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Examining the Effects of Reflection Type and Abstraction Order on Students' Scientific Reasoning Skills During Experiential Learning

Bradley M. Coleman[1], J.C. Bunch[2], Andrew C. Thoron[3], T. Grady Roberts[4]

Abstract

Experiential learning is a foundational element to agriscience education. The purpose of this study was to examine the effects of reflection type and abstraction order on students' scientific reasoning skills when teaching experientially. Three major conclusions can be drawn from this study: (a) reflection type and abstraction order are independent of one another; (b) reflection-on-action, regardless of abstraction order, is more effective when developing students' scientific reasoning skills; and (c) pre-abstraction is more effective when developing students' scientific reasoning skills regardless of reflection type. It is recommended that future studies be replicated with a larger sample population, provide a longer duration of treatment, and consider individual learning styles as they pertain to reflection, abstraction, and other dependent variables not examined in this study. Regarding recommendations for practice, it is recommended that professional development opportunities exist for in-service teachers. The developers of professional development opportunities should focus on how to better develop students' scientific reasoning skills through experiential learning, reflection as a teaching strategy, and designing learning experiences. Finally, the results of this study should be shared with pre-service teachers in teaching methods and curriculum design courses to allow pre-service teachers to make informed decisions when designing learning experiences.

Keywords: experiential learning; agriscience education; reflection; abstraction; scientific reasoning

Introduction

Experiential learning is a frequently utilized pedagogical practice within agriscience and science education (Baker et al., 2012; Barrick, 1989; Handler & Duncan, 2006; Knobloch, 2003; Phipps et al., 2008; Roberts, 2006; Roberts & Ball, 2009; Shoulders & Myers, 2013). Within science education, experiential learning has been found to be influential in increasing students' interest and content knowledge (Handler & Duncan, 2006). Within in agriscience education, experiential learning is often referenced as a foundational element of the discipline (Barrick, 1989; Roberts, 2006). Specifically, Kolb's (1984) cycle of experiential learning is embedded into each of the three traditional components of agricultural education: classroom/laboratory instruction, supervised agricultural experience (SAE)

[1] Bradley M. Coleman is a Doctoral Graduate Assistant of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 310 Rolfs Hall, PO Box 110540, Gainesville, FL 32611, bradleycoleman@ufl.edu, https://orcid.org/0000-0001-5981-5747
[2] J. C. Bunch is an Associate Professor of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 307A Rolfs Hall, PO Box 110540, Gainesville, FL 32611, bunchj@ufl.edu, https://orcid.org/0000-0001-8729-2349
[3] Andrew C. Thoron is an Associate Professor and Department Head in the Department of Agricultural Education and Communication at Abraham Baldwin Agricultural College, ABAC 8, 2802 Moore Hwy, Tifton, GA 31793, andrew.thoron@abac.edu, https://orcid.org/0000-0002-9905-3692
[4] T. Grady Roberts is a Professor of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 117C Bryant Hall, PO Box 112060, Gainesville, FL 32611, groberts@ufl.edu, https://orcid.org/0000-0001-7618-7850

programs, and leadership/FFA (Baker et al., 2012). Knobloch (2003) also cited experiential learning as fundamental to agriscience education and suggested four pillars for its utilization: (a) learning in real-life contexts, (b) learning by doing, (c) learning through projects, and (d) learning through problem-solving. Further support of experiential learning in agriscience education was given by Roberts and Ball (2009), who noted the method as an empirical and sound psychological framework for school-based agricultural education (SBAE).

In addition to experiential learning as a frequented pedagogical approach in agriscience education, inquiry-based approaches which link science concepts to agriculture are often implemented (Phipps et al., 2008). Scientific literacy is an important skillset for those entering agriculturally related careers, and agriscience courses should teach science process skills as they pertain to agriculture (Myers, 2004). Thoron and Myers (2012) suggested agriscience educators should implement learning experiences which promote scientific reasoning and argumentation skills in the classroom. Zimmerman (2005) defined scientific reasoning as, "the thinking skills involved in inquiry, experimentation, evidence evaluation, inference and argumentation that are done in the service of *conceptual change* or scientific *understanding"* (p. 1).

Wiggins and McTighe (2004) argued learning experiences should be designed with the end in mind. It is not enough to implement hands-on activities for the sake of doing so; rather, one should first consider what the overall goal of the learning experience will be (Wiggins & McTighe, 2004). Therefore, while experiential learning is foundational to agriscience education, are there methods of implementing experiential learning which are more effective than others? Additionally, what value might experiential learning have as a pedagogical approach on students' scientific reasoning skills? Thoron and Myers (2012) claimed experiences in inquiry-based instruction strengthen students' argumentation skills. The development of argumentation and scientific reasoning skills can supply students who are equipped to enter the agricultural workforce better prepared to solve problems (Thoron & Myers, 2012).

In a study by Shoulders and Myers (2013), the authors explored how agriscience teachers implemented Kolb's model of experiential learning. It was reported that of teachers who utilized experiential learning, few implemented the pedagogical approach holistically. Baker et al. (2014) determined if the order of abstraction and type of reflection administered to college students affected their content knowledge when learning experientially. Baker et al. (2014) concluded abstraction order and reflection type were independent of one another. However, reflection-in-action was suggested to be a more effective strategy than reflection-on-action for college students' content knowledge gains. In a similar study by Blackburn et al. (2015), the authors determined if the method in which college students reflected when learning experientially effected their knowledge gained. While the type of reflection did not merit significant findings, the authors emphasized the importance of reflection, and suggested that students should be given multiple options for reflection to span across various learning styles.

Replication by DiBenedetto et al. (2017) detected no difference in abstraction order or reflection type on SBAE students' content knowledge or mathematical calculation scores. However, a significant interaction was detected when analyzing students' discussion question scores. In a separate part of this study, pre-abstraction and reflection-on-action were determined to be dependent upon one another when assessing SBAE students' content knowledge retention (Coleman et al., 2020).

This study is warranted because of the initial significant findings in the aforementioned studies (Dooley, 2001). Baker et al. (2014) recommended replication of the initial study at the secondary school level and recommended the inclusion of additional dependent variables aside from content knowledge. Additionally, it was recommended to increase the number of participants to increase statistical power.

Blackburn et al. (2015) echoed these recommendations stating increased participants and a secondary school setting would be ideal. DiBenedetto et al. (2017) recommended conducting such an experiment in a block-schedule setting to increase meaningful reflection time. Lastly, Thoron and Myers (2012) recommended conducting more experimental studies to identify the best methods in which to teach agriscience, especially those related to experiences in scientific reasoning and argumentation. This study was implemented to address these recommendations and to determine if teaching experientially in SBAE has an effect on students' scientific reasoning skills.

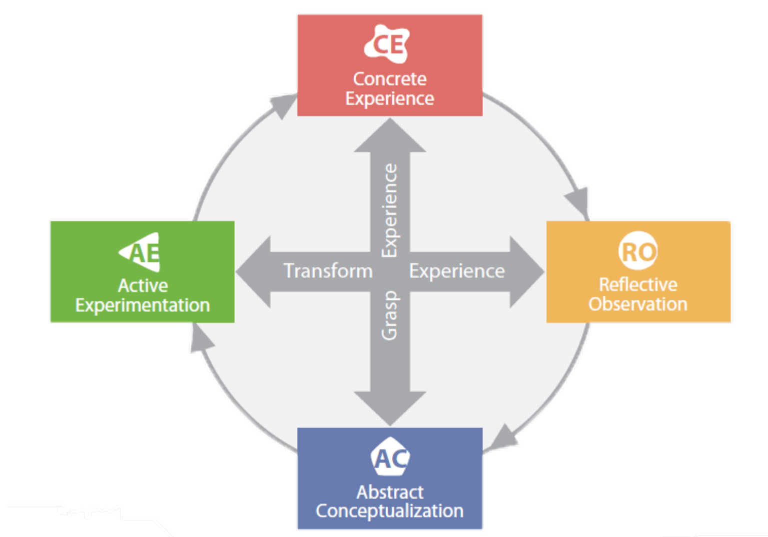
Theoretical Framework

This study was primarily framed using the theory of experiential learning (Dewey, 1938; Kolb, 1984, 2015; Roberts, 2006). Kolb (2015) defined experiential learning as a process by which one's experiences are transformed into knowledge. In the experiential learning cycle, Kolb (2015) suggested four phases: (a) concrete experience, (b) reflective observation, (c) abstract conceptualization, and (d) active experimentation. Of these phases, there are two modes of grasping experiences, concrete experience and abstract conceptualization, and two modes of transforming experiences into knowledge, reflective observation and active experimentation (Kolb, 1984, 2015; Figure 1).

As this model is cyclical, it should be noted there is no specific start or end point. As such, there is no defined order in which a learner should participate in each of the four phases (Kolb, 2015; Roberts, 2006). Dewey (1938) posited while all learning stems from one's experiences, not every experience constitutes learning. Kolb (2015) purported each of the four phases are important in transforming experiences into knowledge.

Figure 1

Model of the Experiential Learning Cycle (Kolb, 2015)



Note. Reprinted from *Experiential Learning: Experience as the Source of Learning and Development* (2nd ed.), by David A. Kolb, ©2015. Reprinted by permission of Pearson Education, Inc., New York, New York.

Reflective Observation

Reflection is a crucial component to experiential learning (Kolb, 2015). Reflection can be defined as the internal process in which an experience is transformed into learning. Kolb (2015) argued that reflection is often overlooked; as a result, learning and development can be impeded or absent. Schön (1983) introduced the idea of reflection-in-action and reflection-on-action. Reflection-in-action occurs while learners are engaged in an experience and the internal process of reflection happens simultaneously. Contrary to reflection-in-action, reflection-on-action occurs after a learner has completed an experience (Schön, 1983). Schön (1983) compared reflection-in-action to the idea of knowledge-in-action. As such, Schön (1983) purported that reflection-*in*-action allows the learner to transform performance to knowledge. Conversely, reflection-*on*-action depends on perceptive knowledge which is created from an internal exemplification of the learner's experience (Schön, 1983).

Embedded in the literature, several studies have examined the overall concept of reflection and reflection methods (Andrysyszyn & Davie, 1997; Blackburn et al., 2015; Lamm et al. 2011; Phan, 2013). In earlier works, Andrusyszyn and Davie (1997) stated reflection and learning have an interdependent relationship. Thus, as the degree of student reflection increases, so does the degree of learning (Andrusyszyn & Davie, 1997). Lamm et al. (2011), espoused that reflection is vital to learning when teaching experientially, and learners prefer to reflect differently. Hence, it is imperative for instructors who teach experientially, to exert time and careful thought to types of reflection activities occurring in the teaching and learning process (Lamm et al., 2011). Supporting the assertions made by Lamm et al. (2011), Phan (2013) found a statically significant relationship between higher-order reflection and positive student achievement. Ultimately, educators should consider the vital role reflection plays in the teaching and learning process and provide learners with different opportunities to reflect throughout the process (Andrysyszyn & Davie, 1997; Blackburn et al., 2015; Lamm et al. 2011; Phan, 2013).

Abstract Conceptualization

Abstract conceptualization is a learner's ability to build knowledge based on evidence separate from a concrete experience (Kolb, 2015). Specifically, the learner creates theories or concepts to explain their observations (Kolb, 2015). When constructing knowledge through the process of abstract conceptualization, the learner's working memory becomes engaged and situates new knowledge with prior knowledge. This specific function, known as intelligence, compels emotional and mechanistic aspects of learning to occur (Kolb, 2015).

Prior knowledge and relevant information are foundational to new knowledge construction and the retention of knowledge (Ausubel, 2000; Dewey, 1916). Dewey (1916) suggested experiences should build upon one another over time to make meaning and create knowledge. Further stated, "The more that is taken in, the greater capacity there is for further assimilation" (Dewey 1916, p. 244). The *level* of abstraction impacts learning and the development of learners. For example, the more abstract, higher-order, and complex of topics being taught, the more impact the experience has on learners' intellectual ability. Thus, the level of abstraction influences thinking processes (i.e., scientific reasoning). To that point, learning is hierarchal, and the level of abstraction one receives plays an important role in the hierarchy (Ausubel, 2000). This assertation supports Kolb's (2015) idea that the quality of an experience is more important than the order in which the learning process occurs.

Scientific Reasoning (Argumentation)

Argumentation skill is the development of logical explanations in consideration of opposing courses of action by weighing evidence, determine merit based upon evidence, and then forming a conclusion of answer to solving the problem (Kuhn, 1992, 1993; Thoron, 2010). Argumentation is the study of logic in a given context where individuals work through authentic problems, consider all solutions, and solve the problem with the best course of action (Driver et al., 2000; Thoron, 2010). Argumentative practices are utilized by real-world scientists. Students developing argumentation skill will lead to enhanced science and a public that has a better understanding of science (Driver et al., 2000).

Toulmin (1958) created Toulmin's Argumentation Pattern (TAP) which is the seminal work for argumentation skill development. Toulman (1958) identified four components: (a) *data*- where students are presented with data in order to form their claim/solution; (b) *claim*- established merit why utilizing data with explanations why the data is important or how it is useful; (c) *warrants*- reason that connect the data and claim; and finally, (d) *backing*- which provides assumptions and justifications for the warrants. The TAP provides a structure for learners to guide their reasoning and better describe their thoughts when solving problems/creating a solution (Thoron, 2010).

Purpose and Objectives

The purpose of this study was to examine the effects of reflection type and abstraction order on students' scientific reasoning skills when teaching experientially. This study aligned with research priority four of the National Research Agenda (Edgar et al., 2016) and included three research questions:

1. What effect does the interaction between abstraction order and reflection type have on scientific reasoning?
2. What is the variance in scientific reasoning attributed to abstraction order?
3. What is the variance in scientific reasoning attributed to reflection type?

The following null hypotheses were created for statistical analyses:

H_0 1: There is no variance in scientific reasoning scores due to the interaction of abstraction order and reflection type.
H_0 2: There is no difference in the overall mean scientific reasoning scores between reflection-in-action and reflection-on-action groups.
H_0 3: There is no difference in the overall mean scientific reasoning scores between pre-abstraction and post-abstraction groups.

Methods

Design

This study was part of a larger-scaled study (Coleman et al., 2020). According to the *Publication Manual of the American Psychological Association* (2020), multiple publications from a large-scale research project can have the same methods section (i.e., design, population/sampling, and procedures) with some uniqueness. As such, the way in which data were collected was the same (Coleman et al., 2020); however, this study focused on a different dependent variable than the larger study. This study was experimental in nature and employed a 2x2 completely randomized factorial (CRF-*pq*) design as prescribed by Kirk (1995). This design allows for random assignment of participants into one of four treatment groups. This 2x2 CRF design is used to test the effects of two independent variables and their interaction effect (Kirk, 1995; see Figure 2). The two independent variables included reflection type and abstraction order. The two methods of reflection tested included reflection-in-action and reflection-on-action. The two methods of abstraction tested were pre-abstraction and post-abstraction. The dependent variable of this study was students' scientific reasoning skills.

Figure 2

CRF-pq (2x2) Design for Random Assignment of Student Participants

	Reflection-In-Action	Reflection-On-Action
Pre-Abstraction	Treatment Group A *n* = 13	Treatment Group B *n* = 14
Post-Abstraction	Treatment Group C *n* = 16	Treatment Group D *n* = 13

Population

The population of interest was secondary school students in grade levels nine through twelve who were enrolled in agriscience courses. This experiment was conducted at a rural high school in Florida with a total school enrollment of approximately 800 students during the spring semester of 2019. There were approximately 140 students enrolled in the eight agriscience courses offered at the high school. The agriscience teacher informed students about the study, and students were given the option to participate. In total, 56 students agreed to participate in this study. The agriscience teacher, school administration, and school board personnel provided prior approval to conduct this study. Additionally, Institutional Review Board and parental consent were obtained prior to student participation.

Sampling and Procedures

The selection of the school and participants was conducted via non-probability, convenience sampling. Participating students were randomly assigned to one of the four treatment groups. Random assignment is effective for minimizing threats to internal validity (Ary et al., 2010). To randomly assign students, each student was assigned a number (one through four) to determine their treatment group. Therefore, the groups were deemed statistically normal due to this randomization of students. Threats to internal validity should be controlled for by a well-designed experiment (Ary et al., 2010). There are 11 threats to internal validity as purported by Ary et al. (2010), all of which were controlled for by the design of this study.

Lab-Aids© Investigating Photovoltaic Cells laboratory kits were used to provide a formal learning experience in solar-powered energy. This lab kit provided an interactive, hands-on learning experience in which students investigated the transformation of sunlight energy into electrical energy. Students were given permission to participate in a three and a half-hour block class period in which the treatment was provided. There were four instructors who lead each of the four treatment groups in four separate classrooms, concurrently. The instructors included two faculty members and two graduate students of agricultural education, three of which were researchers of this study. For consistency of instructional delivery, the instructors met prior to the experiment to review (a) the PowerPoint© guided lecture/discussion, (b) the reflection guides, (c) the verbal reflection questions, (d) the laboratory kits, and (e) the assessment. Pre-abstraction treatment groups (A and B) received the 50-minute lecture/discussion lesson on solar-powered energy before conducting the 90-minute laboratory experience. Suitably, post-abstraction groups (C and D) were instructed to conduct the laboratory experience prior to receiving the lecture/discussion lesson. Reflection-in-action treatment groups (A and C) were issued a reflection guide which prompted students to pause and intentionally reflect on their experience. They were also asked pre-written, verbal reflection questions throughout the experience by the instructor. In the reflection-on-action treatment groups (B and D), students were issued a reflection guide which prompted them to complete the entire laboratory experience without interruption, and then respond to all reflection questions at the end. Instructors of these groups waited to ask the pre-written, verbal reflection questions until the end of the laboratory experience.

Scientific Reasoning Instrument

The instrument used to measure scientific reasoning scores was a researcher-developed argumentation assessment. Face and content validity of the assessment were evaluated by an expert panel composed of two faculty and three graduate students of agricultural education. Minimal grammar and punctuation edits were suggested by the panel. The assessment was administered in the agriscience classrooms where participants were accustomed to meeting. To ensure consistency, testing instructions were read aloud to participants from a pre-developed script. The assessment delivered a case study scenario related to solar energy. Following the scenario, participants responded to seven open-ended response questions which measured scientific reasoning skills. Some examples of assessment questions included:

1. What is a conclusion that you can draw from the data regarding these relationships?
2. What data are you using to support this relationship?
3. What rationale links this data to your conclusion?

A 10-point rubric, originally developed by Schen (2007), was adapted and used for scoring purposes. Dooley (2001) recommended the practice of percent agreement to measure interrater equivalence. Agreement was defined as exact score agreement. However, in the case of a near miss or adjacency (i.e. off by one point), credit can be given (Dooley, 2001). First, one researcher used the rubric to score all of the assessments (n = 56). After all assessments were scored, a second researcher randomly selected 12 of the assessments to be scored using the same rubric. An 83% (10) exact agreement reliability estimate was achieved by the two raters. In the 17% (2) of assessments that were not exact agreements, the cases were one-point adjacencies. As a result of strong agreement, the original researcher's scores were used for statistical analysis.

Data Analysis

Data were analyzed with IBM SPSS Statistics Version 26. A two-way independent analysis of variance (ANOVA) was used to calculate the two main effects and the interaction effect between these independent variables (Field, 2018). Field (2018) recommended the use of the two-way ANOVA for testing the effects of two independent variables (abstraction order and reflection type) on a dependent variable (scientific reasoning skills).

The assumptions regarding the use of ANOVA were examined and met before the use of the statistical tool. Homogeneity of variance was analyzed using Levene's test which yielded a result of $F(3, 52) = .78$, $p = .51$. Field (2018) expressed the use of caution when testing for homogeneity of variance using *Levene's test* for two reasons: (a) in large sample sizes, Levene's test may be over sensitive and detect significance for unimportant variables, and (b) in small samples, Levene's test often lacks enough power to detect violations of the assumption of normality. Caution should be exercised when using Levene's test by also analyzing other indicators of normality such as histograms and Q-Q plots (Field, 2018). Therefore, in addition to the Levene's Test, histograms and Q-Q plots were examined to ensure normality as recommended by Field (2018). Thus, the data were deemed statistically normal.

The statistical and practical effects were both reported for the findings. An *a priori* alpha level of .05 was set to determine statistical significance. The statistical significance was used to determine rejection or failure to reject the null hypotheses (Ary et al., 2010; Kirk, 1995). The practical significance of the effect should also be considered when conducting research (Ary et al., 2010). Partial eta squared was utilized to determine the practical effect size. Miles and Shevlin (2001) categorize partial eta squared effect sizes as follows: (a) 0.01 – small effect size, (b) 0.06 – medium effect size, and (c) 0.14 – large effect size.

Findings

When analyzing the scientific reasoning examination scores, the mean scores for reflection-in-action and reflection-on-action, were 2.41 (SD = 2.04) and 3.74 (SD = 2.57). The mean scores for pre-abstraction and post-abstraction were 4.04 (SD = 2.55) and 2.14 (SD = 1.83). A full report of these descriptive statistics is in Table 1.

Table 1

Mean Scientific Reasoning Test Scores for Reflection Type and Abstraction Order

Type of Reflection	Order of Abstraction	*M*	*SD*	*n*
Reflection In	Pre-Abstraction	2.85	2.41	13
	Post-Abstraction	2.06	1.69	16
	Total	2.41	2.04	29
Reflection On	Pre-Abstraction	5.14	2.21	14
	Post-Abstraction	2.23	2.05	13
	Total	3.74	2.57	27
Total	Pre-Abstraction	4.04	2.55	27
	Post-Abstraction	2.14	1.83	29
	Total	3.05	2.38	56

Note. Scientific reasoning test scores calculated on a 10-point rubric.

The interaction effect of reflection type and abstraction order resulted in an $F(1,52) = 3.61$, $p = .063$, observed power = .462, and was statistically insignificant. As a result of this finding, the first null hypothesis failed to be rejected. The main effect of reflection type was deemed to be significant ($F(1,52) = 4.84$, $p = .032$, observed power = .579). Thus, the second null hypothesis was rejected. This finding resulted in an effect size of .09 which is defined as *medium* by Miles and Shevlin (2001). The main effect of abstraction order was also deemed significant ($F(1,52) = 10.89$, $p = .002$, observed power .899). As such, the third null hypothesis was rejected. The effect size of this finding was .17 which Miles and Shevlin (2001) defined as *large*. The ANOVA summary is presented in Table 2.

Table 2

Scientific Reasoning ANOVA Summary Table

Source	*SS*	*df*	*MS*	*F*	*p*
Reflection	21.11	1	21.11	4.84*	.032[a]
Abstraction	47.46	1	47.46	10.89*	.002[b]
Reflection* Abstraction	15.74	1	15.74	3.61	.063
Error	226.65	52	4.36		
Total	835.00	56			

Note. [a]Effect size = .09 per η_p^2; [b]Effect size = .17 per η_p^2 (Miles & Shevlin, 2001); *$p < .05$.

Figure 3 displays a visual model with the treatment groups and their respective scientific reasoning mean scores. Treatment group A (reflection-in-action and pre-abstraction) had a mean score of 2.85 (*SD* = 2.41). Treatment group B (reflection-on-action and pre-abstraction) had a mean score of 5.14 (*SD* = 2.21). Treatment group C (reflection-in-action and post-abstraction) had a mean score of 2.06 (*SD* = 1.69). Treatment group D (reflection-on-action and post-abstraction) had a mean score of 2.23 (*SD* = 2.05).

Figure 3

Mean Scientific Reasoning Test Scores by Treatment Group

	Reflection-In-Action	Reflection-On-Action
Pre-Abstraction	Treatment Group A *M* = 2.85 (*SD* = 2.41)	Treatment Group B *M* = 5.14 (*SD* = 2.21)
Post-Abstraction	Treatment Group C *M* = 2.06 (*SD* = 1.69)	Treatment Group D *M* = 2.23 (*SD* = 2.05)

Conclusions

The lack of a statistically significant interaction effect indicates reflection type and abstraction order are independent of one another when analyzing students' scientific reasoning skills. This lack of interaction suggests reflection-on-action (*M* = 3.74, *SD* = 2.57, *p* = .03; see table 2 for main effects), regardless of abstraction order, is a more effective reflection strategy for developing students' scientific reasoning skills. While a different dependent variable was analyzed, this finding varies from Baker et al. (2014) who found reflection-in-action as more effective for students' content knowledge gain. This could be due to timeliness. In this study, those who reflected-on-action reflected at the end of the experience and then immediately took the scientific reasoning assessment. Therefore, they could have had a reflection of their experience readily available to transfer to the written assessment verses those who reflected-in-action. However, this finding is congruent with Coleman et al. (2020) who found reflection-on-action as a more effective approach for student content knowledge retention.

The results of this study also denote pre-abstraction (*M* = 4.04, *SD* = 2.55, *p* = .00; see table 2 for main effects) as a more effective strategy in relation to developing students' scientific reasoning skills regardless of reflection type. Interestingly, this finding differs from Kolb's (2015) suggestion that the order in which students receive the experiential learning cycle is of little importance. This also varies from the suggestion by Baker et al. (2014) who found abstraction order had no statistically significant effect on student's content knowledge. This study would suggest the order in which students receive abstract conceptualization of lesson content is important for scientific reasoning skills. This aligns with the assertions by Dewey (1916) and Ausubel (2000) that learning is hierarchal. Providing students abstract conceptualization provides a foundation in which to build further knowledge. Further, this finding supports Roberts' (2006) notion that experiential learning is an on-going, spiral-like process. The act of pre-abstraction could be considered a learning experience within itself in which to further build upon. It is possible those who received pre-abstraction were provided with an *initial focus* followed by an *initial experience* to advance their overall learning.

Recommendations for Research

Statistical power can be increased by having larger sample sizes (Kirk, 1995). This study had a sample population of 56, which is a limitation. It is recommended replications of this or similar studies strive to attain a larger sample size of SBAE students. Further, this study was conducted over a three and a half-hour block course, but the treatment was administered for approximately 140 minutes. A longer duration of treatment is recommended to increase reflection and abstraction time. Conducting this study over the course of an entire unit of instruction, rather than a single-day lesson, could yield additional and different findings. Additionally, this study did not employ a pre-assessment instrument to determine students' prior knowledge of solar power. Thus, it can be recommended that future replication employ a pre-assessment instrument to determine students' prior knowledge before the treatment.

Literature suggested the level and quality of abstraction experience is important to learning (Ausubel, 2000; Kolb, 2015). Therefore, it is recommended a follow-up study be conducted to examine how the intensity or level of abstraction one receives, such as lower and higher order thinking experiences, affects student learning. Kolb (2015) noted it is important to consider various learning styles when teaching. All learners have a preferred style in which they wish to learn. Another follow-up study should consider individual learning styles as they pertain to the independent variables of this study (i.e., abstraction and reflection), and other dependent variables not examined in this study.

Recommendations for Practice

Agriscience and science education programs should provide students with experiences to develop science process skills and scientific reasoning (Handler & Duncan, 2006; Myers, 2004; Thoron & Myers, 2012). However, experiences alone are not enough to constitute learning (Dewey, 1938). As such, it is recommended those wishing to design learning experiences should be intentional in how they design curricula. This study supports the assertion that the way in which we design and implement learning experiences can have implications for student learning. This recommendation aligns with that of Wiggins and McTighe (2004) who suggested planning experiences to meet overall learning goals.

Further, it is recommended the findings of this study, and similar studies, should be shared with pre-service teachers in teaching methods and curriculum design courses. Doing so allows pre-service teachers to make informed decisions about developing learning experiences for agriscience students. Considering SBAE courses can often serve as a dual science course credit, professional development centered around the findings of this study should be offered to in-service agriscience teachers.

Designing experiences and curricula to promote the development of scientific reasoning skills further supports agricultural education as an applied science.

Lastly, student reflection is crucial to learning, especially when implementing experiential learning as a pedagogical approach (Andrusyszyn & Davie, 1997; Baker et al. 2014; Blackburn et al., 2015; Knobloch, 2003; Kolb, 2015; Lamm et al. 2011; Phan, 2013; Roberts 2006; Schön, 1983). Educators who wish to see increased positive learning outcomes should implement reflection strategies which allow students to transform experiences into knowledge. It is recommended teacher professional development be offered to promote reflection as an important teaching tool.

Discussion

This study yielded two statistically significant main effects and no statistically significant interaction effect. This could likely be due to the relatively small sample ($N = 56$) which could impede the ability of the statistical test to detect differences. Additionally, the treatment duration in this study was somewhat short regarding student exposure. Even with these limitations in mind, this experimental study remains comparable to others in the profession of education (Colclasure & Thoron, 2018; Thoron & Myers, 2012). As we know, experimental designs in natural settings can be difficult for numerous reasons. However, researchers should not shy away from the challenge of conducting rigorous experimental designs in natural settings. Researchers should continue to conduct experimental research with students and educational settings while working hard to control what we can. Echoing the sentiments of Thoron and Myers (2012) and Colclasure and Thoron (2018), educational professions should continue the pursuit of publishing experimental research which will further shape education.

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