishy, and 52% of the drawing groups reporting that they had not participated in a project like this before. Likewise, 30.5% of the participants in the paper packet group and 43.4% of the wiring group said the same (Figure 12). A Chi Square analysis was run and the results upheld my postulation that the novelty level was related to the project type X^2 (12, N=152) = 22.35, p = .034.

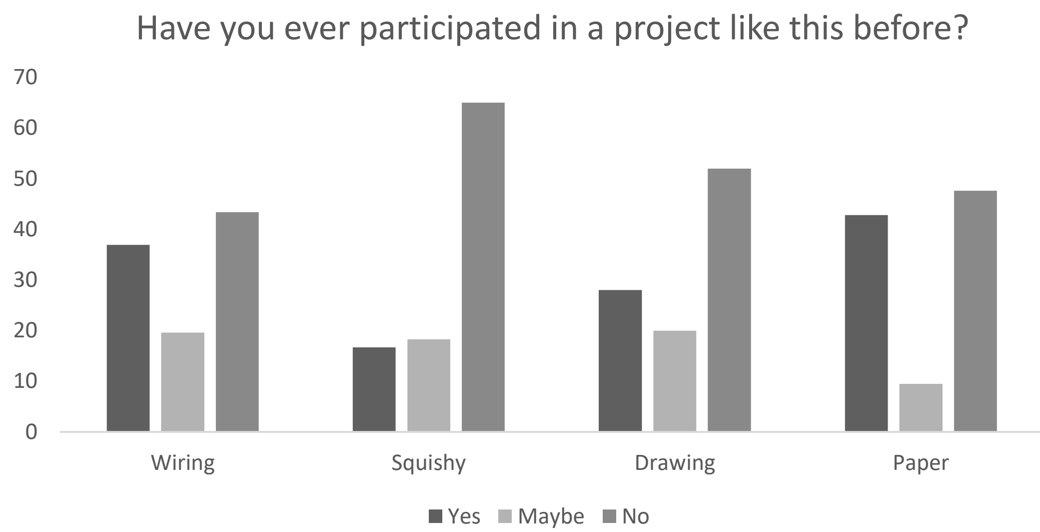

Figure 12. Novelty report by participants. Participants were asked if they had ever participated in a project like this one before. The more negative the response the more novelty.

Upon further examination, this novelty effect likely plays a part in the focus participants gave to the project. That in turn, may have affected the amount of information students gained. My findings support assertions made by Carroll (1963, 1989). The focus students give to study is one of the inputs that lead to academic achievement. This novelty effect likely played a part in the amount of time students were willing to spend into learning which according to Carroll is the primary factor that determines likelihood of student learning. If students perceive the project to be interesting due to its uniqueness, they might have paid attention longer, and thus learn more.

Another take on the novelty of the project is the effects the uniqueness of the project had on the amount of assumptions students had to put aside to operate within the new system they developed. In texts that focus on inquiry teaching of introductory sciences, time is spent on the development of an understanding of systems (Dewey, 1938; Ethredge & Rudnitsky, 2003). Students must spend time becoming acquainted with the system to understand how what is presented is similar and dissimilar from the previously known. To be successful, students must interact with what they believe to be true, encounter something they do not believe or did not previously see as truth, and find a way to resolve the dissonance between the two (Festinger, 1957; Hewson & Hewson, 1984; Hewson, 1981). Cognitive dissonance or cognitive conflict has been considered important for decades as evidenced by the work of Dewey (1910; 1916), Festinger (1957), Piaget (1964), and Berlyne (1965). I believe this cognitive dissonance was partly what spurred the learning forward in this study.

Students in the 9th grade have a basic understanding of what a circuit is and what makes up a circuit. When introduced to the task of drawing a circuit, students were forced to interact with electricity in a more abstract fashion, which possibly created some form of dissonance. Likewise, squishy circuits created a dissonance with the system that is wiring simple circuits. Students were likely to understand circuits are wires, bulbs, and power supplies. The system of squishy circuits takes the system of wires, bulbs, and power, and in a certain sense, perverts the system. In the common understanding of the system known as circuits, wires are made of copper or another conductive metal, bulbs have threaded ends that fit female sockets, and batteries are attached via spring or hardware means. In the system known as squishy circuits, playdoh conducts electricity, bulbs are pushed in via needle-like protrusions and batteries have probes to electrify anything they touch. This system shift likely created a dissonance which students were forced to confront in order to complete the task. In the new system, conductors were anything that conducts (not just wires); loads were more than screw-bottom bulbs, and power sources were not just positive lock batteries. Students interacting with squishy circuits had learn the proxies for the system. They had to learn how the proxies are understood in another context. That relearning forced them to see the parts for what they were in the system (a conductor, a load, a power source) rather than wire, bulb, and battery.

Conversely, when wiring a circuit using traditional methods students interacted with a system they have previously encountered. Preconceived notions were upheld and no dissonance was created. They progressed through the project without having to think about how all of the parts worked together. This helps to solidify the support of Dewey's (1910) model of problem-based experiential learning rather than Kilpatrick's (1918) various project models as spoken about in Stevenson (1925), and later in Moore (1988). The use of a problem led to the likelihood that students would encounter a dissonance. Students in a purely project-based lesson (i.e., one devoid of problems), can potentially perform the task successfully with no dissonance, as seems to be the case in the wiring treatment. Through problems, or with projects that lead to problems, students encounter the necessary dissonance.

Recommendations

Based on the findings and conclusions of this study, there are many recommendations for practice in agricultural education, as well as recommendations for future research. These recommendations include the following:

In the context of this study, I concluded that students learned more physics concepts when projects were performed that challenged the way they understand systems. Students that were forced to rethink their preconceptions about what criteria are and are not important learned better. I recommended that practitioners assess what students understand about systems, what the important components of that system are, and what criteria define both system and component. Based on those assessments, instructors and curriculum designers should design projects that strip away the irrelevant criteria (e.g., all conductors are insulated wires) and force them to identify the truly relevant criteria.

I also recommend that focus should not be taken away from the skill development of coursework. No attempt in this study was made to assess the skill development of electrical work at any level. Previous research findings support the idea that you can develop skill and still teach skills; however, that research was not done using methods that disrupt the system. Skills should not be dismissed, as they are a truly important part of what agricultural education provides. Research should be done on whether or not this type of project work using disruption affects skill development.

This study revealed that the “most authentic” project did not yield the highest levels of learning. Based on those findings, the models for project-based learning need to be revised to remove or clarify the “authenticity” label. In this study, many assumptions were made as to the other criteria of high-quality project-based learning. Those other criteria need to be tested on an individual basis.

Professional development should be done to teach practicing teachers how to implement projects that challenge student’s understandings of systems. Training should be done that helps teachers see the difference between practical application of skill and the principles of learning behind those skills. Practicing teaches should be shown how cognitive dissonance and disruption can be used to challenge students’ beliefs about systems and that a student who knows how to perform a task does not necessarily understand what is happening.

Teachers in the study expressed anxiety facilitating the student-centered projects. They felt very uncomfortable being removed from the position of authority and giving the project the authority to instruct, therefore giving the student the authority to learn. This is common in constructivist theory. Professional development needs to be done with teachers on implementing student-centered projects that involve the teacher moving from the role of authority and into the role of facilitator. Teacher personality types need to be examined as to their abilities to facilitate student-centered projects.

Students’ internal motivation should be further encouraged. Results show that students with higher perceptions of the effectiveness of the project did indeed learn more. Those who thought they learned very little, learned very little. These respondents could have been “click through” respondents, which create suspicion. I recommend implementing a protocol to handle click through respondents. Due to the suspect nature of the lowest student responses, more research should be done on assessing student perceptions of the projects' effectiveness more thoroughly.

Other research recommendations based on this study:

1. This study should be replicated in a truly experimental design under more clinical conditions to determine if the findings manifest.
2. This study used as its context very simple scientific principles. The study should be replicated using higher-order concepts to determine if the complexity of concept affects the results.
3. The sample frame in this study did not provide adequate results to make any recommendations about the number of years or agriculture courses taken. As such, research should be conducted to ascertain if students who take more years of agricultural education do better than those with fewer years do, or is there an initial peak and then a gradual decline back to normality.
4. Due to attrition and using cohort assignment, the overall treatment numbers were not as even as were originally assigned. Though the findings were not statistically affected, questions can be levied at the findings due to the unequal treatment sizes. This study should be replicated with a larger sample size to ensure equal groups.
5. In this study, the use of random assignment across schools took teacher influence out of the equation; however, an assessment of teacher abilities

should be made. Those abilities within science should be tested related to student achievement.

Final Summary for Practice

Teachers and designers of curriculum should utilize projects that will encourage students to learn about the system and not rely solely on what they have learned previously. Those projects do not have to mimic what students will see in the "real world." Abstract projects that challenge students are beneficial to student learning. Teachers should feel free and empowered to use creative projects that challenge the way students understand information.

As teachers implement lessons, they need to be conscious of what the student thinks about the lesson. We all need to be careful to not make the experience negative. We need to not tell students that things are going to be difficult, bad, annoying, boring, not fun, or that students will have to just shoulder through. If a student has a negative opinion of what they are doing, they do worse.

Students in agriculture classes assume agriculture is science and math based. Do not be afraid or apprehensive to incorporate science and math into lessons.

The educational benefits of a student taking an agriculture class can happen in year one. All students should experience an agriculture course at some point in their school career. Those who only have one period their junior or senior year available will still benefit. They do not have to be a part of the entire sequence of courses. However, a sequence may provide more opportunities for students to experience the information.

Agriculture can provide a novel opportunity for students to experience science. Agricultural science teachers have the opportunity to provide the unique hands on activity that is different from what the students are experiencing in traditional science courses. Teachers should feel confident in using projects that challenge students understanding of how the information fits together.

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APPENDIX A

District Permission Request

Texas School District:

The Texas A&M University Agricultural Leadership, Education, & Communications department would like to invite you to participate in a research study that will examine students ability to learn science content in an agricultural context.

Thank you for considering participating in this study. Your students participation is voluntary, there is no potential negative ramifications for your not participating. Your decision to participate or not to participate, will in no way affect your relationship with your school, Texas A&M or the ALEC department. The purpose of this study is to examine the effect various authenticity levels of projects will affect a student's ability to learn physics information.

Your Ag Science teacher has been identified as a partner in this research. They will be asked to use provided teaching materials, developed by our department to teach a unit on <u>Direct Current Electricity</u>. The content and delivery of that information will be accurate and following all norms of direct instruction. Teachers will be provided with lesson plans and the direct instruction piece of the lesson. Teachers will then be asked to facilitate one of several application lessons to accompany the direct instruction. Once direct instruction is complete students will be given a scenario with a problem to solve, four of the five groups will be asked to solve that problem by completing various using the various levels of authenticity to represent that completed project. Projects to be randomly assigned will be: a paper based worksheet, drawing a solution, constructing a circuit using a computer based simulation, constructing a representative circuit using conductive playdoughs, or constructing a small working circuit.

All application pieces and projects are level and content appropriate as well as safe and will present no more danger to the student, instructor, or facilities than would normally occur in an average teaching day. Students will not intentionally receive reduced levels of instruction or be given incorrect information at any time during the duration of this study. The information presented to the students is in keeping with the state approved TEKS for the courses we are asking to conduct the study within.

Student participants will be assessed two times using a computer based assessment. That assessment is comprised of items taken with permission directly from the state high school assessment used in the state of Massachusetts and released questions from the Advanced Placement physics exam. These assessments will be given in a pre/post model. One assessment before the instruction and one at the conclusion of the project. Each student will be given a number to aid in the comparing scores across the three assessments. This number will not be directly associated with the student in a manner that would allow their identity to be known to anyone other than the research personnel. The use of coding sheets will be used. Code sheets will be stored in a locked and secure cabinet with approved research personnel only having access.

As part of the study research personnel, myself or my research advisor, may come to observe the facilitation of the lessons to ensure treatment fidelity or help troubleshoot with your instructors.

We thank you for considering participating in this study. It is through collaboration between researchers and districts such as yours that together we are able to move education forward for our young people.

Kind Regards,

Jason McKibben

Texas A&M University

PhD Student, ALEC department

Tim H Murphy, PhD.

Texas A&M University

Professor

Dissertation Research Chair & Research Advisor

By signing below I am giving the above permission to conduct the afore outlined research as outlined.

Printed name:______________________________

Title:_____________________________________

Signiture:_________________________________

APPENDIX B

Parental Consent Form

Parent/Guardian:

The Texas A&M University Agricultural Leadership, Education, & Communications department would like to invite you to participate in a research study that will examine students ability to learn science content in an agricultural context.

Thank you for considering participating in this study. Your students participation is voluntary, there is no potential negative ramifications for your not participating. Your decision to participate or not to participate, will in no way affect your relationship with your school, Texas A&M or the ALEC department. The purpose of this study is to examine the effect various authenticity levels of projects will affect a student's ability to learn physics information.

Your Ag Science teacher has been identified as a partner in this research. They will be asked to use provided teaching materials, developed by our department to teach a unit on <u>Direct Current Electricity</u>. The content and delivery of that information will be accurate and following all norms of direct instruction. Teachers will be provided with lesson plans and the direct instruction piece of the lesson. Teachers will then be asked to facilitate one of several application lessons to accompany the direct instruction. Once direct instruction is complete students will be given a scenario with a problem to solve, four of the five groups will be asked to solve that problem by completing various using the various levels of authenticity to represent that completed project. Projects to be randomly assigned will be: a paper based worksheet, drawing a solution, constructing a circuit using a computer based simulation, constructing a representative circuit using conductive playdoughs, or constructing a small working circuit.

All application pieces and projects are level and content appropriate as well as safe and will present no more danger to the student, instructor, or facilities than would normally occur in an average teaching day. Students will not intentionally receive reduced levels of instruction or be given incorrect information at any time during the duration of this study. The information presented to the students is in keeping with the state approved TEKS for the courses we are asking to conduct the study within.

Student participants will be assessed two times using a computer based assessment. That assessment is comprised of items taken with permission directly from the state high school assessment used in the state of Massachusetts. These assessments will be given in a pre/post model. One assessment before the instruction, and one at the conclusion of the project. Each student will be given a number to aid in the comparing scores across the three assessments. This number will not be directly associated with the student in a manner that would allow their identity to be known to anyone other than the research personnel. The use of coding sheets will be used. Code sheets will be stored in a locked and secure cabinet with approved research personnel only having access.

Risks and Benefits:

There are no known or intended risks to your students, you, or your facility. All application pieces and projects are level and content appropriate as well as safe and will present no more danger to the student, instructor, or facilities than would normally occur in an average teaching day. Students will not intentionally receive reduced levels of instruction or be given incorrect information at any time during the duration of this study. The information presented to the students is in keeping with the state approved TEKS for the courses we are asking to conduct the study within.

The perceived benefits are the lesson and materials will be given to you along with all other lessons used in this study after its completion. Since this is a completely voluntary study your choice to or not to participate will in no affect your relationship with Texas A&M or the Agricultural Leadership, Education,& Communications Department.

Confidentiality:

Your students, your school, and you can be assured that records of this study will be kept private and any information collected will be confidential. Any reports or articles generated using this study will remain confidential and will not include any identifying information regarding your students, your school, or you.

Contact information:

If you have any questions now or as we progress please do not hesitate to contact me or Dr. Murphy.

Jason McKibben	Dr. Tim H Murphy
jasonmckibben@tamu.edu	TMurphy@tamu.edu

If you have any concerns about the way this research is conducted or your rights as a volunteer participant you may contact the Texas A&M University Institutional Review Board (IRB) Chair; Dr. Name; Address; email

You will be provided with a copy of this document for your records.

Statement of removal from study:

By signing and returning this document I **DO NOT** want my student ________________________ to participate in this study.

Printed name:_________________________ Signature: _____________________________

APPENDIX C

Example of Four Column Number Code Sheet

Student number	Period	Parent permission yes/no	Name
E401			
E402			
E403			
E404			
E405			
E406			
E407			
E408			
E409			
E410			
E411			
E412			
E413			
E414			
E415			
E416			
E417			
E418			

APPENDIX D

Sample of Exam

Q45 What project did you participate in?

- I used wires and bulbs to wire 2 circuits (1)
- I used dough and LED's to create 2 circuits (2)
- I drew 2 circuits on poster boards (3)
- I completed printed notes packets (4)

Q1 Jamal wants to make an electrical circuit, but he only has the objects shown below Which of the following must Jamal have to make an electric circuit?

- a motor (1)
- a switch (2)
- a bar magnet (3)
- a power source (4)

Q2 Which of the following shows two objects that are both conductors of electricity?

- Image:Spoon and wire q9 2013 a (1)
- Image:Nail and wire q9 2013 b (2)
- Image:Paper clip and yarn q9 2013 c (3)
- Image:Penny and toothpick q9 2013 d (4)

Q3 The diagram below shows a project that a student made to test an electrical circuit. Part of the electrical circuit is underneath the board. When the student connects the two nails using a wire, the bulb lights up. Which of the following must be underneath the board?

- a magnet and a switch (1)
- a switch and some wires (2)
- a magnet and a power source (3)
- a power source and some wires (4)

Q4 Which of the following best explains why electrical wires are usually covered with plastic or rubber?

- to keep the electrical wire warm (1)
- to make the electrical wire stronger (2)
- to make the electrical wire more flexible (3)
- to insulate the electrical wire (4)

Q5 in which circuit are both bulbs lit?

- Image:Bulb and battery q16 2010 a (1)
- Image:Bulb and battery q16 2010 b (2)
- Image:Bulb and battery q16 2010 c (3)
- Image:Bulb and battery q16 2010 d (4)

Q6 The circuit diagram below shows D-cells connected to four light bulbs and four different materials labeled 1, 2, 3, and 4. Which of the four materials is acting as an insulator rather than a conductor?

- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)

Q7 Which of the following statements best compares direct current (DC) and alternative current (AC)?

- AC flows in only one direction, and DC flows in both directions. (1)
- DC flows in only one direction, and AC flows in both directions. (2)
- AC comes directly from a power plant, and DC comes from a magnetic field. (3)
- DC can maintain a constant voltage over time, and AC loses voltage over time (4)

Q8 The circuit shown below consists of a power source, a switch, a fuse, a resistor, nichrome wire, and a light bulb. When the power is on and the switch is closed, the light bulb does not light. Which of the following is the most likely explanation for why the light bulb does not light in this circuit?

- ❍ The switch should be in the open position. (1)
- ❍ The nichrome wire does not conduct electricity. (2)
- ❍ The current flowing through the circuit has exceeded the rating of the fuse. (3)
- ❍ The placement of the resistor has created too much resistance in the circuit. (4)

Q9 A diagram for a circuit with two switches, S1 and S2, is shown below. If S1 is left open and S2 is closed, which resistors will be in series?

- ❍ R1 and R2 only (1)
- ❍ R1 and R3 only (2)
- ❍ R2 and R3 only (3)
- ❍ R1, R2, and R3 (4)

Q10 Lupe built the simple circuit shown below. Lupe modifies this circuit by decreasing the voltage of the battery by one-half. In order to keep the amount of current flowing through the circuit the same as it was before, which other change must Lupe make to the circuit?

- ❍ She must add a switch. (1)
- ❍ She must increase the resistance. (2)
- ❍ She must decrease the resistance. (3)
- ❍ She must remove a section of wire. (4)

Q11 The diagram below shows a circuit with three resistors. At which of the following points should the two leads of a voltmeter be placed to measure the voltage across R1?

- ❍ at points U and W (1)
- ❍ at points S and X (2)
- ❍ at points S and T (3)
- ❍ at points T and U (4)

Q12 The diagram below shows an electrical circuit. Which of the following statements describes a function of component X when the switch is closed?

- ❍ Component X turns the circuit on and off. (1)
- ❍ Component X supplies energy to the circuit. (2)
- ❍ Component X uses a low current to control a higher-current circuit. (3)
- ❍ Component X allows electrical current to flow in only one direction (4)

Q13 Which of the following statements accurately describes electrical circuits?

- ❍ Only AC circuits can transmit electrical energy. (1)
- ❍ Only DC circuits can transmit electrical energy. (2)
- ❍ Current in AC circuits flows in both directions. (3)
- ❍ Current in DC circuits flows in both directions. (4)

Q14 The diagram below shows a circuit with three different resistors, R1, R2, and R3. Which of the following equations should be used to calculate the total resistance, RT, of the circuit?

- ❍ RT =R1 x R2 x R3 (1)
- ❍ RT =R1 + R2 + R3 (2)
- ❍ RT =(1/R1) x (1/R2) x (1/R3) (3)
- ❍ RT =(1/R1) + (1/R2) + (1/R3) (4)

Q15 Which of the following objects is a controller in a circuit?

- ❍ ammeter (1)
- ❍ battery (2)
- ❍ motor (3)
- ❍ switch (4)

Q16 An automobile battery produces which type of current?

- ❍ alternating current (1)
- ❍ digital current (2)
- ❍ direct current (3)
- ❍ interval current (4)

Q17 Maria needs to measure the amount of current flowing through a closed circuit. Which of the following instruments should she use for this task?

- ❍ ammeter (1)
- ❍ hygrometer (2)
- ❍ ohmmeter (3)
- ❍ voltmeter (4)

Q18 In a circuit, an electrician replaces a 4 ft. section of wire with a wire that has a larger diameter. This change in wire diameter will cause which of the following results?

- The current in the new wire section will be less than in the original wire. (1)
- The resistance of the new wire section will be less than that of the original wire. (2)
- A greater power loss in the circuit will occur because of the new wire section. (3)
- A greater voltage drop across the circuit will occur because of the new wire section. (4)

Q19 A simple circuit with one resistor is shown below The voltmeter reads 6 V and the ammeter reads 3 A. Which of the following is the resistance of R?

- 0.5 Ω (1)
- 2 Ω (2)
- 9 Ω (3)
- 18 Ω (4)

Q20 A series circuit with two resistors is shown below. At which two points should a voltmeter be connected to measure the voltage of the circuit?

- points Y and Z (1)
- points W and X (2)
- points X and Y (3)
- points W and Z (4)

Q21 The electrical resistance of a wire may change depending on which of the following?

- the luster of the wire (1)
- the elasticity of the wire (2)
- the malleability of the wire (3)
- the temperature of the wire (4)

Q22 A simple circuit diagram is shown below. What is the resistance of the circuit if the current is 0.5 A?

- ❍ 3.0 Ω (1)
- ❍ 9.0 Ω (2)
- ❍ 12.0 Ω (3)
- ❍ 24.0 Ω (4)

Q23 A current of 1.2 A flows through a 5.0 Ω resistor in a circuit. What is the voltage across this resistor?

- ❍ 0.24 V (1)
- ❍ 3.8 V (2)
- ❍ 6.0 V (3)
- ❍ 7.5 V (4)

Q41 An electrical circuit can be constructed using a conductor, an insulator, a load, and a power source.Identify three objects that can be used a load in an electrical circuit.

1 (1)

2 (2)

3 (3)

Q47 An electrical circuit can be constructed using a conductor, an insulator, a load, and a power source.Identify three objects that can be used as an insulator in an electrical circuit.

1 (1)

2 (2)

3 (3)

Q42 Ammeters and Voltmeters are instruments used to make measurements in electrical circuits. Describe how to connect an Ammeter to make a measurement.

Q43 Ammeters and Voltmeters are instruments used to make measurements in electrical circuits. Describe how to connect an Voltmeter to make a measurement.

Q44 Some basic electrical components of a circuit are listed below: Battery Resistor Fuse Switch Load Relay   Pick three of the above components on the list. Describe the basic function of each in terms of how it is used in a DC electric circuit.

APPENDIX E

Perception Assessment

Q36 Answer the following questions about your experience with the project

	Definitely yes (1)	Probably yes (2)	Maybe (3)	Probably not (4)	Definitely not (5)
Do you think the project helped you to learn? (1)	❍	❍	❍	❍	❍
Did you feel prepared for the project? (2)	❍	❍	❍	❍	❍
Do you know more after completing the project than you knew before? (3)	❍	❍	❍	❍	❍
Did completing the project make you frustrated? (4)	❍	❍	❍	❍	❍

Q37 Answer the following questions about what you normally do in Ag class

	Definitely yes (1)	Probably yes (2)	Maybe (3)	Probably not (4)	Definitely not (5)
Have you ever done a project like this one before? (1)	❍	❍	❍	❍	❍
Do you like projects in class? (2)	❍	❍	❍	❍	❍
Do you do hands-on projects in Ag class usually? (3)	❍	❍	❍	❍	❍
Do you think the normal projects you do in Ag class looks like the "real-world"? (4)	❍	❍	❍	❍	❍

Q38 Answer the following questions about Ag

	Definitely yes (1)	Probably yes (2)	Maybe (3)	Probably not (4)	Definitely not (5)
Is Agriculture part of Science? (1)	❍	❍	❍	❍	❍
Is Agriculture part of Math? (2)	❍	❍	❍	❍	❍
Is there Science in Agriculture? (3)	❍	❍	❍	❍	❍
Is there Math in Agriculture? (4)	❍	❍	❍	❍	❍
Do you learn Math in Ag class? (5)	❍	❍	❍	❍	❍
Do you learn Science in Ag class? (6)	❍	❍	❍	❍	❍

Q39 Respond these statements about your experience with the project.

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I didn't learn anything by participating in this project. (1)	❍	❍	❍	❍	❍
The lesson did not prepare me to complete this project. (2)	❍	❍	❍	❍	❍
I don't know any more now than I did before I did the project. (3)	❍	❍	❍	❍	❍
This project was easy. (4)	❍	❍	❍	❍	❍
This project didn't have anything do to with the "real-world" (5)	❍	❍	❍	❍	❍

Q40 Respond to these statements.

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
We do too many projects in Ag class. (1)	❍	❍	❍	❍	❍
I don't like doing projects. (2)	❍	❍	❍	❍	❍
I would rather teachers just tell me what I need to know. (3)	❍	❍	❍	❍	❍
Projects are just busy work. (4)	❍	❍	❍	❍	❍
I don't think we learn from projects. (5)	❍	❍	❍	❍	❍

Q27 What class/grade are you?

❍ 9th grade (1)
❍ 10th grade (2)
❍ 11th grade (3)
❍ 12th grade (4)

Q28 What science class have you taken before this year?

- ❑ Chemistry (1)
- ❑ Physical Science (2)
- ❑ Biology (3)
- ❑ Physics (4)
- ❑ IPC (5)
- ❑ None of These (6)
- ❑ Astronomy (7)
- ❑ Earth and Space (8)
- ❑ Environmental Systems (9)

Q29 Is this your first Ag Class?

- ❍ Yes (1)
- ❍ No (2)

Q32 Do you know if you are on a pathway?

- ❍ Yes (1)
- ❍ No (2)

Answer If Do you know if you are on a pathway? Yes Is Selected
Q34 What pathway?

- ❍ Animal Science/Vet Medicine (1)
- ❍ Ag Mechanics/Construction/Power systems (2)
- ❍ Natural Resources (3)
- ❍ Food Science (4)
- ❍ Plant Systems (5)
- ❍ Agribusiness (6)
- ❍ Other (7) ____________________

Q26 What is your gender?

- ❍ Male (1)
- ❍ Female (2)
- ❍ I do not want to answer (3)

Q31 How many years have you taken agriculture classes?

- ❍ First year in ag (1)
- ❍ Second year in ag (2)
- ❍ Third year in ag (3)
- ❍ Fourth year in ag (4)
- ❍ Fifth year in ag (5)
- ❍ Sixth or more year in ag (6)

Q30 What ag classes have you taken before or are you taking now ? (Include this year)

- ❑ Horticulture (1)
- ❑ Agricultural Mechanics and Metal technologies (2)
- ❑ Principles of Agricultural Food and Natural Resources (101) (3)
- ❑ Livestock Production (4)
- ❑ Veterinary Medicine (5)
- ❑ Practicum in Agriculture (6)
- ❑ Agricultural Math Applications (7)
- ❑ Floral Design (8)
- ❑ Welding (9)
- ❑ Wildlife (10)
- ❑ Food Technology (11)
- ❑ Range Ecology and Management (12)
- ❑ Forestry (13)
- ❑ Advanced Plant and Soils (14)
- ❑ Agricultural Power Systems (15)
- ❑ Equine (16)
- ❑ Small Animal Management (17)
- ❑ Advanced Animal Science (18)
- ❑ Concepts of Engineering and Technology (19)
- ❑ Small Engine Technology (20)
- ❑ Advanced Welding (21)
- ❑ Exploring Careers (Middle School) (22)
- ❑ Career Portals (Middle School) (23)

APPENDIX F

Treatment Instructions

Paper packet instructions

Your students have been assigned the paper packet task. DC electricity will be the overarching idea behind this lesson. They will have to read and answer questions about that information. You can help facilitate their understanding of the concepts as long as it doesn't give them the answer. Allow them, to find the answer on their own.

Procedures:

- Assign your students a number- Use the number sheet provided
- Administer the pretest to the students, it is online the link is in the lesson plan and on its own document.
- Use the instruction video to instruct your students. Don't add to the instruction, or discount anything in the instruction. This instruction is sent to ensure all students across the study (at many different schools) receive ***exactly*** the same direct instruction.
- Students in their groups of three are to complete the paper packets. There are two packets.
- Administer the posttest (You are welcome to use this as a test grade, however if you do please let me know if you have done so. As we all have seen, some students can act differently if they know it is going to be for a grade and this could skew the results of the study)
- Complete the teacher reflection assessment

Information about "Paper packet"

- **This is the "control" for this experiment**
- **The control is needed to understand what, if any differences the other treatments have on the students learning.**

Squishy circuit instructions

Your students have been assigned the Squishy Circuit Simulation project task. DC electricity will be the overarching idea behind this lesson. They will have to design a device that uses DC electricity to solve the problem in the scenario. You can help facilitate their understanding of the concepts as long as it doesn't give them the answer. Allow them, no matter if it's frustrating to find the answer on their own.

Procedures:

- Assign your students a number- Use the number sheet provided
- Administer the pretest to the students, it is online the link is in the lesson plan and on its own document.
- Use the instruction video to instruct your students. Don't add to the instruction, or discount anything in the instruction. This instruction is sent to ensure all students across the study (at many different schools) receive ***<u>exactly</u>*** the same direct instruction.
- Pass out the supplies, Each group of three should have one bag of colored conductive dough and one bag of white insulative dough, The need to be able to string up three lights per circuit. The color does not matter. You may pass out six of the LEDs to each group, but let them use more if they want to explore the system a little bit when then get started.
- Facilitate your students in the project you have been assigned. Do not help them solve the problem, allow them to become frustrated, let them reach a solution.
- Allow your students to present and explain their solutions to each other.
- Administer the posttest (You are welcome to use this as a test grade, however if you do please let me know if you have done so. As we all have seen, some students can act differently if they know it is going to be for a grade and this could skew the results of the study)
- Complete the teacher reflection assessment

Information about "squishy Circuits":

- **The colored dough is conductive**
- **The white dough is insulative**
- **The students will place the ends of the battery pack in the dough**
- **The LED light ends will be placed in the dough**
- **Don't let the LED's touch the battery pack leads**
- **If students mix the dough you can't un-mix them. So be careful of that**
- **The dough is just flour, water, salt, sugar, lemon juice and food coloring**
- **If the dough is left out it will harden**
- **If it gets hard in the bag, put a little water in it and knead it.**

Drawing a circuit Instructions

One of your classes have been assigned the Drawing a circuit project task. DC electricity will be the overarching idea behind this lesson. They will have to design a device that uses DC electricity to solve the problem in the scenario. You can help facilitate their understanding of the concepts as long as it doesn't give them the answer. Allow them, no matter if it's frustrating to find the answer on their own.

They will be working in groups of three.

Procedures:

- Assign your students a number- Use the number sheet provided
- Administer the pretest to the students, it is online the link is in the lesson plan and on its own document.
- Use the instruction video to instruct your students. Don't add to the instruction, or discount anything in the instruction. This instruction is sent to ensure all students across the study (at many different schools) receive ***<u>exactly</u>*** the same direct instruction.
- Facilitate your students in the project you have been assigned. Do not help them solve the problem, allow them to become frustrated, let them reach a solution.
- Allow your students to present and explain their solutions to each other.
- Administer the posttest (You are welcome to use this as a test grade, however if you do please let me know if you have done so. As we all have seen, some students can act differently if they know it is going to be for a grade and this could skew the results of the study)
- Complete the teacher reflection assessment

Information about "draw a circuit"

- **They can choose the color of poster they want, it doesn't matter**
- **They should try to use the symbols and techniques they learned in the video**
- **They should do each design on a separate piece of poster board.**

Wiring a circuit instructions

One of your classes have been assigned the Wiring a circuit project task. DC electricity will be the overarching idea behind this lesson. They will have to design a device that uses DC electricity to solve the problem in the scenario. You can help facilitate their understanding of the concepts as long as it doesn't give them the answer. Allow them, no matter if it's frustrating to find the answer on their own.

They will be working in groups of three.

Procedures:

- Assign your students a number- Use the number sheet provided
- Administer the pretest to the students, it is online the link is in the lesson plan and on its own document.
- Use the instruction video to instruct your students. Don't add to the instruction, or discount anything in the instruction. This instruction is sent to ensure all students across the study (at many different schools) receive ***exactly*** the same direct instruction.
- Facilitate your students in the project you have been assigned. Do not help them solve the problem, allow them to become frustrated, let them reach a solution.
- Allow your students to present and explain their solutions to each other.
- Administer the posttest (You are welcome to use this as a test grade, however if you do please let me know if you have done so. As we all have seen, some students can act differently if they know it is going to be for a grade and this could skew the results of the study)
- Complete the teacher reflection assessment

Information about "Wiring a circuit":

The bulbs are kind of sensitive so I didn't put them in the baggies for each group.

Pass them out as needed

APPENDIX G

Pairwise Comparison of All Perception Scores

(I) Perception score	(J) Perception score	Mean Difference (I-J)	Std. Error	*p*	95% Confidence Interval for Difference Lower bound	95% Confidence Interval for Difference Upper bound
1.00	1.25	13.708*	5.613	.016	2.598	24.818
	1.50	1.107	5.553	.842	-9.884	12.098
	1.75	2.201	5.564	.693	-8.811	13.214
	2.00	.445	4.954	.929	-9.360	10.250
	2.25	1.367	5.215	.794	-8.955	11.688
	2.50	2.693	4.958	.588	-7.120	12.507
	2.75	2.956	4.814	.540	-6.572	12.484
	3.00	6.516	4.731	.171	-2.847	15.880
	3.25	8.290	5.173	.112	-1.948	18.529
	3.50	-1.471	7.568	.846	-16.449	13.507
	3.75	9.936	6.655	.138	-3.237	23.108
	4.00	13.515*	6.461	.039	.726	26.304
	4.25	1.910	9.455	.840	-16.804	20.623
	4.50	3.833	8.075	.636	-12.150	19.816
	5.00	26.560*	7.366	.000	11.981	41.139
1.25	1.50	-12.601*	6.136	.042	-24.746	-.457
	1.75	-11.507	6.141	.063	-23.662	.649
	2.00	-13.263*	5.552	.018	-24.253	-2.274

	2.25	-12.341*	5.732	.033	-23.688	-.995
	2.50	-11.015*	5.555	.050	-22.009	-.020
	2.75	-10.752	5.469	.052	-21.577	.073
	3.00	-7.192	5.321	.179	-17.724	3.340
	3.25	-5.418	5.786	.351	-16.870	6.034
	3.50	-15.179	7.985	.060	-30.983	.625
	3.75	-3.772	7.066	.594	-17.758	10.213
	4.00	-.193	6.942	.978	-13.932	13.547
	4.25	-11.799	9.785	.230	-31.166	7.569
	4.50	-9.875	8.431	.244	-26.563	6.812
	5.00	12.852	7.653	.096	-2.296	27.999
1.50	1.75	1.095	6.064	.857	-10.908	13.097
	2.00	-.662	5.389	.902	-11.328	10.004
	2.25	.260	5.616	.963	-10.856	11.376
	2.50	1.587	5.526	.774	-9.350	12.523
	2.75	1.849	5.338	.730	-8.715	12.414
	3.00	5.409	5.254	.305	-4.990	15.809
	3.25	7.183	5.709	.211	-4.117	18.484
	3.50	-2.578	7.914	.745	-18.243	13.087
	3.75	8.829	6.989	.209	-5.004	22.662
	4.00	12.408	6.852	.073	-1.154	25.971
	4.25	.803	9.735	.934	-18.466	20.071

	4.50	2.726	8.348	.745	-13.797	19.250
	5.00	25.453*	7.557	.001	10.495	40.411
1.75	2.00	-1.757	5.284	.740	-12.214	8.701
	2.25	-.835	5.595	.882	-11.910	10.240
	2.50	.492	5.378	.927	-10.153	11.137
	2.75	.755	5.368	.888	-9.870	11.380
	3.00	4.315	5.245	.412	-6.067	14.697
	3.25	6.089	5.784	.295	-5.360	17.537
	3.50	-3.673	7.826	.640	-19.163	11.818
	3.75	7.734	6.997	.271	-6.115	21.583
	4.00	11.314	6.862	.102	-2.269	24.896
	4.25	-.292	9.676	.976	-19.443	18.859
	4.50	1.631	8.340	.845	-14.876	18.139
	5.00	24.358*	7.723	.002	9.073	39.644
2.00	2.25	.922	4.926	.852	-8.827	10.671
	2.50	2.249	4.748	.637	-7.149	11.646
	2.75	2.512	4.634	.589	-6.661	11.684
	3.00	6.071	4.479	.178	-2.794	14.937
	3.25	7.845	5.221	.135	-2.488	18.179
	3.50	-1.916	7.470	.798	-16.700	12.869
	3.75	9.491	6.423	.142	-3.221	22.203
	4.00	13.070*	6.433	.044	.338	25.803

	4.25	1.465	9.269	.875	-16.881	19.810
	4.50	3.388	7.834	.666	-12.118	18.894
	5.00	26.115*	7.190	.000	11.884	40.346
2.25	2.50	1.327	4.835	.784	-8.244	10.897
	2.75	1.590	4.927	.748	-8.163	11.342
	3.00	5.149	4.698	.275	-4.149	14.448
	3.25	6.924	5.306	.194	-3.579	17.426
	3.50	-2.838	7.768	.715	-18.212	12.537
	3.75	8.569	6.587	.196	-4.468	21.606
	4.00	12.149	6.260	.055	-.242	24.539
	4.25	.543	9.436	.954	-18.133	19.219
	4.50	2.466	7.987	.758	-13.343	18.276
	5.00	25.193*	7.211	.001	10.921	39.465
2.50	2.75	.263	4.619	.955	-8.880	9.406
	3.00	3.823	4.504	.398	-5.093	12.738
	3.25	5.597	5.167	.281	-4.630	15.823
	3.50	-4.165	7.407	.575	-18.826	10.497
	3.75	7.242	6.461	.264	-5.546	20.030
	4.00	10.822	6.207	.084	-1.464	23.108
	4.25	-.784	9.330	.933	-19.250	17.683
	4.50	1.140	7.895	.885	-14.487	16.766
	5.00	23.866*	7.150	.001	9.714	38.019

2.75	3.00	3.560	4.480	.428	-5.307	12.427
	3.25	5.334	5.138	.301	-4.835	15.503
	3.50	-4.427	7.469	.554	-19.211	10.356
	3.75	6.979	6.433	.280	-5.754	19.713
	4.00	10.559	6.198	.091	-1.708	22.826
	4.25	-1.047	9.313	.911	-19.480	17.386
	4.50	.877	7.893	.912	-14.746	16.500
	5.00	23.604*	7.131	.001	9.490	37.717
3.00	3.25	1.774	4.904	.718	-7.931	11.480
	3.50	-7.987	7.308	.277	-22.451	6.477
	3.75	3.420	6.312	.589	-9.073	15.912
	4.00	6.999	6.258	.266	-5.387	19.385
	4.25	-4.607	9.237	.619	-22.890	13.677
	4.50	-2.683	7.776	.731	-18.075	12.708
	5.00	20.044*	6.990	.005	6.208	33.880
3.25	3.50	-9.761	7.617	.202	-24.838	5.316
	3.75	1.646	6.755	.808	-11.725	15.016
	4.00	5.225	6.605	.430	-7.848	18.298
	4.25	-6.381	9.576	.506	-25.334	12.573
	4.50	-4.457	8.161	.586	-20.611	11.697
	5.00	18.270*	7.327	.014	3.767	32.772
3.50	3.75	11.407	8.673	.191	-5.759	28.572

	4.00	14.986	8.565	.083	-1.966	31.939
	4.25	3.381	10.988	.759	-18.368	25.130
	4.50	5.304	9.795	.589	-14.082	24.691
	5.00	28.031*	9.177	.003	9.868	46.194
3.75	4.00	3.580	7.713	.643	-11.688	18.847
	4.25	-8.026	10.288	.437	-28.389	12.336
	4.50	-6.103	8.980	.498	-23.876	11.671
	5.00	16.624*	8.306	.048	.185	33.063
4.00	4.25	-11.606	10.278	.261	-31.948	8.737
	4.50	-9.682	8.996	.284	-27.488	8.123
	5.00	13.045	8.224	.115	-3.234	29.323
4.25	4.50	1.923	11.216	.864	-20.275	24.122
	5.00	24.650*	10.766	.024	3.342	45.959
4.50	5.00	22.727*	9.483	.018	3.957	41.497

APPENDIX H

Variable Coding Sheets

Variable	Question or Description (Label)	Measure	Coding	Source
V1	ResponseID	Nominal		V1
V6	IPAddress	Nominal		V6
Q47	StudentID	Nominal		Q47
School	School of participant	Nominal	{1 = Clear, 2 = Early, 3 = Hutt, 4 = Rud, 5 = Wimb }	Q47
PRE_Q1	Jamal wants to make an electrical circuit, but he only has the objects shown below Which of th...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q1
PRE_Q2	Which of the following shows two objects that are both conductors of electricity?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q2
PRE_Q3	The diagram below shows a project that a student made to test an electrical circuit. Part of the...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q3
PRE_Q4	Which of the following best explains why electrical wires are usually covered with plastic or rub...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q4
PRE_Q5	In which circuit are both bulbs lit?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q5
PRE_Q6	The circuit diagram below shows D-cells connected to four light bulbs and four different materia...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q6
PRE_Q7	Which of the following statements best compares direct current (DC) and alternative current (AC)?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q7
PRE_Q8	The circuit shown below consists of a power source, a switch, a fuse, a resistor, nichrome wire,...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q8
PRE_Q9	A diagram for a circuit with two switches, S1 and S2, is shown below. If S1 is left open and S2 ...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q9

Variable	Question or Description (Label)	Measure	Coding	Source
PRE_Q10	Lupe built the simple circuit shown below. Lupe modifies this circuit by decreasing the voltage o...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q10
PRE_Q11	The diagram below shows a circuit with three resistors. At which of the following points should t...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q11
PRE_Q12	The diagram below shows an electrical circuit. Which of the following statements describes a func...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q12
PRE_Q13	Which of the following statements accurately describes electrical circuits?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q13
PRE_Q14	The diagram below shows a circuit with three different resistors, R1, R2, and R3. Which of the fo...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q14
PRE_Q15	Which of the following objects is a controller in a circuit?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q15
PRE_Q16	An automobile battery produces which type of current?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q16
PRE_Q17	Maria needs to measure the amount of current flowing through a closed circuit. Which of the follo...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q17
PRE_Q18	In a circuit, an electrician replaces a 4 ft. section of wire with a wire that has a larger diame...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q18
PRE_Q19	A simple circuit with one resistor is shown below The voltmeter reads 6 V and the ammeter reads 3...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q19
PRE_Q20	A series circuit with two resistors is shown below. At which two points should a voltmeter be con...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q20

Variable	Question or Description (Label)	Measure	Coding	Source
PRE_Q21	The electrical resistance of a wire may change depending on which of the following?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q21
PRE_Q22	A simple circuit diagram is shown below. What is the resistance of the circuit if the current is...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q22
PRE_Q23	A current of 1.2 A flows through a 5.0 Ω resistor in a circuit. What is the voltage across this...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q23
(PRE_Q1_WW) – (PRE_Q23_WW)	PRE_Q1 – PRE_Q23 CONVERTED TO BINARY CORRECT OR INCORRECT	Nominal	{0 = incorrect, 1 = Correct}	Q1-Q23
Pre_MC_Total	Total of pretest multiple choice items correct	Interval	0-11	Q1-Q23
Pre_MC_Percentage	Percentage of multiple choice items correct	Ratio	0 - 100	Q1-Q23
~~Q41_1_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD-1~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q41_1_TEXT~~
~~Q41_2_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD - 2~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q41_2_TEXT~~
~~Q41_3_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD - 3~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q41_3_TEXT~~
PRE_Q41_GRADED	CORRECT OR INCORRECT MARKING OF PRE_Q 41 (1 - 3)	Interval	{0 - 3} (1 POINT FOR EACH ITEM DESCRBED CORRECTLY)	Q41 1-3
~~PRE_Q47_1_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR-1~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_1_TEXT~~

Variable	Question or Description (Label)	Measure	Coding	Source
~~PRE_Q47_2_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR-2~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_2_TEXT~~
~~PRE_Q47_3_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR -3~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_3_TEXT~~
PRE_Q47_GRADED	CORRECT OR INCORRECT MARKING OF PRE_Q 47 (1 - 3)	Interval	{0 - 3} (1 POINT FOR EACH ITEM DESCRBED CORRECTLY)	Q47_1_TEXT-3_TEXT
PRE_Q43	Ammeters and Voltmeters are instruments used to make measurements in electrical circuits. Describe how to connect an Voltmeter to make a measurment...	Nominal	{PARTICIPANT TEXT ENTRY}	Q43
PRE_Q43_GRADED	CORRECT OR INCORRECT MARKING OF PRE_Q 43	Interval	{0 = INCORECT, 1 = CORRECT}	Q43
PRE_Q44	Some basic electrical components of a circuit are listed below: Battery, Resistor, Fuse, Switch, Load... PICK THREE OF THE ABOVE…Describe the basic function of each in terms of how it is used in a DC electric circuit	Nominal	{PARTICIPANT TEXT ENTRY}	Q44
PRE_Q44_GRADED	CORRECT OR INCORRECT MARKING OF PRE_Q44	Interval	{0 - 3} (1 POINT FOR EACH ITEM DESCRBED CORRECTLY)	Q44
Pre_WRITTEN_SCORE_TOTAL	TOTAL OF PRE_Q41_GRADED, PRE_Q47_GRADED, PRE_Q43_GRADED, & PRE_Q44_GRADED	Interval		Q41, Q47, Q43, Q44
PRE_Q36_1	Answer the following questions about your	Ordinal	{1 = DEFINITELY YES, 2 =	Q36_1

Variable	Question or Description (Label)	Measure	Coding	Source
	experience projects - Do you think projects helped you to learn?		PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	
PRE_Q36_2	Answer the following questions about your experience projects - Did you feel prepared for the projects?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_2
PRE_Q36_3	Answer the following questions about your experience projects - Do you know more after completing projects than you knew before?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_3
PRE_Q36_4	Answer the following questions about your experience projects - Does completing projects make you frustrated?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_4
PRE_Q38_1	Answer the following questions about Ag - Is Agriculture part of Science?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_1
PRE_Q38_2	Answer the following questions about Ag - Is Agriculture part of Math?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_2
PRE_Q38_3	Answer the following questions about Ag - Is there Science in Agriculture?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT,	Q38_3

Variable	Question or Description (Label)	Measure	Coding	Source
			5 = DEFINITELY NOT}	
PRE_Q38_4	Answer the following questions about Ag - Is there Math in Agriculture?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_4
PRE_Q38_5	Answer the following questions about Ag - Do you learn Math in Ag class?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_5
PRE_Q38_6	Answer the following questions about Ag - Do you learn Science in Ag class?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_6
PRE_Q40_1	Respond to these statements. - We do too many projects in Ag class.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_1
PRE_Q40_2	Respond to these statements. - I don't like doing projects.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_2
PRE_Q40_3	Respond to these statements. - I would rather teachers just tell me what I need to know.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_3
PRE_Q40_4	Respond to these statements. - Projects are just busy work.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5	Q40_4

Variable	Question or Description (Label)	Measure	Coding	Source
			= STRONGLY AGREE}	
PRE_Q40_5	Respond to these statements. - I don't think we learn from projects.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_5
PRE_Q27	What class/grade are you?	Interval	{1 = 9TH GRADE YES, 2 = 10TH GRADE , 3 = 11TH GRADE, 4 = 12TH GRADE)	Q27
Q28_1_Chem	What science class have you taken? (include this school year) - Chemistry	Nominal	{1 = = Selected}	Q28_1
Q28_2_Phy_Sci	What science class have you taken? (include this school year) - Physical Science	Nominal	{1 = = Selected}	Q28_2
Q28_3_Bio	What science class have you taken? (include this school year) - Biology	Nominal	{1 = = Selected}	Q28_3
Q28_4_Physics	What science class have you taken? (include this school year) - Physics	Nominal	{1 = = Selected}	Q28_4
Q28_5_IPC	What science class have you taken? (include this school year) - IPC	Nominal	{1 = = Selected}	Q28_5
Q28_6_None	What science class have you taken? (include this school year) - None of These	Nominal	{1 = = Selected}	Q28_6
Q28_7_Astron	What science class have you taken? (include this school year) - Astronomy	Nominal	{1 = = Selected}	Q28_7
Q28_8_E_and_S	What science class have you taken? (include this school year) - Earth and Space	Nominal	{1 = = Selected}	Q28_8
Q28_9_Enviro	What science class have you taken? (include this school year) - Environmental Systems	Nominal	{1 = = Selected}	Q28_9
Q29	Is this your first Ag Class?	Nominal	{1 = YES, 2 = NO}	Q29

Variable	Question or Description (Label)	Measure	Coding	Source
Q32	Do you know if you are on a pathway?	Nominal	{1 = YES, 2 = NO}	Q32
Q34	What pathway?	Nominal	{1 = ANIMAL SCIENCE/VET MEDICINE, 2 = AG MECHANICS/CONSTRUCTION/POWER SYSTEMS, 3 = NATURAL RESOURCES, 4 = FOOD SICNECE, 5 = PLAN SCIENCE, 6 = AGRIBUSINESS, 7 = OTHER (ACTIVATES Q34_TEXT)	Q34
Q34_TEXT	What pathway? - TEXT	Nominal	{PARTICIPANT TEXT ENTRY}	Q34_TEXT
Q26	What is your gender?	Nominal	{1 = MALE, 2 = FEMALE, 3 = I DO NOT WANT TO ANSWER}	Q26
Q31	How many years have you taken agriculture classes?	Interval	{1 = FIRST YEAR IN AG, 2 = SECOND YEAR IN AG, 3 = THIRD YEAR IN AG, 4 = FOURTH YEAR IN AG, 5 = FIFTH YEAR IN AG, 6 = SIXTH OR MORE YEAR IN AG}	Q31
Q30_1	What ag classes have you taken before or are you taking now? (Include this year) - Horticulture	Nominal	{1 = = Selected}	Q30_1
Q30_2	What ag classes have you taken before or are you taking now? (Include this year) - Agricultural Mechanics and Metal technologies	Nominal	{1 = = Selected}	Q30_2
Q30_3	What ag classes have you taken before or are you	Nominal	{1 = = Selected}	Q30_3

Variable	Question or Description (Label)	Measure	Coding	Source
	taking now? (Include this year) - Principles of Agricultural Food and Natural Resources (101)			
Q30_4	What ag classes have you taken before or are you taking now? (Include this year) - Livestock Production	Nominal	{1 = = Selected}	Q30_4
Q30_5	What ag classes have you taken before or are you taking now? (Include this year) - Veterinary Medicine	Nominal	{1 = = Selected}	Q30_5
Q30_6	What ag classes have you taken before or are you taking now? (Include this year) - Practicum in Agriculture	Nominal	{1 = = Selected}	Q30_6
Q30_7	What ag classes have you taken before or are you taking now? (Include this year) - Agricultural Math Applications	Nominal	{1 = = Selected}	Q30_7
Q30_8	What ag classes have you taken before or are you taking now? (Include this year) - Floral Design	Nominal	{1 = = Selected}	Q30_8
Q30_9	What ag classes have you taken before or are you taking now? (Include this year) - Welding	Nominal	{1 = = Selected}	Q30_9
Q30_10	What ag classes have you taken before or are you taking now? (Include this year) - Wildlife	Nominal	{1 = = Selected}	Q30_10
Q30_11	What ag classes have you taken before or are you taking now? (Include this year) - Food Technology	Nominal	{1 = Selected}	Q30_11
Q30_12	What ag classes have you taken before or are you taking now? (Include this year) - Range Ecology and Management	Nominal	{1 = = Selected}	Q30_12

Variable	Question or Description (Label)	Measure	Coding	Source
Q30_13	What ag classes have you taken before or are you taking now? (Include this year) - Forestry	Nominal	{1 = = Selected}	Q30_13
Q30_14	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Plant and Soils	Nominal	{1 = = Selected}	Q30_14
Q30_15	What ag classes have you taken before or are you taking now? (Include this year) - Agricultural Power Systems	Nominal	{1 = = Selected}	Q30_15
Q30_16	What ag classes have you taken before or are you taking now? (Include this year) - Equine	Nominal	{1 = = Selected}	Q30_16
Q30_17	What ag classes have you taken before or are you taking now? (Include this year) - Small Animal Management	Nominal	{1 = = Selected}	Q30_17
Q30_18	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Animal Science	Nominal	{1 = = Selected}	Q30_18
Q30_19	What ag classes have you taken before or are you taking now? (Include this year) - Concepts of Engineering and Technology	Nominal	{1 = = Selected}	Q30_19
Q30_20	What ag classes have you taken before or are you taking now? (Include this year) - Small Engine Technology	Nominal	{1 = = Selected}	Q30_20
Q30_21	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Welding	Nominal	{1 = = Selected}	Q30_21
Q30_22	What ag classes have you taken before or are you	Nominal	{1 = = Selected}	Q30_22

Variable	Question or Description (Label)	Measure	Coding	Source
	taking now? (Include this year) - Exploring Careers (Middle School)			
Q30_23	What ag classes have you taken before or are you taking now? (Include this year) - Career Portals (Middle School)	Nominal	{1 = = Selected}	Q30_23
POST_ID	StudentID	Nominal		POST_ID
POST_V1	ResponseID	Nominal		POST_V1
POST_V8	StartDate	Nominal		POST_V8
POST_V9	EndDate	Nominal		POST_V9
POST_Q47	Type the number your teacher gave you below.	Nominal		POST_Q47
POST_45	What treatment did you participate in?	Nominal	{1 = WIRING, 2 = SQUISHY, 3 = DRAWING, 4 =paperPACKET}	POST_45
Project_No Project_Dummy	Did the participant experience a treatment (Project) or control (No Project)	Nominal	{0 = No Project, 1 = Project}	POST_45
Wiring_Dummy	Participants who participated in the wiring treatment.	Nominal	{0 = did not wire, 1 = wire project}	POST_45
Drawing_Dumy	Participants who participated in the drawing treatment.	Nominal	{0 = did not draw, 1 = drawing project}	POST_45
Squishy_Dummy	Participants who participated in the squishy circuit treatment.	Nominal	{0 = did not do squishy circuit, 1 = did squishy circuit}	POST_45
IMS_Dummy	Participants who participated in thepaper packet treatment.	Nominal	{0 = did not usepaperpacket, 1 = did usepaperpacket}	POST_45
POST_Q1	Jamal wants to make an electrical circuit, but he only has the objects shown below Which of th...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q1
POST_Q2	Which of the following shows two objects that are	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q2

Variable	Question or Description (Label)	Measure	Coding	Source
	both conductors of electricity?			
POST_Q3	The diagram below shows a project that a student made to test an electrical circuit. Part of the...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q3
POST_Q4	Which of the following best explains why electrical wires are usually covered with plastic or rub...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q4
POST_Q5	in which circuit are both bulbs lit?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q5
POST_Q6	The circuit diagram below shows D-cells connected to four light bulbs and four different materia...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q6
POST_Q7	Which of the following statements best compares direct current (DC) and alternative current (AC)?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q7
POST_Q8	The circuit shown below consists of a power source, a switch, a fuse, a resistor, nichrome wire,...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q8
POST_Q9	A diagram for a circuit with two switches, S1 and S2, is shown below. If S1 is left open and S2 ...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q9
POST_Q10	Lupe built the simple circuit shown below. Lupe modifies this circuit by decreasing the voltage o...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q10
POST_Q11	The diagram below shows a circuit with three resistors. At which of the following points should t...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q11
POST_Q12	The diagram below shows an electrical circuit. Which of the following statements describes a func...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q12
POST_Q13	Which of the following statements accurately describes electrical circuits?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q13

Variable	Question or Description (Label)	Measure	Coding	Source
POST_Q14	The diagram below shows a circuit with three different resistors, R1, R2, and R3. Which of the fo...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q14
POST_Q15	Which of the following objects is a controller in a circuit?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q15
POST_Q16	An automobile battery produces which type of current?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q16
POST_Q17	Maria needs to measure the amount of current flowing through a closed circuit. Which of the follo...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q17
POST_Q18	In a circuit, an electrician replaces a 4 ft. section of wire with a wire that has a larger diame...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q18
POST_Q19	A simple circuit with one resistor is shown below The voltmeter reads 6 V and the ammeter reads 3...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q19
POST_Q20	A series circuit with two resistors is shown below. At which two points should a voltmeter be con...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q20
POST_Q21	The electrical resistance of a wire may change depending on which of the following?	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q21
POST_Q22	A simple circuit diagram is shown below. What is the resistance of the circuit if the current is...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q22
POST_Q23	A current of 1.2 A flows through a 5.0 Ω resistor in a circuit. What is the voltage across this...	Nominal	{1 = A, 2 = B, 3 = C, 4 = D}	Q23
(POST_Q1_WW – POST_Q23_WW)	POST_Q1 – POST_Q23 CONVERTED TO BINARY CORRECT OR INCORRECT	Nominal	{0 = incorrect, 1 = Correct}	Q1-Q23

Variable	Question or Description (Label)	Measure	Coding	Source
Post_MC_ Total	Total of multiple choice items correct	Interval	0 - 23	
Post_MC_ Percentage	Percentage of multiple choice items correct	Ratio	0 - 100	
~~POST_Q41_1_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD 1~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	Q41_1 _TEXT
~~POST_Q41_2_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD 2~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	Q41_2 _TEXT
~~POST_Q41_3_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...LOAD 3~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	Q41_3 _TEXT
POST_Q41_GRADED	CORRECT OR INCORRECT MARKING OF POST_Q41(1 - 3)	Interval	{0 - 3} {1 point for each item described correctly}	Q41_1 _TEXT - Q41_3 _TEXT
~~POST_Q47_1_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR 1~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_1 _TEXT~~
~~POST_Q47_2_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR 2~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_2 _TEXT~~
~~POST_Q47_3_TEXT~~	~~An electrical circuit can be constructed using a conductor, an insulator, a load, and a power sou...INSULATOR 3~~	~~Nominal~~	~~{PARTICIPANT TEXT ENTRY}~~	~~Q47_3 _TEXT~~
POST_Q47_GRADED	CORRECT OR INCORRECT MARKING OF POST_Q47 (1 - 3)	Interval	{0 - 3} {1 point for each item described correctly}	~~Q47_1 _TEXT -~~

Variable	Question or Description (Label)	Measure	Coding	Source
				~~Q47_3_TEXT~~
POST_Q42	Ammeters and Voltmeters are instruments used to make measurements in electrical circuits. Describ....	Nominal	{PARTICIPANT TEXT ENTRY}	Q42
POST_Q43	Ammeters and Voltmeters are instruments used to make measurements in electrical circuits. Describ...	Nominal	{PARTICIPANT TEXT ENTRY}	Q43
POST_Q43_ GRADED	CORRECT OR INCORRECT MARKING OF POST Q42 OR POST Q 43	Interval	{0 = INCORRECT, 1 = CORECT}	Q42, Q43
POST_Q44	Some basic electrical components of a circuit are listed below: Battery, Resistor, Fuse, Switch, Load... PICK THREE OF THE ABOVE…Describe the basic function of each in terms of how it is used in a DC electric circuit	Interval	{0-3} (1 POINT FOR EACH ITEM DESCRBED CORRECTLY)	Q44
POST_Q44_GRADED	CORRECT OR INCORRECT MARKING OF POST_Q44	Interval	{0 - 3} {1 point for each item described correctly}	Q44
WRITTEN_SCORE_TOTAL	TOTAL OF POST_Q41_GRADED, POST_Q47_GRADED, POST_Q43_GRADED, POST_Q44_GRADED	INTERVAL		Q41, Q47, Q43, Q44
POST_Q36_1	Answer the following questions about your experience with the project - Do you think the project helped you to learn?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_1
POST_Q36_2	Answer the following questions about your experience with the project	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 =	Q36_2

Variable	Question or Description (Label)	Measure	Coding	Source
	- Did you feel prepared for the project?		PROBABLY NOT, 5 = DEFINITELY NOT}	
POST_Q36_3	Answer the following questions about your experience with the project - Do you know more after completing the project than you knew before?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_3
POST_Q36_4	Answer the following questions about your experience with the project - Did completing the project make you frustrated?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q36_4
POST_Q37 _1	Answer the following questions about what you normally do in Ag class - Have you ever done a project like this one before?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q37_1
POST_Q37_2	Answer the following questions about what you normally do in Ag class - Do you like projects in class?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q37_2
POST_Q37_ 3	Answer the following questions about what you normally do in Ag class - Do you do hands-on projects in Ag class usually?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q37_3
POST_Q37_4	Answer the following questions about what you normally do in Ag class - Do you think the normal projects you do in Ag class looks like the "real-world"?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q37_4

Variable	Question or Description (Label)	Measure	Coding	Source
POST_Q38_1	Answer the following questions about Ag - Is Agriculture part of Science?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_1
POST_Q38_2	Answer the following questions about Ag - Is Agriculture part of Math?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_2
POST_Q38_3	Answer the following questions about Ag - Is there Science in Agriculture?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_3
POST_Q38_4	Answer the following questions about Ag - Is there Math in Agriculture?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_4
POST_Q38_5	Answer the following questions about Ag - Do you learn Math in Ag class?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_5
POST_Q38_6	Answer the following questions about Ag - Do you learn Science in Ag class?	Ordinal	{1 = DEFINITELY YES, 2 = PROBABLY YES, 3 = MAYBE, 4 = PROBABLY NOT, 5 = DEFINITELY NOT}	Q38_6
STEM_Perception	Aggregated score Post_Q38_1 - Post_Q38_ - 6	Interval	0 - 5	Q38_1 - Q38_6

Variable	Question or Description (Label)	Measure	Coding	Source
POST_Q39_1	Respond these statements about your experience with the project. - I didn't learn anything by participating in this project.	Ordinal	{1 = STRONGLY DISAGREE, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q39_1
POST_Q39_2	Respond these statements about your experience with the project. - The lesson did not prepare me to complete this project.	Ordinal	{1 = STRONGLY DISAGREE, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q39_2
POST_Q39_3	Respond these statements about your experience with the project. - I don't know any more now than I did before I did the project.	Ordinal	{1 = STRONGLY DISAGREE, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q39_3
POST_Q39_4	Respond these statements about your experience with the project. - This project was easy.	Ordinal	{1 = STRONGLY DISAGREE, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q39_4
POST_Q39_5	Respond these statements about your experience with the project. - This project didn't have anything do to with the "real-world"	Ordinal	{1 = STRONGLY DISAGREE, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q39_5
Post_Q39_1_Recode	Respond these statements about your experience with the project. - I didn't learn anything by participating in this project.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q39_1
Post_Q39_2_Recode	Respond these statements about your experience with the project. - The lesson did not prepare me to complete this project.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q39_2
Post_Q39_3_Recode	Respond these statements about your experience with the project. - I don't know	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD,	Q39_3

Variable	Question or Description (Label)	Measure	Coding	Source
	any more now than I did before I did the project.		4 = DISAGREE, 5 = STRONGLY DISAGREE}	
Post_Q39_4_Recode	Respond these statements about your experience with the project. - This project was easy.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q39_4
Post_Q39_5_Recode	Respond these statements about your experience with the project. - This project didn't have anything do to with the "real-world"	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q39_5
POST_Q40_1	Respond to these statements. - We do too many projects in Ag class.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_1
POST_Q40_2	Respond to these statements. - I don't like doing projects.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_2
POST_Q40_3	Respond to these statements. - I would rather teachers just tell me what I need to know.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_3
POST_Q40_4	Respond to these statements. - Projects are just busy work.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_4
POST_Q40_5	Respond to these statements. - I don't think we learn from projects.	Ordinal	{1 = STRONGLY DISAGREE YES, 2 = DISAGREE , 3 = NAD, 4 = AGREE, 5 = STRONGLY AGREE}	Q40_5

Variable	Question or Description (Label)	Measure	Coding	Source
Post_Q40_1_Recode	Respond to these statements. - We do too many projects in Ag class.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q40_1
Post_Q40_2_Recode	Respond to these statements. - I don't like doing projects.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q40_2
Post_Q40_3_Recode	Respond to these statements. - I would rather teachers just tell me what I need to know.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q40_3
Post_Q40_4_Recode	Respond to these statements. - Projects are just busy work.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q40_4
Post_Q40_5_Recode	Respond to these statements. - I don't think we learn from projects.	Ordinal	{1 = STRONGLY AGREE , 2 = AGREE , 3 = NAD, 4 = DISAGREE, 5 = STRONGLY DISAGREE}	Q40_5
POST_Q27	What class/grade are you?	Interval	{1 = 9TH GRADE YES, 2 = 10TH GRADE , 3 = 11TH GRADE, 4 = 12TH GRADE)	Q27
POST_Q28_1	What science class have you taken before this year?-Chemistry	Nominal	{1 = = Selected}	Q28_1
POST_Q28_2	What science class have you taken before this year?-Physical Science	Nominal	{1 = = Selected}	Q28_2
POST_Q28_3	What science class have you taken before this year?-Biology	Nominal	{1 = = Selected}	Q28_3

Variable	Question or Description (Label)	Measure	Coding	Source
POST_Q28_4	What science class have you taken before this year?-Physics	Nominal	{1 = = Selected}	Q28_4
POST_Q28_5	What science class have you taken before this year?-IPC	Nominal	{1 = = Selected}	Q28_5
POST_Q28_6	What science class have you taken before this year?-None of These	Nominal	{1 = = Selected}	Q28_6
POST_Q28_7	What science class have you taken before this year?-Astronomy	Nominal	{1 = = Selected}	Q28_7
POST_Q28_8	What science class have you taken before this year?-Earth and Space	Nominal	{1 = = Selected}	Q28_8
POST_Q28_9	What science class have you taken before this year?-Environmental Systems	Nominal	{1 = = Selected}	Q28_9
POST_Q29	Is this your first Ag Class?	Nominal	{1 = YES, 2 = NO}	Q29
POST_Q32	Do you know if you are on a pathway?		{1 = YES, 2 = NO}	Q32
POST_Q34	What pathway?	Nominal	{1 = ANIMAL SCIENCE/VET MEDICINE, 2 = AG MECHANICS/CONSTRUCTION/POWER SYSTEMS, 3 = NATURAL RESOURCES, 4 = FOOD SICNECE, 5 = PLAN SCIENCE, 6 = AGRIBUSINESS, 7 = OTHER(ACTIVATES POST_Q34_TEXT)	Q34
POST_Q34_TEXT	What pathway? - TEXT	Nominal	{PARTICIPANT TEXT ENTRY}	Q34_TEXT
POST_Q26	What is your gender?	Nominal	{1 = MALE, 2 = FEMALE, 3 = I DO NOT WANT TO ANSWER}	Q26

Variable	Question or Description (Label)	Measure	Coding	Source
POST_Q31	How many years have you taken agriculture classes?	Interval	{1 = FIRST YEAR IN AG, 2 = SECOND YEAR IN AG, 3 = THIRD YEAR IN AG, 4 = FOURTH YEAR IN AG, 5 = FIFTH YEAR IN AG, 6 = SIXTH OR MORE YEAR IN AG}	Q31
POST_Q30_1	What ag classes have you taken before or are you taking now? (Include this year)-Horticulture	Nominal	{1 = = Selected}	Q30_1
POST_Q30_2	What ag classes have you taken before or are you taking now? (Include this year)-Agricultural Mechanics and Metal technologies	Nominal	{1 = = Selected}	Q30_2
POST_Q30_3	What ag classes have you taken before or are you taking now? (Include this year) - Principles of Agricultural Food and Natural Resources (101)	Nominal	{1 = = Selected}	Q30_3
POST_Q30_4	What ag classes have you taken before or are you taking now? (Include this year) - Livestock Production	Nominal	{1 = = Selected}	Q30_4
POST_Q30_5	What ag classes have you taken before or are you taking now? (Include this year) - Veterinary Medicine	Nominal	{1 = = Selected}	Q30_5
POST_Q30_6	What ag classes have you taken before or are you taking now? (Include this year) - Practicum in Agriculture	Nominal	{1 = = Selected}	Q30_6
POST_Q30_7	What ag classes have you taken before or are you taking now? (Include this	Nominal	{1 = = Selected}	Q30_7

Variable	Question or Description (Label)	Measure	Coding	Source
	year) - Agricultural Math Applications			
POST_Q30_8	What ag classes have you taken before or are you taking now? (Include this year) - Floral Design	Nominal	{1 = = Selected}	Q30_8
POST_Q30_9	What ag classes have you taken before or are you taking now? (Include this year) - Welding	Nominal	{1 = = Selected}	Q30_9
POST_Q30_10	What ag classes have you taken before or are you taking now? (Include this year) - Wildlife	Nominal	{1 = = Selected}	Q30_10
POST_Q30_11	What ag classes have you taken before or are you taking now? (Include this year) - Food Technology	Nominal	{1 = = Selected}	Q30_11
POST_Q30_12	What ag classes have you taken before or are you taking now? (Include this year) - Range Ecology and Management	Nominal	{1 = = Selected}	Q30_12
POST_Q30_13	What ag classes have you taken before or are you taking now? (Include this year) - Forestry	Nominal	{1 = = Selected}	Q30_13
POST_Q30_14	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Plant and Soils	Nominal	{1 = = Selected}	Q30_14
POST_Q30_15	What ag classes have you taken before or are you taking now? (Include this year) - Agricultural Power Systems	Nominal	{1 = = Selected}	Q30_15
POST_Q30_16	What ag classes have you taken before or are you taking now? (Include this year) - Equine	Nominal	{1 = = Selected}	Q30_16
POST_Q30_17	What ag classes have you taken before or are you taking now? (Include this	Nominal	{1 = = Selected}	Q30_17

Variable	Question or Description (Label)	Measure	Coding	Source
	year) - Small Animal Management			
POST_Q30_18	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Animal Science	Nominal	{1 = = Selected}	Q30_18
POST_Q30_19	What ag classes have you taken before or are you taking now? (Include this year) - Concepts of Engineering and Technology	Nominal	{1 = = Selected}	Q30_19
POST_Q30_20	What ag classes have you taken before or are you taking now? (Include this year) - Small Engine Technology	Nominal	{1 = = Selected}	Q30_20
POST_Q30_21	What ag classes have you taken before or are you taking now? (Include this year) - Advanced Welding	Nominal	{1 = = Selected}	Q30_21
POST_Q30_22	What ag classes have you taken before or are you taking now? (Include this year) - Exploring Careers (Middle School)	Nominal	{1 = = Selected}	Q30_22
POST_Q30_23	What ag classes have you taken before or are you taking now? (Include this year) - Career Portals (Middle School)	Nominal	{1 = = Selected}	Q30_32
PP_RIGHT_DIFFERENCE	POSTPRE MC SCORE	INTERVAL	{-10 - 10}	Pre_MC_Total Post_MC_Total
PP_PERCENT DIFFERENCE_MC	**Change Score**	RATIO	{-100 – 100}	Pre_MC_Percentage Post_MC_Percentage

Variable	Question or Description (Label)	Measure	Coding	Source
PP_WRITEN_DIFFERENCE	POSTPRE WRITTEN SCORE DIFFERENCE	INTERVAL	{-10 – 10}	Pre_WRITTEN_SCORE_TOTAL WRITTEN_SCORE_TOTAL
Postitive_Post36_1_2_3_37_4	Aggregated score of positively worded summated score questions on perception of project	INTERVAL	0 – 5	PostQ36_1, PostQ36_2, PostQ36_3, PostQ37_4
STEM_Perception_in_AG	Aggregated score Post_Q38_1 - Post_Q38_ - 6	INTERVAL	0 - 5	PostQ38_1 – PostQ38_2 – PostQ38_3 – PostQ38_4 – PostQ38_5 – PostQ38_6 – PostQ38_7 – PostQ38_8

APPENDIX I

Institutional Review Board Approval

DIVISION OF RESEARCH

TEXAS A&M UNIVERSITY

DATE: September 09, 2015

MEMORANDUM

TO: Timothy Murphy
ALRSRCH - Agrilife Research - Ag Leadership, Education & Communication

FROM: Dr. James Fluckey
Chair, IRB

SUBJECT: Expedited Approval

Study Number:	IRB2015-0500D
Title:	Integrating STEM in Agricultural Science Curriculum
Date of Determination:	
Approval Date:	09/09/2015
Continuing Review Due:	08/01/2016
Expiration Date:	09/01/2016
Documents Reviewed and Approved:	Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area.

Submission Components			
Study Document			
Title	Version Number	Version Date	Outcome
wiring plan	Version 1.0	07/23/2015	Approved
squish circuit plan	Version 1.0	07/23/2015	Approved
phet lab plan	Version 1.0	07/23/2015	Approved
paper project plan	Version 1.0	07/23/2015	Approved
student electricity exam all questions	Version 1.0	07/23/2015	Approved
Teacher_Informed_Consent	Version 1.1	07/23/2015	Approved
Parent_Guardian_Consent	Version 1.2	08/09/2015	Approved
Parent_Guardian_letter	Version 1.0	07/23/2015	
District_Informed_Consent	Version 1.4	07/23/2015	Approved
Student Assent	Version 1.0	08/18/2015	Approved

Document of Consent: Written consent in accordance with 45 CF 46.116/ 21 CFR 50.27

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