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The Effect of Authenticity on Project-Based Learning: A Quasi-Experimental Study of STEM Integration in Agriculture

Jason D. McKibben[1] and Timothy H. Murphy[2]

Abstract

Researchers have reported that participation in agricultural education reinforces STEM concepts, often through project-based learning. The use of projects is common in agricultural education. However, the instructional importance of certain elements of these projects is not well understood. We conducted a quasi-experimental study to examine the effect of project authenticity on learning. Agriculture students in Texas were sampled and assigned as a cohort to one of four treatment groups (N = 219). Fourteen cohort groups (class periods) were identified across five sites. Each cohort was randomly assigned to one of four project types to learn about electricity. The four project types varied in their degree of project authenticity. Analysis of covariance (ANCOVA) was used to test the effects of project authenticity on change scores in a pretest-posttest quasi-experimental design. Learning 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 did reveal statistically significant differences between the two projects with medium levels of authenticity, and the other two (i.e., least authentic and most authentic). The relationship between learning and authenticity was not linear. We recommend that teachers and curriculum designers deliberately consider the importance of authenticity when designing project-based learning opportunities for students.

Keywords: STEM integration; project-based learning; agricultural mechanics; physics; electricity; authenticity

Author Note: Jason D. McKibben ORC: https://orcid.org/0000-0003-2080-202X
Tim H. Murphy ORC: https://orcid.org/0000-0002-2846-8655
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Correspondence concerning this article should be addressed to Jason D. McKibben Agriscience Education at Auburn University, 5060 Haley Center, Auburn University, Auburn, AL 36849. Email: jdm0184@auburn.edu

Introduction

Agricultural education has long been recognized as an applied, practical, and experiential segment of education (Newcomb et al., 1993; Phipps & Osborn, 1988), and a prime context to provide credence and relevance to the concepts taught in core classes (Lee, 1994; National Research Council, 1988). Purposefully integrating science concepts into agricultural contexts has a net positive effect for students in agriculture and students in science (Clark et al., 2013; Chaisson & Burnett, 2001; Enderlin & Osborne, 1992; Myers & Dyer, 2006; Myers & Thompson, 2009; Rickets et al., 2006). Given the opportunities available within the agricultural mechanics content area to integrate science concepts, primarily physics and chemistry, along with mathematics, engineering, and technology, makes

[1]Jason McKibben is an Assistant Professor of Agriscience Education at Auburn University, 5060 Haley Center, Auburn University, Auburn, AL 36849. jdm0184@auburn.edu
[2]Tim Murphy is a Professor of Agricultural Education in the Department of Agricultural Leadership, Education, and Communications at Texas A&M University, 2116 TAMU, 600 John Kimbrough Boulevard, College Station, TX 77843-2116, tmurphy@tamu.edu.

agricultural mechanics courses a logical place to focus integration efforts (Blackburn, 2013; Edney, 2009; Scales et al., 2009).

Project-based learning within agricultural education is often understood to have begun with the Stimson Home Project Method (Moore, 1988). Stimson's method was predominately concerned with projects taking place outside of the traditional school day, at home (Roberts & Harlin, 2007; Stimson, 1915, 1919). Research in agricultural education addressing project-based learning has largely focused on supervised agricultural experiences (SAE). The links between project-based learning (PBL) and SAE 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 prescribed for use both in and out of school (Roberts & Harlin, 2007). The focus of PBL research in School-Based Agricultural Education (SBAE) in the intervening years has been on projects completed outside of the school day, and away from the schoolhouse (Roberts & Harlin, 2007). This study sought to reconnect project-based learning in SBAE with in-school methodological research.

This study sought to examine how the use of project work as a teaching and learning method, foundational to agricultural education (Dewey, 1916, 1938; Hummel & Hummel, 1913; Kilpatrick, 1918, 1925; Stimson, 1915, 1919), affects the integration of science, technology, engineering, and math (STEM) concepts in an agricultural education classroom setting. Research in agricultural education addressing project-based learning has typically focused on supervised agricultural experience (SAE). These home-based project-based educational activities are designed to extend school learning to authentic, real-life, practical, complex, unpredictable, even messy, applications away from the formal school setting. However, the use of projects in learning environments is more generally understood to occur within the classroom as well, outside of the more frequently examined SAE context. Roberts and Harlin's (2007) work on the implementation of projects in agricultural education could lead to the belief that, in the years since the founding of formal school-based agricultural education (SBAE), the focus on projects has shifted from a two-faceted approach of school-based and home-based (SAE) projects, to focusing exclusively on out-of-school SAE projects. This focus on home-based, and thus not school-based, SAE projects has led to a lack of foundational research addressing project utilization in the context of SBAE classrooms.

Krajcik and Blumenfeld (2006), as well as Greeno (2006), advocated for the use of school-based projects in the classroom setting as way to learn through situated perspectives within the general learning environment (Greeno, 2006). SBAE has been described as particularly adept at this task (Lee, 1994; National Research Council, 1988; Newcomb et al., 1993; Phipps & Osborn, 1988). However, most project-based learning (PBL) research has been conducted in the non-contextualized world of formal/traditionally recognizable science classes (i.e. biology, physics, chemistry, etc…). There is a gap in the SBAE literature concerning the use of projects within classrooms, most specifically outside of the SAE context. In this study, PBL methodology was used in agriculture classrooms and will be discussed as it pertains to the in-class project, not SAE. Project-based learning, as used in this study, is the classroom-based method of instruction advocated by experiential learning theorists (Krajcik & Blumenfeld, 2006).

The project-based learning literature, outside of SBAE, is almost exclusively focused on implementation within a formal school setting. Researchers have reported many criteria, elements, or models to effectively implement projects in science classrooms (Blumenfeld et al., 1994; Krajcik & Blumenfeld 2006; Krajcik et al., 2002; Larmer & Mergendoller, 2015). The PBL method has many forms and frameworks that define how it is to be effectively implemented. Examining these frameworks revealed 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 et al., 1994; Krajcik et al., 2002; Larmer & Mergendoller, 2015). Some of these elements or criteria of project-based learning, described as foundational, were not well-defined or thoroughly researched before they were suggested as necessary (Mergendoller, personal communication, October 15, 2015; Larmer, personal communications, October 12, 2015). One common element in many models of PBL that is specifically lacking clarity is the element of authenticity.

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

- Represent a felt need in the world outside the classroom as perceived by the students.
- Be directly relatable to students' lives, "the more directly, the better."
- Ensure the situation surrounding the scenario be realistic, even if the problem is manufactured.
- Use the tools or processes that would be used by adults and professionals in the "real-world" setting.

Newmann et al. (2001) described typical school learning activities as "contrived and superficial" (p. 14). Newmann et al. 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" (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 the real expression of those new ideas and findings in a coherent manner. These expressions should have value beyond school for the intended audience.

Schoolwork has as a motivating factor the development of internal capabilities for their 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 problems that are externally focused, requiring deep development, and the thoughtful communication of solutions and results.

The effect of the element known as authenticity on learning is the focus of this study. Curriculum designers advocate for "high levels of authenticity," and define authenticity in terms of several qualifiers (Larmer & Mergendoller, 2015). 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). These qualifiers are reminiscent of the suggestions made by the situated cognition and situated learning academy. According to the accepted norms within situated cognition psychologists, authentic activities are the practices that can be considered ordinary in the cultural norms of the group (Brown et al., 1989). However, it is the use of the "or" in the more modern definition that calls for the refinement of authenticity as criterion. According to some of the modern leading advocates for the use of project-based learning, and the developer of a widely advocated model of PBL, a project that is any one of these criteria can be considered authentic. Which of these qualifiers makes the project fully "authentic"? Which matters the most?

Theoretical Framework

Maximizing authenticity in project-based learning is thought to help increase the effectiveness of students' experiences when participating in a PBL lesson (Larmer, 2012; Larmer & Mergendoller, 2015). The goal of increasing the effectiveness of the experiences is to increase students' academic achievement. Increases in authentic experiences adding to academic achievement in the context of classroom instruction is in line with the theories of situated cognition (Brown et al., 1989; Greeno, 1998; Lave, 1991; Wilson & Myers, 2000).

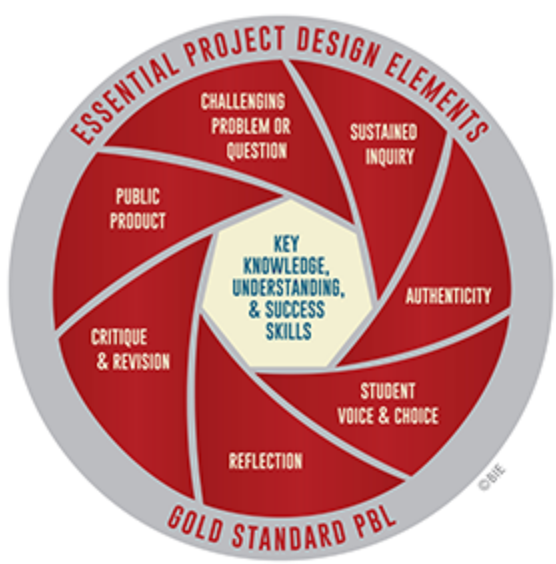
Situated cognition is an approach that gives credence to the interaction between practitioners and the work in which those practitioners participate (Brown et al., 1989; Greeno, 1998; Lave, 1991; Wilson & Myers, 2000). Lave, working in informal educational settings such as apprenticeships, noted that the term situated is not synonymous with "concrete or particular" (1991, p. 84). Working in what they labeled "communities of practice" novice practitioners would learn the process and knowledge in the context (Lave, 1991).

The term cognitive apprenticeship has been used to describe the method of learning within a community of practice (Brown et al., 1989). The cognitive apprentices are naturalized into "authentic practices through activity and social interaction in a way similar to that evident and evidently successful in craft apprenticeship" and run counter to the educational norm of abstract concepts being untouched by the activity in which they are learned (Brown et al., 1989. p. 37). In the framework of situated learning there is an agreed upon norm of culture that must be navigated or understood to be able to learn the entirety of the information being conveyed (Lave, 1991). In the school setting, the lack of authentic activity, as the term is used by Brown et al. (1989), is often caused by the mismatch of cultural norms. They go on to say that school-based activities are most often not the activities of the culture they are mimicking, and those activities would not be endorsed by the cultures they are representing. This study uses the theoretical belief of situated cognitivists that for a project to be authentic it must be seen as authentic by the culture to which the activity is common.

Operational Framework

The design of the protocols and treatments for this study followed one of the widely used models of project-based learning, the "New Model for Gold Standard PBL," published by the Buck Institute for Education (Figure 1). This framework prescribes seven primary elements for the project-based learning experience to be most effective. Those elements are; a challenging problem or question, sustained inquiry, authenticity, student voice or choice, reflection, critique and revision, and public product (Larmer & Mergendoller, 2015). Of these seven elements, the one most lacking a thorough and deep literature base is "authenticity" (Mergendoller, personal communication, October 15, 2015; Larmer, personal communications, October 12, 2015).

Figure 1
New Model For Gold Standard PBL. Reprinted From (Buck, 2015).



Purpose and Hypothesis

The purpose of this quasi-experimental study was to test the effect of the level of project authenticity in PBL on academic achievement in physics.

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

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

Methods

We conducted a quasi-experimental study to test the effect of authenticity of projects in PBL on student achievement. Agriculture Food and Natural Resources students enrolled in an introductory agricultural mechanics course 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. Eight sites were initially approached based on the research team's trust in the instructors' abilities to consistently follow the research protocol. These instructors were explained the importance of faithfully following the lesson plan as designed by the curriculum developers. Any instructors who the research team felt would not be faithful to the lesson elements put in place to ensure the fidelity of the treatment were not approached to participate. Of the eight sites, five were able to complete the research. Reasons the three sites left the study included shifts in administration, pregnancy, and illness of the primary instructor. Each of the 14 cohort groups were randomly assigned to one of the four project types, varying in their design according to the degree of project authenticity, to promote learning about electricity. After analysis of the data all individuals who missed any portion of the data collection, absence being the most common reason, were removed from the analysis. The removal of unreliable data resulted in the removal of 60 participants ($n = 159$). The 159 remaining participants represented ninth through twelfth grade students ($9^{th} = 103$, $10^{th} = 37$, $11^{th} = 13$, $12^{th} = 6$). The aim of the research was to target students in the ninth grade. Students in upper grades are more likely to be exposed to physics or integrated physics and chemistry course work. To mitigate for the effect of grade in school and the potential for advanced course work, both grade and course work were collected and used as covariates.

Level of project authenticity, the experimental treatment level, was varied based on suggestions made by Larmer and Mergendoller (2015) as described in Table 1. The treatments, in decreasing level of authenticity were: Wiring, Drawing, Squishy, and Paper Packet. Curricular design and lesson plans were analyzed for fit to gold standard PBL model by college of education experts who specialize in curriculum design in science education and implementation of student-centered learning (which project-based learning is included). Agricultural education curriculum designers analyzed the lessons for effectiveness of instruction and appropriateness of fit in an agricultural mechanics class. This was done to ensure all elements, other than the element of interest were being controlled. The only element that could not be controlled in design is "be deemed personally important" (Table 1). To mitigate for errors caused by the inability to control for this variable, data were collected in the form of a post exam questionnaire. On a six response Likert type question, students were asked about their beliefs concerning the importance of the project. Testing change in score against the students responses no significance was found across responses ($F(4,157) = 1.91$. $p = .111$).

Analysis of covariance (ANCOVA) was used to test the effects of project authenticity on academic achievement change scores in the pretest-posttest quasi-experimental design.

Table 1
Requirements for a Project to be Considered Authentic

	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. 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) involves 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). The context for this study was an agriculturally relevant context (DC circuitry). S = Satisfying or exceeding the requirement. U = unknown beforehand. Blank cell = not meeting the requirement.

Paper packet (Treatment X_1) was a commercially available packet of information, readings, fill in the blank questions, true/false questions, and short answer questions commonly used as curriculum support in Texas agricultural education. Paper packet (Treatment X_1) was used as a control treatment and contains no elements of gold standard PBL. Squishy Circuits (Treatment X_2) was a wiring proxy activity using electroconductive 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 a conductive dough and a resistive dough, as a proxy for typical wiring materials, and instructed to construct working series and parallel circuits. The students assigned to draw a diagram (Treatment X_3) were asked to draw a diagram for a parallel and series circuits. Students were provided markers and poster paper to ensure the materials available were the same, thus helping to ensure treatment fidelity. Those students assigned to wire circuits (Treatment X_4) were given materials to construct working series and parallel circuits. Those materials were lights, power sources, wires, and light sockets. In all three hands-on projects (X_2, X_3, and X_4), students subsequently explained how power would move through the circuits, working the loads, during an oral presentation, as is best practice in project-based learning models (Larmer & Mergendoller, 2015).

All knowledge assessment items were taken from The Massachusetts Comprehensive Assessment System (MCAS). The assessment included 23 multiple-choice items. The assessment was centered on questions that probed students understanding of the electrical system from the theoretical (i.e. Ohm's law and electron theory) to the physical (i.e. which of the listed items is a conductor, and which light will be illuminated if a certain switch is activated). The MCAS was selected due to the high percentage of Massachusetts students who pass the physics electricity and magnetism advanced placement exam (Massachusetts Department of Elementary and Secondary Education, 2014). We selected items from 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 assessment would resemble, although not be identical to, the more nationally recognized exam. In addition, the MCAS exam is unlikely to have been seen by students in Texas, reducing the threat of test–retest bias. "Inclusion of the MCAS instrument does not constitute an endorsement of this or any other publication" (J.A. Marcella, personal communication, June 29, 2015).

The reliability of this instrument was estimated using the Cronbach's α test of internal consistency. Field (2013) suggested an alpha level of 0.80 or greater is considered sufficient reason for an instrument to be considered reliable (Field, 2013). The knowledge portion of the assessment has been determined by Hambleton et al. (2008) to hold an internal consistency of .87 for the multiple-choice items. This α coefficient is considered acceptable by current standards ($\alpha > .80$; Field, 2013). The internal consistency of the summated scale questions was calculated and reported according to the norms reported by Warmbrod (2014).

Findings

Pretest score, previous coursework completed, and grade in school were used as covariates in the analysis. Field (2013) suggests that all covariates be tested against the independent variable to ensure their independence of any assignment. These data were tested as prescribed, and all covariates were determined to be independent. Descriptive statistics for treatment are in Table 2.

Table 2
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

Tested at the ($\alpha = .025$) level, to guard against rising chance of Type I error due to an increase in number of tests, the results of the ANCOVA indicate that statistical differences do exist when different levels of authenticity are applied to project-based methods ($F(3,145) = 3.59$. $p = .015$). The hypothesis (H_O) that no change would be detected was rejected. 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 between three treatment pairs: squishy circuit / wiring ($p = .038$) with a mean difference of 5.19 positive toward the squishy treatment, squishy circuit / paper packet ($p = .002$) with a mean difference of 9.93 positive toward the squishy circuit treatment, and drawing / paper packet ($p = .049$) with a mean difference of 7.43 positive toward the drawing treatment (Table 3). It should be noted that the wiring treatment, the most authentic, did not yield significantly higher scores than any of the treatments.

Table 3
Pairwise Comparison of Change Score (DV) by Treatments (IV)

					95% Confidence Interval for Difference	
(I) Treatment	*(J) Treatment*	*Mean Difference (I-J)*	*Std. Error*	*p*	*Lower bound*	*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

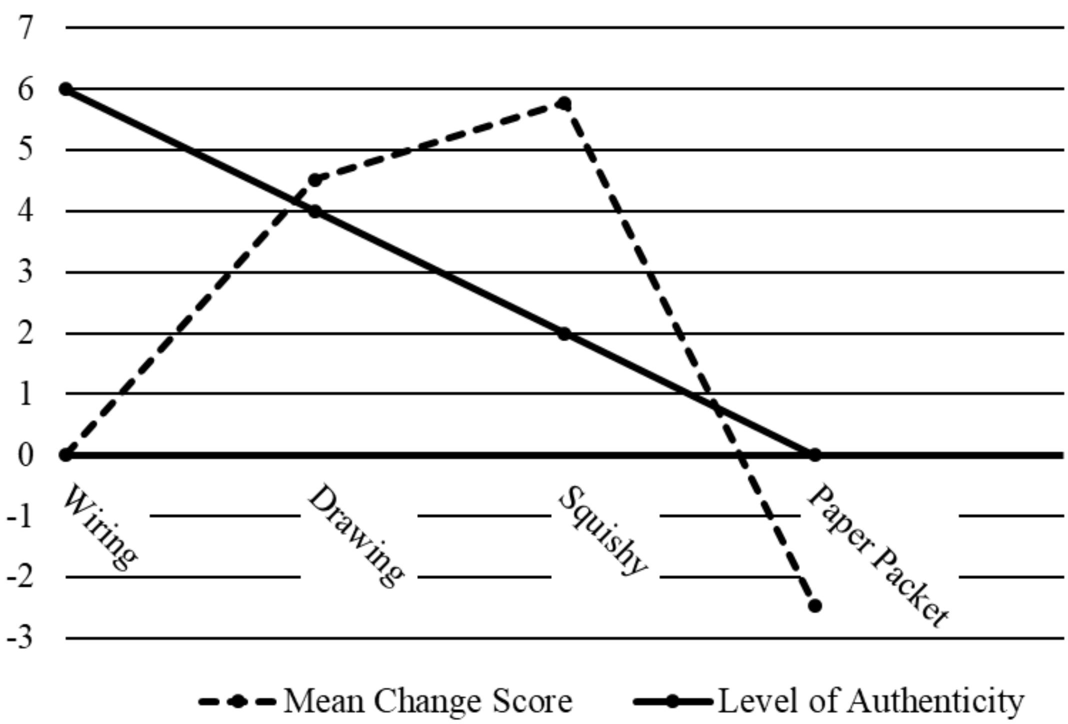
*significant at the $p = .05$ alpha level.

Discussion and Implications

Larmer and Mergendoller recommended that to properly implement projects in project-based learning, projects must have "high levels of authenticity" (2015). In this study, we found that authenticity did indeed play a part in the educational gains of students, thus concurring with Larmer and Mergendoller (2015). However, upon further examination, gains in achievement were not linearly related to the authenticity of the project. Gains for students engaged in the most authentic project, a hands-on wiring activity, and gains for students engaged in the least authentic, a paper and pencil activity that could not be described as hands-on, were not significantly different (Figure 3). This finding supports Johnson et al.'s (1997) findings that traditional paper and pencil activities yield the same academic results as hands-on activities to teach physics in agricultural mechanics courses. Johnson et al. (1997) also noted that their projects, while hands-on, did not stimulate student interest. The findings of Larmer and Mergendoller (2015), and those of Johnson et al.'s, (1997) would be incongruent with the findings of this study if the relationship between authenticity and achievement were linear. The results of this study suggest that the stimulation of interest in the learning process, and increases in achievement, occur using projects with, what could be labeled as, medium levels of authenticity.

Figure 3

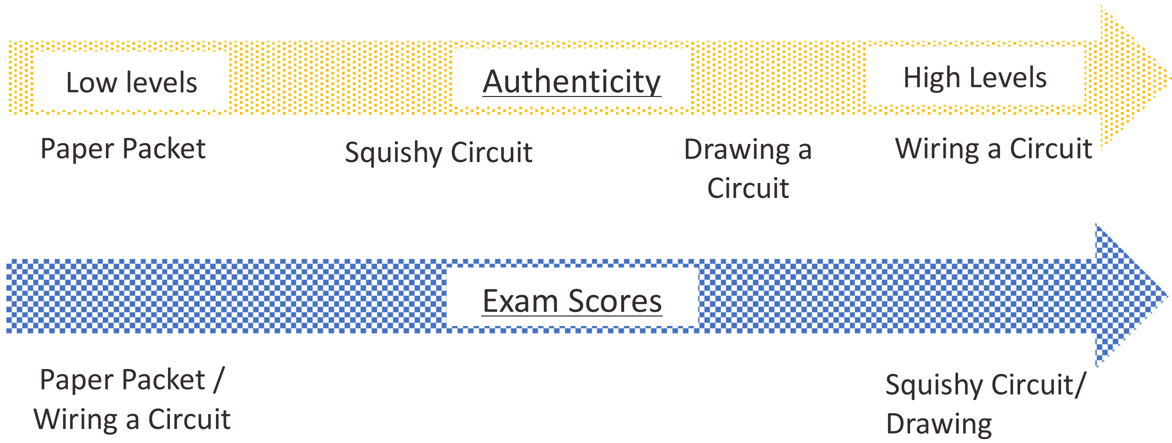
M*ean Change Score of Treatment (Table 2) And Level Of Authenticity As Described In Table 1*



According to results in this study, the fully authentic project (wiring a circuit using wires, switches, and loads) did not provide a better opportunity for students to learn STEM concepts than reading a paper packet and answering questions, as is consistent with Johnson et al. (1997). Differences in achievement appeared when the two projects with medium levels of authenticity were examined (Figure 4). 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 of the hands-on projects, squishy circuits, had a statistically higher change score than both wiring, the most authentic, and paper packet, the least. The two mid-level authenticity projects were not statistically different from each other.

Figure 4

Diagram of The Relationship Between Authenticity And Exam Scores



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) involves the building or creation of something that will be experienced by others, f) be deemed personally important, and g) be involved in context. Which of these requirements did the two highest achievement, mid-level authenticity, projects have in common with each other, but not with the other projects? None. There were no authenticity requirements in the mid-level authenticity projects that were not also present in the fully authentic wiring project. It is our assertion that authenticity, as defined in the context of this study, has a positive but non-linear relationship to achievement. As such, authenticity can be described as important, but not paramount to learning science concepts in agricultural contexts.

The findings and implications of this study warrant further examination. Additional research should seek to confirm the non-linear relationship between authenticity and achievement and identify the components of that relationship. The authors posit that several factors may be involved in which achievement may be positively and/or negatively influenced by four intermediary factors. While this study attempted to isolate a component within the outlined norms of authenticity, if the learners were completely unfamiliar with electrical wiring, the tools and skills necessary to make the connections, then the most authentic environment may also have been the one in which the ability to understand instruction was lowest. To this, the authors would suggest that testing within a broader understanding of the importance of culture within situated learning be applied and comparing those data to the data reported in this paper. The authors also considered that the outcome may have been affected by the novelty effect. Recognizing that very few students in agriculture classes had previously been exposed to Squishy Circuits, their change scores could have been affected by increased interest due to the novelty of this new technology. This observation is consistent with Johnson et al.'s (1997) suggestion that student interest may be more important than hands-on authenticity. With additional study and confirmation, the newest PBL models should note that adjusting authenticity alone does not necessarily result in a corresponding adjustment in learner achievement.

This study attempted to measure the effects of an aspect of project design in PBL on STEM (physics) conceptual learning outcomes in a project-based learning unit within agricultural education. The measures used were designed to only assess knowledge as it pertains to physics. No other student learning outcomes were assessed. The variables measured in this study could have if other learning outcomes had been measured (skills for example) provided different results. It has been noted in previous studies that hands-on learning can, and often should, be measured using additional quantifiers, particularly if skill attainment is among the intended outcomes (McKeachie et al., 2006; Murphy, 2000). As was the case in Murphy (2000), this study did not set out to measure outcomes such as skill attainment. As such, the true "worth" many educators might ascribe to the most authentic project type is not being assessed, nor are any value statements being made. This study was completely focused on the measures of knowledge that much of the education world outside of the career and technical education literature, and many secondary school administrators, use as measures. Those being measures of knowledge and facts, not skills.

In practice, teachers and curriculum designers attempting to improve student knowledge-based achievement should feel empowered to stray from the widely accepted norms of providing "real-world" authenticity in their project-based learning activities, and move into more novel projects that stimulate student interest and creativity.

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