# Effect of the Inquiry-Based Teaching Method on Students' Content Knowledge and Motivation to Learn about Biofuels


Carmelita E. Goossen
Oklahoma State University
439 Ag Hall
Stillwater, OK 74078
P: 405-744-8036
E: carmelita.goossen@okstate.edu

F. Richie Roberts
Oklahoma State University
439 Ag Hall
Stillwater, OK 74078
P: 405-744-8036
E: richie.roberts@okstate.edu

Amanda Kacal
Oklahoma State University
439 Ag Hall
Stillwater, OK 74078
P: 405-744-8036
E: carmelita.goossen@okstate.edu

Ashley S. Whiddon
Oklahoma State University
439 Ag Hall
Stillwater, OK 74078
P: 405-744-8036
E: carmelita.goossen@okstate.edu

J. Shane Robinson
Oklahoma State University
100 ITLE
Stillwater, OK 74078
P: 405-744-3094
E: shane.robinson@okstate.edu


Quantitative Research

Teaching and Learning in Undergraduate Academic Programs

**Effect of the Inquiry-Based Teaching Method on Students' Content Knowledge and Motivation to Learn about Biofuels**

Carmelita Goossen, Southwestern Heights High School, Kismet, KS
F. Richie Roberts, North Carolina A&T University
Amanda Kacal, Cinco Ranch High School, Katy, TX
Ashley Whiddon, Perry Middle School, Perry, GA
J. Shane Robinson, Oklahoma State University

## Abstract

*Students in secondary education are failing in science and are not prepared adequately for college. This deficit has led to the use of innovative teaching methods, including inquiry-based instruction. Inquiry-based instruction has gained popularity because of its realistic and problem-based strategy. The purpose of this study was to determine the effect of inquiry-based instruction, compared to lecture, on the content knowledge and motivation for completing a science-based laboratory activity of pre-service agricultural education teachers (N = 41) at Oklahoma State University. Students were assigned randomly to either an inquiry group or lecture group in the completely randomized 2x2 design. A biofuels unit containing a fully developed classroom kit developed by Lab Aids® served as the content for the treatment. The findings of the study revealed a statistically significant increase in biofuels content knowledge for those who received inquiry-based instruction when compared to those who received lecture. However, no effects were detected regarding the treatment on students' motivation for completing the activity. As this study was exploratory in nature, it is recommended that it be replicated with a larger sample size to increase generalizability.*

*This work has been funded, partially, by the NSF EPSCoR award EPS 0814361.*

## Introduction

American secondary students are failing in the area of science (Kuenzi, 2008) and are not ready for college (Cavanagh, 2004). Unfortunately, the progress of science aptitudes of American students in secondary school systems has been stagnant for years (National Center for Education Statistics, 2005; Provasnik, Gonzales, & Miller, 2009). The report, *A Nation at Risk: The Imperative for Educational Reform* (1983), stated, "the educational foundations of our society are being eroded by a rising tide of mediocrity" (p. 5).

The lack of science proficiency has led to an educational change in how science is taught (Lloyd, 1992). Science educators have turned their attention to the inquiry teaching method (Karukstis & Elgren, 2007). Inquiry-based instruction is "the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities" (Colburn, 2000, p. 42). With inquiry, students are allowed to explore the learning situation, develop hypotheses about the outcome of activities, and test solutions (Colburn, 2000).

Historically, inquiry-based education has been celebrated as an instrumental pedagogy for both the mathematics and science disciplines (National Research Council, 1996), which has strong ties to agriculture. Additionally, empirical evidence supporting inquiry-based teaching methods has been documented well throughout science, technology, engineering, and mathematics (STEM) education (Bransford, Brown, & Cocking, 1999; Bybee et al., 2006; Llewellyn, 2002; National Commission on Excellence in Education, 1983; National Commission on Mathematics and Science Teaching, 2000; National Council of Teachers of Mathematics, 2000).

Efforts to connect science and agriculture better have been observed throughout the years. For instance, in some states, students who enroll in agriscience classes receive science credit for graduation (Connors & Elliot, 1995; Thoron & Myers, 2011). Attempts to update the equipment and technology necessary for teaching laboratory science in agricultural settings has improved and become *commonplace* in agriscience programs (Shoulders & Myers, 2012). Also, agricultural instructors have reported having positive experiences teaching science-based laboratory activities (Myers & Dyer, 2006; Myers, Washburn, & Dyer, 2004; Osborne & Dyer, 2000). In addition, numerous agricultural educators have the necessary desire to integrate more science into their program's curricula (Washburn & Meyers, 2010); yet, they do not always have the knowledge to do so appropriately (Scales, Terry, & Torres, 2009).

Agricultural education and science have a longstanding history. Agricultural education has been referred to as the oldest science in the world (Ricketts, Duncan, & Peake, 2006). The National Research Council (1988) initially called for agriculture to integrate more science into its courses by urging that, "ongoing efforts should be expanded to upgrade the scientific and technical content of vocational agricultural education class" (p. 35). The relation of the two fields was described further by Buriak (1992) in his definition of agriscience, "Instruction in agriculture emphasizing the principles, concepts, and laws of science and their mathematical relationships supporting, describing and explaining agriculture" (p. 4).

Agricultural education has been a good medium for teaching students science skills and proficiencies (Thompson & Balschweid, 2000). The reverse is true also. When teachers employed a science-enhanced curriculum to teach agricultural competencies, students' learned agricultural concepts better than students whose teachers used an agricultural curriculum (Haynes, Robinson, Edwards, & Key, 2012a). Interestingly, though, a similar study yielded no statistically significant differences regarding students' science aptitudes (Haynes, Robinson, Edwards, & Key, 2012b). That study (Haynes et al., 2012b) recommended that professional development should focus on assisting agricultural education teachers in learning how to integrate science concepts better. One strategy could be to emphasize how to use the inquiry-based instructional method.

Inquiry is a method of instruction that has become a popular teaching strategy in agricultural education due to its unique realistic, problem-based method of instruction (Phipps, Osborne, Dyer, & Ball, 2008). Inquiry-based teaching places individuals "in-action" to solve problems instead of learning "out-of-context" (Applebee, 1996, p. 130). This method also is a natural complement for the integration of STEM education into agricultural education instruction because encouraging cognitive retention requires that students' prior preconceptions be engaged early and often throughout the learning process (Bybee et al., 2006). Therefore, students go beyond obtaining a fact-based education and instead utilize deep cognitive processing skills more readily (Donovan & Bransford, 2005; Willingham, 2003) to deepen their science capacities.

Employing students to think actively about the content and participate in hands-on activities enables them to develop a stronger conceptual understanding of science (Minner, Levy, & Century, 2010). Therefore, the science discipline has placed a large emphasis on using inquiry-based teaching when delivering its course content (Dormody, 1993)

Despite this strong track record, numerous educators avoid implementing inquiry instruction into their classrooms because of its complexity and intensity during the instructional process (Puntambekar, Stylianou, & Goldstein, 2007). Additional reasons explaining why teachers are hesitant to utilize this teaching method relates to their lack of training and experience with constructivist style teaching (Llewellyn, 2002).

What is more, the research has been somewhat conflicting regarding the effectiveness of inquiry as a pedagogy. Specifically, controversy exists regarding how science should be taught (Kirschner, Sweller, & Clark, 2006; Furtak, Seidel, Iverson, & Briggs, 2012). Evidence supporting the use of inquiry for teaching science is strong; however, not everyone involved in public school systems believes science should be taught through inquiry-based approaches (Crawford, 2007) mostly because a lack of empirical validation exists suggesting that it affects student learning positively (Kirschner et al., 2006). In fact, Kirschner et al. (2006) stated, "minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process" (p. 75).

Unlike inquiry-based learning, lecture is usually organized by the teacher and can sometimes lack interaction (Akkus, Gunel, & Hand, 2007; Yore, 2001). Typically, the teacher tries to drill the information into the student so that he or she can memorize the desired facts (Moore & Moore, 1984). Some researchers claim that science should be offered by way of teacher-centric methods, such as lecture (Klahr & Nigam, 2004). What is more, teachers are more confident in their ability to use lecture than any other method, and therefore do so more frequently, when teaching science, technology, engineering, and mathematics (STEM) principles (Smith, Rayfield, & McKim, 2015). Others claim that the only way to learn science is through student-centric pedagogies, such as inquiry (Granger et al., 2012). Recent inquiry studies, however, suggest that this method of teaching has a positive effect on learning outcomes (Easterly III & Meyers, 2011; Friedel et. al, 2008; Parr & Edwards, 2004; Thoron & Myers, 2011).

Inquiry-based teaching often is advertised as a fun and engaging method of teaching that motivates students to learn science at a higher level by exploring their own learning (Minner et al., 2010). Therefore, students have positive perceptions of inquiry (Washburn & Myers, 2010; Wolf & Fraser, 2008). However, additional research is warranted regarded how motivation is affected by inquiry teaching (Pintrich, 2003). Specifically, Smith et al. (2015) recommended that

> Teacher educators should make sure that instruction is included for preservice teachers in effective lecture techniques, and instruction should be given to allow novice teachers to make appropriate decision[s] related to when it is appropriate to substitute student-centered alternatives to traditional methods. (pp. 197-198)

Furtak et al. (2012) stated that, "while the debate between inquiry-based and traditional instructional approaches has continued to simmer, researchers have investigated inquiry-based teaching reforms with particular interest in the specific features that appear to lead to increased student learning" (p. 301). Additionally, Hu, Kuh, and Li (2008) called for research "to take into account the fit between the nature or inquiry-oriented activities and students' interests, competencies, and motivation . . . ." (p. 78). Therefore, what effect does the type of instruction have on students' content knowledge and perceived motivation to complete a science-based, laboratory activity in the context of agriculture?

This study was grounded in the expectancy-value theory (Schunk, Pintrich, & Meece, 2008). People have expectations regarding their abilities to perform a task and place value on the reasons "they might engage in a task" (Schunk et al., 2008, p. 44). Ultimately, the expectancy-value theory depends on peoples' aspirations for participating in an activity (Eccles, 2007). If people have a solid motive for participating, believe they have a realistic opportunity to achieve success, and are offered a meaningful incentive, their motivation for participating increases (Schunk et al., 2008). How much value a person has for an activity depends on the personal importance they place on the activity (also known as attainment value), their intrinsic motivation, their perceived usefulness of the activity (also known as utility value), and the cost of participating (Eccles, 2007). Answering this study's research question will provide a response to the American Association for Agricultural Education's priority number four (Doerfert, 2011). Specifically, a key outcome to that priority is that learners will be " . . . actively and emotionally engaged in learning, leading to high levels of achievement . . ." (p. 21).

## Purpose and Objectives

The purpose of this study was to determine the effect of inquiry-based instruction, compared to lecture, on students' content knowledge and motivation for completing a science-based laboratory activity. The following research objectives guided the study.

1. Determine the effect of inquiry-based instruction and lecture on students' content knowledge.
2. Determine the effect of inquiry-based instruction and lecture on students' overall perception of the activity.
3. Determine the effect of inquiry-based instruction and lecture on students' perceived interest and enjoyment regarding the activity.
4. Determine the effect of inquiry-based instruction and lecture on students' perceived value and usefulness of the activity.
5. Determine the effect of inquiry-based instruction and lecture on students' perceived choice of the activity.

The following null hypotheses guided the statistical analysis of the study.

$H_0$1: There is no statistically significant difference between students' content knowledge due to the effect of inquiry-based instruction and lecture.

$H_0$2: There is no statistically significant difference in overall activity perception of students due to the effect of inquiry-based instruction and lecture.

$H_0$3: There is no statistically significant difference in interest and enjoyment of the activity due to the effect of inquiry-based instruction and lecture.

$H_0 4$: There is no statistically significant difference in value and usefulness of the activity due to the effect of inquiry-based instruction and lecture.

$H_0 5$: There is no statistically significant difference in perceived choice of the activity due to the effect of inquiry-based instruction and lecture.

## Methods and Procedures

This exploratory, experimental study employed an independent variable with two levels to assess two treatment groups. The independent variable of this study was laboratory instruction method. The two levels were inquiry-based instruction and lecture. The dependent variables were students' content knowledge, and their motivation for participating in and completing the activity. Content knowledge was measured utilizing a 10-item criterion-referenced test. Student activity perceptions were measured using the Intrinsic Motivation Inventory (IMI), a 25-item activity perception questionnaire (Intrinsic Motivation Inventory, n.d.). The IMI is a self-regulated perception instrument in which participants determine their level of motivation for completing laboratory experiments.

The population of interest was all students ($N$ = 41) enrolled in a junior-level foundations course in agricultural education at Oklahoma State University. Although 41 students were enrolled in the course, originally, not all were present for the duration of the treatment. Therefore, if any student missed a class meeting during the treatment period, he or she was omitted from the study. As a result of this, 37 students participated fully in all experimental conditions.

This research study was conducted to provide students' evidence as to which pedagogy (i.e., lecture versus inquiry-based teaching) is most useful in teaching content related to agriscience. This study followed the exact protocol of two similar studies regarding similar populations of interest at Oklahoma State University (Baker, Brown, Blackburn, & Robinson, 2014; Blackburn, Robinson, & Kacal, 2015). The biofuels unit was chosen due to its connection to agriculture and because of its scarcity within the state's curriculum. As such, the researchers felt as though students would not have been exposed to the curriculum before; thus, no bias would affect pre-test scores.

Because the population consisted of pre-service teachers, this study was presented to the students within the course topic of teaching and managing an agriscience laboratory and was included in the course syllabus. At the beginning of the semester, students were informed of this research study, by way of the course syllabus, and how its findings might impact them as future teachers.

Following Institutional Review Board approval, students were assigned randomly to two groups as a means for controlling threats to internal validity (Gay, Mills, & Airasian, 2009). The treatment group consisted of students who were assigned to receive content via the inquiry-based teaching section ($n$ = 19). The counterfactual group consisted of students who were assigned to receive the content via lecture ($n$ = 17) (see Figure 1).

| Method of Instruction | Repeated Measures: Pre-Test | Repeated Measures: Post-Test |
|---|---|---|
| Lecture | Treatment Group A<br>*n* = 17 | Treatment Group A<br>*n* =17 |
| Inquiry-based Instruction | Treatment Group B<br>*n* = 19 | Treatment Group B<br>*n* = 19 |

*Figure 1*. Random Assignment to a SPF 2x2 design.

To ensure that both groups were equal prior to instruction, a one-way ANOVA was utilized to determine if statistically significant differences existed between students' pre-test and post-test scores based on treatment group. Prior to employing ANOVA, Levene's test for equality of error variances was calculated to ensure error variances were equal (Field, 2009). The Levene's test indicated no statistically significant differences $p = .196$; therefore, equality of error variances was assumed. It was found that no statistically significant differences ($p > .05$) existed between the two groups (i.e., inquiry-based instruction and the lecture) (see Table 1). Thus, both groups were deemed to be equal in their content knowledge of biofuels prior to the experiment.

Table 1

*Lecture Versus Inquiry Based Learning on Pre-test Scores*

| Type of Instruction | *M* | *SD* | *F* | *p* |
|---|---|---|---|---|
| Lecture (*N* = 17) | 5.53 | 1.42 | 2.53 | .12[a] |
| Inquiry (*N* = 19) | 4.74 | 1.52 | | |

*Note*. [a]Effect size = 0.54 (*medium*, per Cohen's *d*, Kirk, 1995)

Following the pre-test, students relocated to their assigned laboratory setting to experience a 30-minute lesson on course content related to biofuels. Both groups received instruction consisting of the same objectives, basic concepts, and terminology of biofuels. A kit developed by the Science Education for Public Understanding Program (SEPUP) supplied laboratory procedures and protocols used to conduct the biofuels experiment employed in this study. Students completed investigation two titled, *Comparing the Energy Stored in Two Fuels.* This investigation is part of a larger kit produced by Lab-Aids® Incorporated titled, *Biofuels: Investigating Ethanol Production and Combustion* – Kit 39S (Lab-Aids® Incorporated, 2007). In this investigation, students compared the energy levels of two fuels – ethanol and kerosene. Students formulated hypotheses based on their current knowledge and prior experiences and then completed the experimental investigation. The students used mathematical formulae and calculations for testing their hypotheses. The major scientific and mathematical concepts within this investigation included the chemical make-up of fuels, pollutants, experimental design and control, converting units of measurement, and averaging. The Lab-Aids® Incorporated biofuels kit utilized in this investigation also was employed by two similar studies conducted at Oklahoma State University (Baker et al., 2014; Blackburn et al., 2015). Biofuels kits and supplies used in the study were supported partially by the NSF EPSCoR award EPS 0814361.

Although the content was held consistent, the delivery of the content was altered. Content was delivered using the assigned teaching method for the respective treatment groups. In the treatment group, content was delivered through the inquiry-based method (i.e., student-centered teaching), and in the counterfactual group, the content was delivered through the lecture method (i.e., teacher-centered teaching).

*Inquiry-Based Instruction Treatment*

The National Research Council (1996) reinforced inquiry based instruction as a student-centered teaching approach stating, "inquiry teaching requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (p. 6). During the biofuels laboratory experiment, students in the inquiry-based instruction treatment group employed their prior knowledge to develop their experimental procedures using the laboratory materials they were provided. The laboratory procedures and protocols supplied for the Lab-Aids® Biofuels investigation two were adapted for this treatment group using the Science Teacher Inquiry Rubric (STIR) (National Research Council, 2000) to increase inquiry and enhance learner-centered teaching methods to guide instruction. The STIR was developed based on the National Science Education Standards' essential features of inquiry instruction (National Research Council, 2000, p. 6).

> The five essential features of inquiry include: (a) learners are engaged by scientifically oriented questions, (b) learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions, (c) learners formulate explanations from evidence to address scientifically oriented questions, (d) learners evaluate their explanations in light of alternate explanations, particularly those reflecting scientific understanding, (e) learners communicate and justify their proposed explanations. (National Research Council, 2000, p. 14)

The STIR places these essential features on a continuum to assist teachers in implementing inquiry-based instruction through curriculum adaptation. One side of the continuum describes teacher-centered teaching methods, while the other side of the continuum describes student-centered teaching methods (National Research Council, 2000).

In the inquiry-based group, students were expected to develop their own hypothesis related to the outcome of the experiment. They were encouraged to obtain approval from the instructor at multiple checkpoints throughout the experiment to validate that their hypotheses, data collection, and procedures aligned with experiment protocols. The laboratory instructor's role was to facilitate the process, not teach the content. When students were confused, the instructor was allowed to ask questions to the students, answer questions asked by students, and provide pertinent and timely information to get students progressing again.

*Lecture Treatment*
In contrast, students in the lecture treatment were taught the concepts of biofuels with a PowerPoint® presentation. In addition, students were provided laboratory procedures and protocols supplied for the Lab-Aids® Biofuels investigation two. Laboratory instructors provided these procedures at the beginning of the experiment; therefore, students simply followed the step-by-step protocol instead of developing their own data collection procedure to conduct the experiment. The Lab-Aids® curriculum comes with a booklet of scripted laboratory exercises in which students are to complete. Students received the step-by-step procedures included in the Lab-Aids® Biofuels kits. The instructors leading this group followed the scripted exercises exactly as they were printed in the booklets.

The three instructors (one in the treatment room and two in the counterfactual room) who led both treatment and counterfactual groups were graduate students in agricultural education at Oklahoma State University. These instructors were formerly certified agricultural education teachers and had been trained to use their respective teaching methods, as assigned. In all, the instructors had a combined 12 years of secondary teaching experience in three different states. Specifically, the instructor who led the inquiry-based teaching treatment group is a National Agriscience Teacher Ambassador specially trained in inquiry methods with more than 90 hours of training in inquiry-based teaching techniques to improve agriscience curriculum.

*Instrumentation*
The content and questions found in the Lab-Aids ® curriculum was used to develop the criterion-referenced test that served as the dependent variable of the study. The test was assessed, previously, for face and content validity by a panel of experts consisting of pedagogical and content experts (Baker et al., 2014). It also was deemed to be reliable (Blackburn et al., 2015) as a result of procedures outlined by Wiersma and Jurs (1990). Therefore, the test was used in this study without any modification.

In addition, the researchers employed a 25-item activity perception questionnaire that is part of the Intrinsic Motivation Inventory (IMI, n.d.). The IMI "is a multidimensional measurement device" that has been used in numerous experiments related to intrinsic motivation and self-regulation through the assessment of participants' subjective experiences "related to a target activity in laboratory experiments" (IMI, n.d., para. 1). The activity perception questionnaire assessed three constructs including "interest/enjoyment, value/usefulness, and perceived choice" (IMI, n.d., p. 8).

## Findings

The first objective was to determine the effect the type of instruction had on students' knowledge, as confirmed by post-test scores. Out of ten possible points, the group that received lecture (*N* = 17) had an average score of 5.76 (*SD* = 1.89) and those in the inquiry group (*N* = 19) had an average score of 7.21 (*SD* = 1.27), which was determined to be statistically significant at the .05 level, $F(1, 34) = 7.39$, $p = .01$ (see Table 2). Prior to analyzing the data, Levene's test of equality of error variances was employed to ensure that homogeneity of variances was not violated. Levene's test was determined to be nonsignificant at the .05 level $F(1, 34) = 1.74$, $p = .196$. Accordingly, the researchers rejected the null hypothesis.

Table 2

*Lecture Versus Inquiry Based Learning on Students' Post-test Scores*

| Type of Instruction | *M* | *SD* | *F* | *p* |
|---|---|---|---|---|
| Lecture (*N* = 17) | 5.76 | 1.89 | 7.39* | .01[a] |
| Inquiry (*N* = 19) | 7.21 | 1.27 | | |

*Note*. *Statistically significant at the .05 level; [a]effect size = 0.90 (*large*, per Cohen's *d*, Kirk, 1995)

A test of simple main effects was necessary due to the statistically significant interaction effect between time and instructional method. Simple main effects are employed to understand the interaction effects better (Kirk, 1995). Table 3 depicts the results of the simple main effects test. It was found that there was a simple main effect regarding the duration of the experiment (i.e., time from pre-test to post-test) and the type of instruction received.

Table 3

*Simple Main Effects Table for the Effect of Time on Instructional Method*

| Source | *SS* | *df* | *MS* | *F* | *p* | *Partial* $\eta^2$ |
|---|---|---|---|---|---|---|
| Time | 32.92 | 1 | 32.92 | 19.01 | .00 | .36 |
| Instruction | 1.91 | 1 | 1.91 | .64 | .43 | .02 |
| Time*Instruction | 22.48 | 1 | 22.48 | 12.98 | .00* | .28 |
| Error | 58.90 | 34 | 1.73 | | | |
| Total | | 37 | | | | |

*Note*. *Statistically significant at the .05 level

Contrast was employed to test the simple effects of instruction within each level combination of the dependent variable. A statistically significant difference ($p = .01$) in post-test score was found for the lecture group (see Table 4). The contrast revealed that 18% of the dependent variable is related to the method of instruction.

Table 4

*Contrast for Time Repeated Measures*

| Time | | *SS* | *df* | *MS* | *F* | *p* | *Partial* $\eta^2$ |
|---|---|---|---|---|---|---|---|
| Pre-test | Contrast | 5.64 | 1 | 5.64 | 2.59 | .12 | .07 |
| | Error | 73.92 | 34 | 2.17 | | | |
| Post-test | Contrast | 18.76 | 1 | 18.76 | 7.40 | .01* | .18 |
| | Error | 86.22 | 34 | 2.54 | | | |

*Note*. *Statistically significant at the .05 level

The purpose of objective two was to determine the effect of the type of instruction on students' perceptions of completing the assignments in the activity. It was found that those in the lecture group (*N* = 14) had a mean score of 4.64 (*SD* = .71), and those in the inquiry group (*N* = 18) had a mean score of 4.47 (*SD* = .81). A between groups analysis deemed non-significant results, and the researchers failed to reject the second null hypothesis (see Table 5).

Table 5

*Effects of Activity Perceptions on the Activity Between Groups*

| Construct | *SS* | *df* | *MS* | *F* | *p* | *Partial* $\eta^2$ |
|---|---|---|---|---|---|---|
| Activity Perception Total | .24 | 1 | .24 | .40 | .53 | .02 |
| Interest/Enjoyment | .45 | 1 | .45 | .56 | .46 | .00 |
| Value/Usefulness | .42 | 1 | .42 | .57 | .46 | .02 |
| Perceived Choice | .01 | 1 | .02 | .02 | .90 | .01 |

*Note*. *Statistically significant at the .05 level

The purpose of objective three was to determine the effect of the type of instruction on students' perceptions of interest/enjoyment of the activity. It was found that those in the lecture group (*N* = 16) had a mean score of 5.02 (*SD* = .90), and those in the inquiry group (*N* = 19) had a mean score of 4.80 (*SD* = .89). A between groups analysis deemed non-significant results, and the researchers failed to reject the third null hypothesis (see Table 5).

The purpose of objective four was to determine the effect of the type of instruction on students' perceptions of value/usefulness of the activity. It was found that those in the lecture group (*N* = 16) had a mean score of 4.94 (*SD* = .80), and those in the inquiry group (*N* = 19) had a mean score of 4.73 (*SD* = .90). A between groups analysis deemed non-significant results, and the researchers failed to reject the fourth null hypothesis (see Table 5).

The purpose of objective five was to determine the effect of the type of instruction on students' perceptions of perceived choice of the activity. It was found that those in the lecture group (*N* = 15) had a mean score of 4.11 (*SD* = .99), and those in the inquiry group (*N* = 18) had a mean score of 4.06 (*SD* = 1.16). A between groups analysis deemed non-significant results, and the researchers failed to reject the fifth null hypothesis (see Table 5).

## Conclusions

The inquiry-based teaching method affected students' biofuel content knowledge positively, as measured on the criterion-referenced test. Not only was this finding statistically significant, but it also had a large practical effect on students' ability to learn biofuels content. This finding supports the notion that students perform better on knowledge-based examinations when content is delivered with student-centered methods, which is consistent with other seminal works in the literature (Crawford, 2007; Easterly III & Myers, 2011; Friedel et. al, 2008; Parr & Edwards, 2004; Furtak et al., 2012; Thoron & Myers, 2011).

A simple main effects test revealed a statistically significant difference in time to type of instruction between the students who were in the inquiry-based instruction group based on post-test scores. Students in the inquiry-based group gained more content knowledge than did their counterparts in the lecture group. There was a statistically significant increase in post-test scores of the students in the inquiry-based groups as 18% of post-test scores were attributed to the inquiry method. This is consistent with studies that suggested that inquiry could have a positive effect on students' learning outcomes (Easterly III & Myers, 2011; Friedel et. al, 2008; Parr & Edwards, 2004; Thoron & Myers, 2011).

The IMI activity perception instrument was utilized to measure the overall experience of the specific method used in the group and the content taught. There were no statistically significant differences between groups in the constructs of *interest/enjoyment*, *value/usefulness,* and *choice* of the activity; thus, the type of pedagogy used did not impact student motivation. Collectively, students reported that they found the activity to be interesting and useful, and they felt like their choice to participate in the activity was at least *somewhat true*. Because both groups were deemed to be motivated to participate in the activity, this finding is consistent with previous studies that reported students having a positive perception toward inquiry as a method of instruction (Washburn & Myers, 2010; Wolf & Fraser, 2008). Additionally, the findings reveal that students were intrinsically motivated to participate in the activity, which is part of the expectancy-value theory (Eccles, 2007; Schunk et al., 2008).

## Recommendations for Research

This study's findings indicate that content knowledge increased for those who received instruction through inquiry-based teaching as opposed to those who received instruction through lecture. However, because this study was exploratory in nature and employed a small sample size (*N* = 41) with low power, further research is needed (Kirk, 1995). It is recommended that the study be replicated with a larger sample size among both secondary and post secondary students. Specifically, the same procedures and protocol should be replicated with similar groups, and the data should be combined with the current study to increase the study's overall power and ability to yield more reliable results regarding the inquiry method's effect on students' content knowledge and motivation for completing the activity.

Researchers have conflicting views regarding inquiry-based instruction (Easterly III & Myers, 2011; Friedel et. al, 2008; Kirschner et al., 2006; Parr & Edwards, 2004; Puntambekar et al., 2007; Thoron & Myers, 2011). However, this study indicated an increase in content knowledge utilizing the inquiry-based method. This could be due to the differences in teaching styles of the instructors delivering the methods. It is possible that *teacher effect* may have impacted the study. To control for the possibility of teacher effect, a similar study should be replicated in which the same teacher instructs both groups.

Since documentation regarding the use of the IMI in agricultural education is limited, it is recommended that further research should be conducted utilizing the instrument to assess students' perceptions with other, various activities. Such studies would help validate the instrument for agricultural education.

Finally, future studies should include qualitative research methods to follow up with students regarding their thoughts of the two interventions to understand additional and more in-depth details regarding the study's findings. Specifically, a qualitative study focusing on what students liked and disliked and valued and devalued (Eccles, 2007) about the inquiry and lecture teaching methods would help inform aspiring teachers regarding the selection of appropriate pedagogies to implement in their own teaching and learning environments in the future (Smith et al., 2015).

## Recommendations for Practice

Considering the small sample size and power attributed to this study, the findings are especially encouraging for inquiry-based teaching. Therefore, it is recommended that additional preparation be devoted to developing pre-service students' efficacies to utilize the inquiry-based teaching method at Oklahoma State University. Information taught through science-enhanced curriculum increases students' agricultural knowledge (Haynes et al., 2012a) and inquiry often is revered as a fun and engaging method that motivates students to learn at a higher level (Minner et al., 2010). Therefore, it is recommended that secondary agricultural education teachers employ inquiry-based teaching methods when teaching science-enhanced curriculum.

Researchers have recommended that professional development should be offered to assist teachers in learning how to integrate science concepts within the agricultural education curriculum more effectively (Haynes et al., 2012a). An implementation strategy could include employing inquiry-based teaching methods. Researchers have indicated that teachers avoid using inquiry because of its complexity and intensity during instruction (Puntambekar et al., 2007), and the avoidance could be related to their confidence in using lecture (Smith et al., 2015) and inexperience and discomfort with using constructivist-teaching methods (Llewellyn, 2002), such as inquiry. It is recommended that agricultural education teachers participate in professional development opportunities regarding inquiry-based teaching when delivering science-enhanced agricultural education curriculum. Also, it was evident from this study that content understanding was lacking. As such, additional effort should be made to help pre-service teachers expand their horizons regarding science competencies that have an agricultural undertone.

## Discussion

This study targeted pre-service teachers regarding their ability to teach science more effectively could have positive implications for future secondary students. Robinson, Kelsey, and Terry (2013) found that pre-service teachers in agriculture at Oklahoma State University do not perceive teaching STEM concepts as an important aspect of their job initially; however, they did begin perceiving it positively once they were introduced to the curriculum. Therefore, the ultimate goal of the researchers is to improve the science literacy of secondary students by improving the competencies of pre-service teachers. One potential approach is to increase pre-service teachers' experiences with STEM-based laboratories in agricultural contexts.

## References


Applebee, A. N. (1996). *Curriculum as conversation: Transforming traditions of teaching and learning*. Chicago, IL: University of Chicago Press

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: Are there differences? *International Journal of Science Education, 29*(14), 1745–1765. doi:10.1080/09500690601075629

Baker, M. A., Brown, N. R., Blackburn, J. J., & Robinson, J. S. (2014). Determining the effects that the order of abstraction and type of reflection have on content knowledge when teaching experientially: An exploratory experiment. *Journal of Agricultural Education, 55*(2), 106–119. doi:10.5032/jae.2014.02106

Blackburn, J. J., Robinson, J. S., & Kacal, A. (2015). Determining the effects of reflection type and cognitive style on students' content knowledge. *Journal of Agricultural Education, 56*(3), 195–209. doi:10.5032/jae.2015.03195

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). How people learn: Brain, mind, experience, and school. Washington, DC: National Academies Press.

Buriak, P. (1992). Filling the gap in agriculture. *The Agricultural Education Magazine, 64*(9), 4, 23.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, CO: BSCS*.

Cavanagh, S. (2004). Students ill-prepared for college, ACT warns. *Education Week, 24*(8). Retrieved from http://www.edweek.org/ew/articles/2004/10/20/08act.h24.html

Colburn, A. (2000). An inquiry primer. *Science Scope, 23*(6), 42–44. Retrieved from http://www.experientiallearning.ucdavis.edu/module2/el2-60-primer.pdf

Connors, J. J., & Elliot, J. F. (1995). The influence of agriscience and natural resources curriculum on students' science achievement scores. *Journal of Agricultural Education*, *36*(3), 57–63. doi:10.5032/jae.1995.03057

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613–642. doi:10.1002/tea.20157

Doerfert, D. L. (Ed.) (2011). *National research agenda: American Association for Agricultural Eductaion's research priority areas for 2011-2015*. Lubbock, TX: Texas Tech University, Department of Agricultural Education and Communications.

Donovan, S. M., & Bransford, J. D. (2005). How students learn: History, mathematics, and science in the classroom. Washington, DC: National Academies Press.

Dormody, T. J. (1993). Science credentialing and science credit in secondary school agricultural education. *Journal of Agricultural Education*, *34*(2), 63–70. doi:10.5032/jae.1993.02063

Easterly III, R. G., & Myers, B. E. (2011). Inquiry–based instruction for students with special needs in school based agricultural education. *Journal of Agricultural Education, 52*(2), 36–46. doi:10.5032/jae.2011.02036

Eccles, J. (2007). *Subjective task value and Eccles et al. model of achievement-related choices*. New York: The Guildford Press.

Field, A. (2009). *Discovering statistics using SPSS (3rd ed.)*. Thousand Oaks, CA: Sage Publications, Inc.

Friedel, C., Irani, T., Rudd, R., Gallo, M., Eckhardt, E., & Ricketts, J. (2008). Overtly teaching critical thinking and inquiry-based learning: A comparison of two undergraduate biotechnology classes. *Journal of Agricultural Education*, *49*(1), 72–84. doi:10.5032/jae.2008.01072

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300–329. doi:10.3102/003465431247206

Gay, L. R., Mills, G. E., & Airasian, P. (2009). *Educational research: Competencies for analysis and applications*. Upper Saddle River, NJ: Pearson.

Granger, E. M., Bevis, T. H., Saska, Y., Southerland, A., Sampson, V., & Tate, R. L. (2012). The efficacy of student-centered instruction in supporting science learning. *Science, 338*(5), 105–108. doi:10.1126/science.1223709

Haynes, J. C., Robinson, J. S., Edwards, M. C., & Key, J. P. (2012a). Determining the effect of a science-enhanced curriculum on agricultural content knowledge: A causal comparative study. *Proceedings of the 2012 AAAE Conference, Asheville, NC.* Retrieved at http://aaaeonline.org/uploads/allconferences/5-23-2012_23_abstracts2012.pdf

Haynes, J. C., Robinson, J. S., Edwards, M. C., & Key, J. P. (2012b). Assessing the effect of using a science-enhanced curriculum to improve agriculture students' science scores: A causal comparative study. *Journal of Agricultural Education, 53*(2), 15–27. doi:10.5032/jae.2012.02015

Intrinsic Motivation Inventory (n.d.). Self-determination theory: An approach to human motivation & personality. Retrieved from http://www.selfdeterminationtheory.org/questionnaires/10-questionnaires/50

Karukstis, K. K., & Elgren, T. E. (2007). *Developing and sustaining a research-supportive curriculum: A compendium of successful practices.* Washington, DC: Council on Undergraduate Research.

Kirk, R. E. (1995). *Experimental design: Procedures for the behavioral sciences (3rd ed.).* Pacific Grove, CA: Brooks/Cole Publishing Co.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86. doi:10.1207/s15326985ep4102_1

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. *Psychological Science, 15*(10), 661–667. doi:10.1111/j.0956-7976.2004.00737.x

Kuenzi, J. J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action*. Congressional Research Service Reports. Retrieved from http://digitalcommons.unl.edu/crsdocs/35/

Lab-Aids, Incorporated (2007). *Biofuels: Investigating ethanol production and combustion (39S).* Ronkonoma, NY: Lab-Aids, Inc.

Llewellyn, D. (2002). Inquiry within: Implementing inquiry-based science standards. Thousand Oaks, CA: Corwin Press.

Lloyd, B. W. (1992). A review of curricular changes in the general chemistry course during the twentieth century. *Journal of Chemical Education, 69*(8), 633–636. doi:10.1021/ed069p633

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction – What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47,* 474–496. doi:10.1002/tea.20347

Moore, G. E., & Moore, B. A. (1984). The problem solving approach to teaching: Has it outlived its usefulness? *Journal of the American Association of Teacher Educators in Agriculture, 25*(2), 3–10. doi:10.5032/jaatea.1984.02003

Myers, B. E., & Dyer, J. E. (2006). Effects of investigative laboratory instruction on student content knowledge and science process skill achievement across learning styles. *Journal of Agricultural Education, 47*(4), 52–63. doi:10.5032/jae.2006.04052

Myers, B. E., Washburn, S. G., & Dyer, J. E. (2004). Assessing agriculture teachers' capacity for teaching science integrated process skills. *Journal of Southern Agricultural Education Research*, *54*(1), 74–85. Retrieved from http://www.jsaer.org/pdf/vol54Whole.pdf

National Center for Education Statistics (2005). *NAEP state comparisons–data table*. Retrieved from http://nces.ed.gov/nationsreportcard/statecomparisons/withinyear.aspx?usrSelections+1%2cSCI%2c0%2c2%2cwithin%2c0%2c0

National Commission on Excellence in Education. (1983). *A nation at risk: An imperative for educational reform*. Washington, DC: U.S. Department of Education.

National Commission on Mathematics and Science Teaching. (2000). *Before it's too late: A report to the nation from the National Commission on Mathematics and Science Teaching for the 21st Century*. Washington, DC: U.S. Department of Education.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM, Inc.

National Research Council. (1988). *Understanding agriculture: New directions for education*. Danville, IL: The Interstate Printers and Publishers.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academies Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington DC: National Academy Press.

Osborne, E. W., & Dyer, J. E. (2000). Attitudes of Illinois agriscience students and their parents toward agriculture and agricultural education programs. *Journal of Agricultural Education*, *41*(3), 50–59. doi:10.5032/jae.2000.03050

Parr, B., & Edwards, M. C. (2004). Inquiry-based instruction in secondary agricultural education: Problem-solving – An old friend revisited. *Journal of Agricultural Education, 45*(4), 106–117. doi:10.5032/jae.2004.04106

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). *Handbook on agricultural education in public schools.* Clifton Park, NY: Thomson Delmar Learning.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667–686. doi:10.1037/0022-0663.95.4.667

Provasnik, S., Gonzales, P., & Miller, D. (2009). *U.S. performance across international assessments of student achievement: Special supplement to the condition of education 2009*. NCES 2009–083: National Center for Education Statistics.

Puntambekar, S., Stylianou, A., & Goldstein, J. (2007). Comparing classroom enactments of an inquiry curriculum: Lessons learned from two teachers. *Journal of the Learning Sciences*, *16*(1), 81–130. doi:10.1080/1050840070933694

Ricketts, J. C., Duncan, D. D., & Peake, J. B. (2006). Science achievement of high school students in complete programs of agriscience education. *Journal of Agricultural Education, 47*(2), 48–55. doi:10.5032/jae.2006.02048

Scales, J., Terry, Jr., R., & Torres, R. M. (2009). Are teachers ready to integrate science concepts into secondary agriculture programs? *Journal of Agricultural Education, 50*(2), 100–111. doi:10.5032/jae.2009.02100

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research, and applications* (3rd ed.). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Shoulders, C. W., & Myers, B. E. (2012). Teachers' use of agricultural laboratories in secondary agricultural education. *Journal of Agricultural Education, 53*(2), 124–138. doi:10.5032/jae.2012.02124

Smith, K. L., Rayfield, J., & McKim, B. R. (2015). Effective practices in STEM integration: Describing teacher perceptions and instructional method use. *Journal of Agricultural Education, 56*(4), 182–201. doi:10.5032/jae.2015.04183

Thompson, G. W., & Balschweid, M. M. (2000). Integrating science into agriculture programs: Implications for addressing state standards and teacher preparation programs. *Journal of Agricultural Education, 41*(2), 73–80. doi:10.5032/jae.2000.02073

Thoron, A. C., & Myers, B. E. (2011). Effects of inquiry-based agriscience instruction on student achievement. *Journal of Agricultural Education*, *52*(4), 175–187. doi:10.5032/jae.2011.04175

Washburn, S. G., & Myers, B. E. (2010). Agriculture teacher perceptions of preparation to integrate science and their current use of inquiry based learning. *Journal of Agricultural Education, 51*(1), 88–98. doi:10.5032/jae.2010.01088

Wiersma, W., & Jurs, S. G. (1990). *Educational measurement and testing*. Boston, MA: Allyn and Bacon.

Willingham, D. (2003). Why students think they understand when they don’t. *American Educator*, 38–41, 48.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education*, *38*(3), 321–341. doi:10.1007/s11165-007-9052-y

Yore, L. D. (2001). What is meant by constructivist science teaching and will the science education community stay the course for meaningful reform? *Electronic Journal of Science Education*, *5*(4). Retrieved from http://unr.edu/homepage/crowther/ejse.