

Effects of Novelty on Project-Based Methods when Integrating Physics into Agriculture Courses

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Abstract

Researchers have reported that participation in agricultural education reinforces STEM concepts. The use of projects is common in agricultural education. However, the foundational understanding of certain tenets of project use is not clear. A quasi-experimental study was conducted to test the effects of project authenticity on learning. AFNR students (N = 219) were sampled and assigned as a cohort to one of four treatments. Treatments were project types which varied in their degree of project authenticity. During analysis, it was apparent that the intended project variable of authenticity had less effect on the outcomes than other factors. An analysis of covariance was used to test the effects of perceived novelty on change scores in a pre-post quasi-experimental design. A test of project type groups, which varied on novelty, yielded statistically significant results ($p < .05$) with small effect size ($\omega^2 = .04$). A Pearson Chi Square was calculated to determine if a relationship between novelty and project type existed and determined to be significant, $X^2(12, N=152) = 22.35, p = .034$. A pairwise comparison was calculated to compare levels of novelty to determine where the variation existed. 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 from those with a novelty level 5 ($p = .012$). Students with less familiarity with the project (a more novel project) showed more improvement on the science exam.

Introduction

Agricultural education has had a long and well-documented history with the use of project-based learning (Hillison, 1998; Roberts & Harlin, 2007; Moore, 1988). Project-based learning methods are ubiquitous in secondary agriculture courses (Buriak, 1989; Hancock et al. 2024; Moore, 1988; Parr & Edwards, 2004; Roberts & Harlin, 2007). Project-based learning specialists Larmer and Mergendollar (2015) suggest that a student's lack of familiarity with the project could reduce the individual's educative outcomes due to the apprehension or uneasiness they feel specifically when using the project-based learning method. However, Headwig von Restorff (1933) demonstrated that students learned quicker and more deeply if the information they were expected to know was presented in a way that was different, or novel, from the rest of the information. The study and subsequent iterations of her experiments used immediately known novelty to the individuals to highlight the different groups (Samuels, 1986). Her experiments utilized multiple colors to illicit novel experiences in learners, and the more novel color was noticed to bring about

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stronger results in students (Samuels, 1986). Similarly, when projects are used to teach adult students, Mezirow's theories of transformative learning conveniently explain how reflection on the disruption of ideals and preconceptions, such as in von Restorff's experiments, is the ideal of true epistemic cognition or learning (Mezirow, 2000). These findings suggests that new and unique experiences in learning lead to more knowledge gained. Both von Restorff and Mezirow's theories about education fly in stark contrast to the modern interpretation, championed by Larmer and Mergendollar (2015) and many of the project-based model builders, that education through project-based learning is most effective when presented in a known and easily understood context. In the context of agricultural education, McKibben and Murphy (2021) also found that an amount of uncertainty affected students learning when project-based methods were used in an agricultural mechanics lesson.

While agricultural education has a history of utilizing project-based learning, the usage has been most extensively explored in the context of supervised agricultural experiences (SAE) or out-of-class based projects. However, the use of projects frequently extends into the classroom, outside of the examined SAE contexts. Roberts and Harlin's (2007) work on the implementation of projects in agricultural education leads to the assumption that in the years since the founding of formal school-based agricultural education (SBAE), project focus has shifted from a two-faceted approach of in-school and out-of-school projects as described by Prosser, Snedden, Dewey, and Kilpatrick (Hummel & Hummel, 1913; Stimson, 1915, 1919; Dewey, 1916, 1938; Killpatrick, 1918, 1925; Prosser & Allen, 1925; Moore, 1988) to focusing heavily on out-of-school (home-based) projects.

Outside of agricultural education, the use of project-based learning is primarily focused on project implementation within a classroom setting. Agricultural education, not engaging in the in-class conversation has left SBAE out of the pedagogical development of curricular design within the in-school model of project-based learning. The use of in-class projects to provide a situated perspective in a gen-ed learning environment has been strongly advocated (Blumenfeld et al, 1991; Grenno, 2006; Krajcik & Blumenfeld, 2006; Krajcik et al., 1994).

Project-based learning was formalized as a go-to method for agricultural education with the development of Stimson's Home Project Method in 1915 (Moore, 1980). However, the method was being used as an in-class method far before Rufus Stimson suggested students take the ideas of class home (Stimson; 1915, 1919). Most of the texts of the late 19th and early 20th century describe the practices and examples of how projects were being used before Stimson's home method. Jackman's 1891 "Nature Study" a general handbook for educating children in the natural ways of life (modern agriculture) is saturated with examples of lesson ideas based on projects that can be implemented by teachers in the classrooms of the 19th century. Hummel (1913) suggests in the opening chapter on the history of agricultural education (as of 1912) that agricultural education at the high school level is the modern practical science of agriculture based on "experiment and practice in the laboratory and on the school agricultural grounds" (p.3). Stimson submits in 1912 that it is a deficiency in large agricultural schools if they put "too great a reliance upon books and observation, to the exclusion... of active participation in the type or types, of productive farming" (p. 31).

Framework

Theoretical Framework

The concept of Predictive Error (PE), as explained by the aggregated work done by van Kesterneer et al. (2012) can be used to underpin the theoretical framework that informed this study. They suggest that when viewed through a lens of Bayesian inference, novelty is a factor in determining the amount of PE a student would have in a system or related to a schema. PE is the difference between what is expected and what is observed. Bayesian inference suggests that as more observations are made, hypotheses and thus predictions can be adjusted. It is further supposed that there are four basic understandings of novelties' influence on the predictive error of information. Those are: a novel item in a novel context, a known item

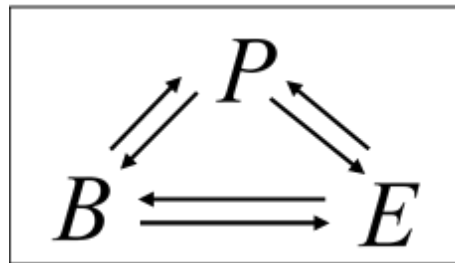
in a novel context, a known item in a known but unexpected context, and a known item in a known and expected setting (Kumaran & Maguire, 2009; Poppenk et al., 2010). PE would be lowest for novel item in a novel context and the known item in a known and expected setting (van Kesteren et al., 2012). In the fully novel situation, there is no prediction to start with so no error can be made, in the fully known situation, there is little to make an error about. The predictive error is highest for a known item in a novel context and the known item in a known but unexpected context. This is thought to be because with some of the information, but not all, there is the greatest potential for error.

Conceptual Framework

Bandura's model of social learning theory (1971, 1978) can be used to understand the design of this study. Bandura 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. Bandura further described the 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. Further, use of SLT allows researchers to predict that any change in any direction of the environment should result in a change in cognition (Figure 1).

Figure 1.

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).



According to the SLT theorists any change in the environment (i.e., instructional design) should result in a change in the behavior and/or the cognition. Using Bandura's model, we focused on the purposeful change of novelty (*E*), measuring the resulting change in cognition (*P*) while using guided behaviors (*B*) within the framework of a hands-on lesson of unique projects in a project-based learning setting. Any manipulation of the project-based lesson would in turn be a manipulation of the environment within which the student is operating. This study was designed to determine if the purposeful manipulation of an educational experience based on novelty (*E*) would result in changes in the cognition (*P*) of the individuals participating, as suggested by Bandura (1971, 1978).

Purpose and Hypothesis

The purpose of this quasi-experiment was to test the effect of project novelty, on academic achievement in physics during an agricultural education course and is a companion piece to McKibben and Murphy's (2021) and McKibben's (2017) exploration of aspects of project design for project-based learning in agricultural mechanics and has been introduced in McKibben and Murphy (2018).

H_{01} : There are no differences in academic achievement change scores $O\Delta$ among the level of novelty with the project when population means have been adjusted for covariation.

$$X_1 (O\Delta) = X_2 (O\Delta) = X_3 (O\Delta) = X_4 (O\Delta) = X_5 (O\Delta)$$

- Variables: IV= Reported level of novelty with the project (X_{1-5})
 DV= Change scores representing academic achievement posttest subtracted from pretest ($O\Delta$)
- 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 = Grade in school (grade 9, grade 10, grade 11, grade 12)

Methods

As part of an effort to identify the effects of project-based learning in STEM learning in agricultural contexts, the researchers conducted a quasi-experimental study to test the effect of elements of project-based learning designs on academic achievement using a nonequivalent control-group design (Gall et al., 2003). A purposive sample of agriculture food and natural resources students in Texas was used ($N = 219$). Fourteen cohort groups (class periods) were identified in five sites. Each of the 14 cohort groups were assigned to one of the four project types. The project types varied in their design based on assertions made by Larmer and Mergendoller (2015) that students perform better if they are familiar with the project type. Those projects were; completing a commercially available paper curriculum packet with readings and questions (Paper); drawing a wiring diagram (Drawing); wiring using “playdough” that are formulated to conduct electricity when charged with battery packs and LED probe lights that can be pushed into the dough via needle like protrusions (Squishy); and wiring using traditional wires and screw-based bulbs (Wiring). The assigned projects were completed during the application phases of a project-based learning lesson housed within a unit of instruction addressing direct current electricity. The project segment of the lesson followed a direct instruction phase delivered via a commercially available video verified by experts in the field of electricity. All students completed the same direct instruction phase, variation in the treatments occurred in the application project phase only. All treatments were normalized for time, in keeping with best practice and with Carrol’s (1963, 1989) model of school learning in mind.

Erring on the side of exclusion, any student who did not complete all portions of the experience (pre-test, direct instruction, project phase, post-test) or did not complete either the pre or post assessment to its fullest extent were excluded. An analysis of covariance (ANCOVA) was used in a pretest - posttest design calculating a change score in the assessment of knowledge ($n = 152$). ANCOVA is the method suggested to help mitigate the potential group differences threat to internal validity that might have influenced the outcome (Gall et al., 2003; Field, 2013)

Instrumentation

The instrument was broken in to three main parts, the first part was the assessment of knowledge, the second was student experience with projects and project-based learning, and the third part was to collect characteristics and academic experience of the students.

The assessment of knowledge portion of the instrument consisted of a 23 multiple choice question assessment taken from the Massachusetts Comprehensive Assessment System (MCAS). These questions covered basic knowledge of electrical theory, electron theory, polarity, ohm’s law, and the relationship of ohms/amps/volts. The MCAS was selected due to the high percentage (63.6%) of Massachusetts students who scored a four or five on the Physics C: Electricity and Magnetism Advanced Placement exam (American Educational Research Association, 2014). 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. The Physics C: Electricity and Magnetism components of the advanced placement exam address the content of the lessons used as treatments in this study; however, rights to this exam could not be secured. The MCAS exam was available and deemed an appropriate assessment. The use of a known

and verified standardized test such as the MCAS was intended to ensure the content validity with physics concept learning.

The instrument also contained questions designed to assess students’ experience with the four project types. Students were asked questions about if they had participated in a project similar to the one they completed during the lesson prior to this experience. These questions were asked to identify if the projects completed were novel to the student, or if they were similar to projects they had already experienced. These questions were evaluated by a panel of experts to ensure the construct validity of those items. 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, secondary science education, and the implementation of project-based methods. Covariates were gathered along with other characteristic data to be used as independent variables in the same instrument, asking students what classes they had participated in prior to that school year and what year of school they were in during the time of the activity.

Findings

Covariates for this analysis were previous coursework and grade in school. According to Field (2013), all covariates should be tested against the independent variable to ensure their independence. Field’s suggested procedure to test the independence of covariates is calculating an analysis of variation, where groups are used as independent variable and covariate is the dependent variable. Using this method, covariates were determined to be independent of the grouping, and all criteria were satisfied to conduct ANCOVA. Novelty is ranked from least to most; 1, 2, 3, 4, and 5 based on the students reporting if they had participated in a project like that before. A level of 5 indicates that students had “definitely not participated” in a project like the one they participated in with this study, indicating a high level of novelty and a level of 1 indicates that they “definitely had participated” in a project like the one they participated in with this study indicating a low level of novelty (Table 1).

Table 1

Reported Novelty of the Project per Treatment Group

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

The change in students’ scores were grouped by indicated level of novelty and the mean and standard deviation for that indicated novelty group was calculated. This change in score from pre-test to post-test by reported novelty group is reported in Table 2.

Table 2

Change Scores for reported novelty groups

Have you ever participated in a project like this before?	<i>M</i>	<i>SD</i>	<i>n</i>
Definitely Yes (1)	0.54	14.18	24
Probably Yes (2)	-3.66	13.92	19
Maybe (3)	2.42	11.96	27
Probably Not (4)	9.10	13.50	33
Definitely Not (5)	1.69	14.39	49
Total	2.57	14.08	152

Using the reported novelty level as the independent variable and the change in score as the dependent variable and ANCOVA was calculated. Analyzing the results of the ANCOVA, statistically significant results were noted based on student’s reported novelty ($F(4,138) = 2.56, p = .041, \omega^2 = .04$). Considering these results, H_{01} was rejected. Field (2013) suggested standards for levels of effect size (ω^2). The effect size of ($\omega^2 = .04$) for this quasi-experiment falls between the small ($\omega^2 < .01$) and medium ($\omega^2 = .06$). A pairwise comparison was calculated to compare levels of novelty using a Bonferroni correction for multiple tests to determine where the variation exists within the variable reported novelty levels. Students with novelty level of 4 (Probably had not participated in a project like this before) had statistically different change scores than those at novelty level 2 (probably had participated in a project like this before, $p = .006$) and students with novelty level 4 were different from those with a novelty level 5 (definitely had not participated in a project like this before, $p = .012$). These results can be seen in Table 3.

Table 3

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

<i>(I) Novelty</i>	<i>(J) Novelty</i>	<i>Mean Difference</i>			<i>95% Confidence Interval for Difference</i>	
		<i>(I-J)</i>	<i>Std. Error</i>	<i>p</i>	<i>Lower bound</i>	<i>Upper bound</i>
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	0.89	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.

In an effort to determine if the design of the projects had the intended effect of different levels of novelty, 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, $X^2(12, N=152) = 22.35, p = .034$. It can be confidently said that the manipulation of the treatment affected the independent variable, as predicted.

Conclusions and Discussions

The findings of this study run contrary to work reported by Larmer and Mergendoller (2015), where they indicate that students need to be familiar with the project type to perform well in a project-based system. In this study, students who reported higher levels of novelty, and thus had less familiarity with the project type, performed best of all. It appears as if students who had a basic familiarity with the project type did worse after completing the projects. Based on these results we would suggest that when it comes to reaffirmation of concepts, teachers would be best served to avoid projects that are very similar to those used earlier in the lesson sequence.

The “Drawing” and “Squishy” projects had the highest reported novelty. Sixty-Five percent of the “Squishy”, and 52% of the “Drawing” groups reported that they had not participated in a project like this before. Likewise, 47.6% of the students in the “Paper” group and 43.4% of the “Wiring” group said the same (Figure 2). The novelty of drawing a circuit, schematically, is frequently done in engineering, but less often done in high school agriculture classes. Students also have likely not participated in the squishy circuit activity. However, by the time they get to 9th grade agriculture course, in our experience many students have done a written packet or used small wires. The results of the Chi Square analysis supported the hypothesis that novelty level was related to the project type $X^2(12, N=152) = 22.35, p = .034$ as the treatments were designed to do. Projects with higher levels of novelty also had statistically higher change scores on the MCAS physics assessment.

Our initial interpretation was that novelty likely affected the focus students gave to the project. That in turn, may have affected the amount of information students gained. This interpretation supports Carroll’s model of school learning (1963, 1989). In Carroll’s model, the focus students give to study is one of the primary inputs that lead to academic achievement. Novelty likely played a part in the amount of time students were willing to spend on learning, which according to Carroll is another primary factor determining the likelihood of student learning. If students perceived the project to be interesting due to its uniqueness, they might have paid attention longer, and thus learned more. Several other theories have been posited over the years that should be considered and can add to the discussion of these results.

Philosophical Discussion for Theory

The von Restorff effect applies to the effect of unique or novel stimuli on the memory of students. The von Restorff theory of novelty’s effect on learning was discovered by showing students multiple items in a learning environment some of which were colored in unusual or novel ways (Hunt, 1994). However, considering Mezerow’s latter work on transformative learning over time there is a case for connecting the two theories. Applying von Restorff’s (1933) theory of novelty across time, parallels could be drawn about the effect of novelty on this study. Rather than students needing to see items that are immediately different, as was done in the original experiments by using multiple unique colors in the curriculum pieces of the experiments, these differences could be drawn out over time. By substantially changing the context or the system the activity functions within, students see something they previously learned in a certain way, operate in a new or novel way. Students are then forced to determine if what part of their understanding is based on context, and which is not. This change from one context/system to another could represent a span of years (i.e., an activity done a certain way elementary school now done a vastly different way in high school) as appears to be the case in this study.

The shift in context or system could be seen as the intentional creation of a dissonance in students. Another interpretation of novelty is the effect the dissonance caused by the project has on the assumptions students must consider or reconsider to successfully operate within the new context or system. In texts that focus on inquiry teaching of introductory sciences, time is spent on the development of an understanding of systems (Jackman, 1891; Dewey, 1916, 1938; Ethridge & Rudnitsky, 2003). Students must spend time mastering a system in order to understand how the material that is presented is similar or dissimilar from information previously known (Jackman, 1891). 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, 1981; Hewson & Hewson, 1984; Jackman, 1891). 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). This cognitive dissonance was likely what spurred some of the positive movement in scores of the students in this study. This also supports the initial concepts of transformative learning as suggested for adults by Mezirow (2000). Transformative learning, a normally andragogical theory, when applied to youth could explain part of the increase in scores for the students who reported the higher levels of novelty. Transformative learning theorists suggest that people who are confronted with ideas that conflict with their current understandings must shift their worldviews to either assimilate or reject the diverging knowledge. Mezirow (2000) goes on to suggest that recognizing and weighing the usefulness of your own implicit expectations, as well as those around you, is a vital part of beginning to learn as an adult. Which is consistent with suggestions made by those who study dissonance in youth.

Davis's 1966 work on what became known as "Torpedoing" helped build Mezirow's own theories about the andragogical implications of finding fault in one's understanding. In torpedoing, students are presented with a similar situation to one that they often see, but this new situation has designed into it a point at which the understood pattern fails (Davis, 1966). The familiar pattern must be reevaluated for what is true, to both the original familiar pattern and to the new or novel pattern. What is common between the two is truth and should be retained. Features unique to either of the patterns are situational, and can be categorized as such, or discarded altogether (Davis, 1966). The common theory shared by all explanations provided is that it would appear that, as has been suggested in countless studies, students needed to be confronted with ways to challenge what they know so they can understand the differences between what is known about the content and what is known about the context.

Pragmatic Discussion for Practice

Students in the 9th grade have a basic understanding of electrical circuits and the components of a circuit (Texas Administrative Code, 2021). When introduced to the task of drawing a circuit, students were forced to interact with electricity in a more abstract fashion, using unfamiliar symbols, which possibly created some form of dissonance. Likewise, squishy circuits created a dissonance with the system that is wiring simple circuits. Students understood circuits comprised wires, bulbs, and power supplies. The system of squishy circuits takes this known system of wires, bulbs, and power, and makes it unfamiliar. 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, playdough conducts electricity, bulbs are pushed in via needle-like protrusions and batteries have probes to electrify anything they touch. This shift in the representation of the system likely created a dissonance that students were forced to confront 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 packs of batteries. Students experiencing squishy circuits had to learn the proxies for the system. They had to learn how those proxies are understood in another context. This relearning forced them to see the parts for what they were in the generalized system (a conductor, a load, a power source) rather than a wire, a bulb, and a battery.

Conversely, when wiring a circuit using traditional methods students interacted with a system they had previously encountered. Preconceived notions were upheld, and no dissonance was created. They progressed through the traditional wiring project without having to think about how all the parts worked together or could be generalized to other systems. This supports Dewey's (1910) model of problem-based experiential learning rather than Kilpatrick's (1918) various project models as described by Stevenson (1925), and later by Moore (1988). The problem in the non-traditional model led to a higher likelihood that students would encounter a dissonance. Students in a project-based lesson with no challenges to context or understanding, can potentially perform the task successfully with no dissonance, as seems to be the case in the wiring treatment.

Recommendations for Practice

In the context of this study, SBAE teachers can routinely provide novel, hands-on activities that are different from what the students typically experience in traditional science courses. Teachers have the freedom, or should be made free, to allow students to find those faults in their students' beliefs. Teachers should not be beholden to the specifics of "real life" activities; rather, teachers should feel confident in using projects with complex problems to challenge students' understanding of how the information fits together. SBAE teachers should be confident in their choice to push students into dissonance and not feel constrained by what could be labeled as normal instructional methods. The abstraction of a known system can push students farther. Mezirow (2000) suggests that "if we are unable to understand, we often turn to tradition, thoughtlessly seize explanations by authority figures [...] to create imaginary meaning" (p. 3). We as teacher educators must empower our future teachers to be comfortable with not knowing the exact outcome and warn them against becoming false authority figures. We should implore our pre-service and active teachers to allow their students to develop and broaden their understanding though testing commonly held understandings.

Additional experiments are needed to identify the underlying cause of the increase in knowledge observed among students with differing reported levels of novelty. The litany of philosophies offered in this paper to explain the observed phenomena should serve to highlight the countless pathways additional research in this area could follow. Further experimental design should be conducted to determine if von Resorff, Transformative Learning, Cognitive Dissonance, Torpedoing, or another theory had any bearing on the results presented. In this study, no attempt was made to assess the development of marketable skills, or the effects disruptive teaching may have on the development of these skills. Those effects should be examined and used to optimize instructional methods according to the goals of the program. Additionally, the effect these disruptive methods have on the critical thinking skills of students should be examined.

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