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A Quasi-Experimental Examination: Cognitive Sequencing of Instruction Using Experiential Learning Theory for STEM Concepts in Agricultural Education

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Abstract

Understanding methods for effectively instructing STEM education concepts is essential in the current climate of education (Freeman, Marginson, & Tyler 2014). Kolb's experiential learning theory (ELT) outlines four specific modes of learning, based on preferences for grasping and transforming information. This quasi-experimental study was conducted to test the effect of cognitive sequencing of instruction in the dimension of grasping information through ELT. Two units of STEM-enhanced instruction were develop, each with two separate sequences; one with concepts presented beginning with a concrete experience and moving to an abstract conceptualization and the other in the opposite sequence. Introductory agricultural science courses in four Texas high schools were randomly assigned to one of four experimental groups (n = 121). This experiment utilized a crossover design to allow each student to experience both cognitive sequences (Shadish, Cook, & Campbell, 2002). This portion of a larger study examined the independent variables of cognitive sequence of instruction and student preference for grasping information in relation to the dependent variables of student change score from pretest to posttest for both units of instruction. Findings indicated significant interactions on both units of instruction between student preference for grasping information and cognitive sequence of instruction.

Keywords: cognitive sequencing, experiential learning theory, STEM, learning preferences

Introduction

In the last ten years, secondary education has been called upon for more than preparing students for a recall of basic information (Carnoy & Rothstein, 2013). This shift in focus is not without warrant. According to the World Economic Forum, the United States ranked fifty-first in quality of math and science education when compared to all nations worldwide (Schwab, 2011). Secondary students in the U.S. have demonstrated declining comparative performance in STEM areas over the last two decades (Carnoy & Rothstern, 2013), and there are growing concerns that students are not completing their education with the skills and knowledge required to enter higher education and skilled careers (Maltese, Potvin, Lung, & Hochbein, 2014).

The abstract nature of many STEM concepts has led researchers to conclude that these topics are best taught using subjects that allow a connection to their real-world application (Boaler, 1998; Kieran, 1992; Stone, 2011; Woodward & Montague, 2002). Career and Technical Education (CTE) courses, including agricultural education, have been seen as a possible context for teaching STEM concepts, as these courses often include a contextual frame for abstract STEM topics (Stone, 2011).

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Agricultural education is rooted in experiential learning (Baker, 2012; Roberts, 2006). The process of integrating abstract concepts in an agricultural setting can be facilitated through the use of Kolb's (1984) experiential learning theory (ELT) as the model through which to deliver, reinforce, and evaluate student learning (Baker, 2012; Roberts, 2006). Quality educators use multiple instructional methods during a given unit, and even within the same class period to help facilitate learning (Marzano, Pickering, & Pollock, 2001).

Although research on single instructional methods may not be a realistic approach to examining effectiveness, studies of the overarching principles of instruction common to all instructional methods could yield viable results (Eggen, Kauchak, & Harder, 1979; Tallmadge & Shearer, 1971). One of the overarching principles of instructional methods is the concept of sequencing instruction (Reigeluth, 2013). In traditional instruction, education begins with providing information related to an abstract concept. This information is then applied to a concrete experience as a demonstration of understanding and a method of retention (Reigeluth, 2013). Switching instructional delivery to begin with a concrete experience prior to the abstract concept could allow an investigation related to the order of educational events. One approach to understanding how agricultural education could assist students in grasping STEM concepts would be to use the ELT model as a framework for exploring the sequencing of STEM instruction in agricultural education courses.

Conceptual Framework

The conceptual framework for this study was developed from Kolb's (1984) experiential learning theory using Gagne's (1965) theory of instruction as a frame for controlling variables in delivering experimental treatments. Gagne's model is widely accepted as a complete overview of the instructional process, provides methods for independent evaluation of variables (Driscoll, 2004; Reigeluth, 1983). This study was heavily influenced by Kolb's experiential learning theory as the method for presenting the stimulus to students. The model shows the cyclical process of learning as a relationship between the four modes of active experimentation (AE), concrete experience (CE), reflective observation (RO) and abstract conceptualization (AC) (Kolb, 1984, 2015). The resulting conceptual model for this study is shown in Figure 1.

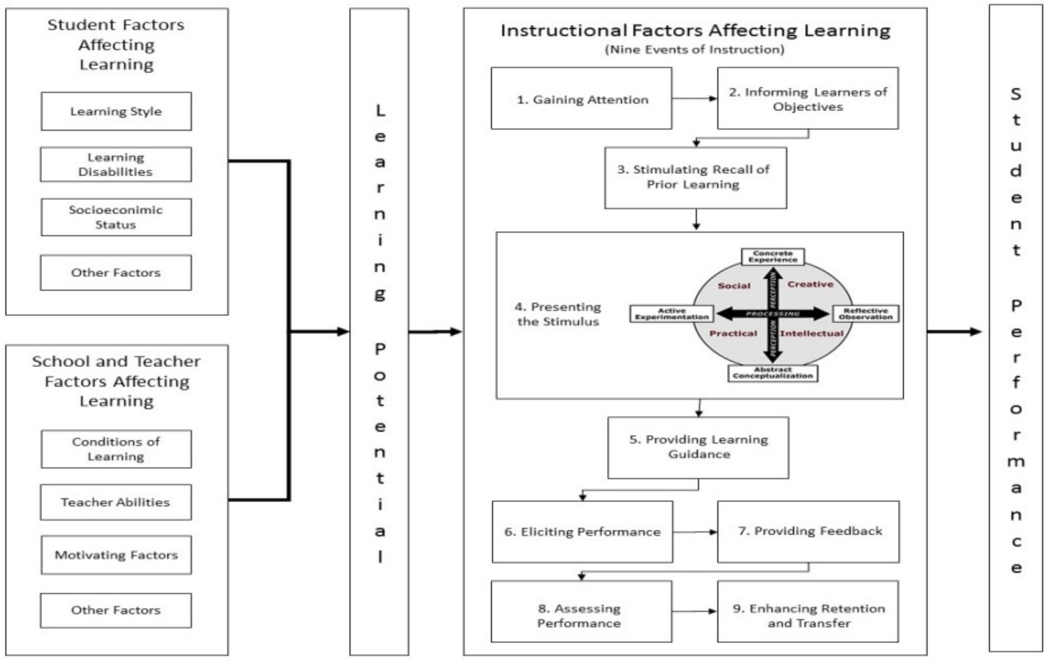

Figure 1. Conceptual model of student learning. Based on Kolb's (1984, 2015) experiential learning theory and Gagne's (1965) nine events of instruction.

This study was designed to employ the conceptual model in an examination of student performance by using experimental curricula developed to standardize the events of instruction as outlined by Gagne (1965), manipulating only the cognitive sequence with which information was presented. Resulting changes in learning between dependent measures were examined in relation to student learning preference and cognitive sequence of instruction.

Review of Literature

Almost every country has examined the importance of integrating STEM concepts into their educational programming (Freeman, Marginson, & Tyler, 2014). In the US, nearly 91% of American adults feel as though science and technology education gives students opportunities for growth and success, and over 60% believe current math and science education is inadequate (Maltese, et. al., 2014). In late 2013, a joint report from the National Science Foundation and the Department of Education highlighted suggestions for STEM education. Among these suggestions was to "provide more opportunities for hand-on, real-world STEM activities at the secondary level" (Ferrini-Mundy, 2013).

Career and Technical Education (CTE) courses have been suggested as a platform for teaching STEM concepts (Stone, 2007, 2011). Stone (2011) analyzed shifts in the pressure applied to CTE courses to integrate STEM concepts beginning in the 1970s. He concluded that models integrating STEM concepts into CTE courses were viable, and noted "STEM-focused education can be incorporated into any CTE delivery system, program, or curricular or pedagogical approach within CTE" (Stone, 2011, p. 13). Both the Math-in-CTE initiative (Stone, Alfeld, & Pearson, 2008) and the Science-in-CTE initiative (Pearson, 2015; Pearson, Young, & Richardson, 2013) have been conducted to examine the successful learning of STEM concepts in CTE courses. These programs have yielded positive results and longitudinal studies are underway.

Contextual learning is not new to CTE or agricultural education. Furner and Kumar (2007) and Shinn et. al. (2003) have examined the important role of agricultural education in bridging the gap between the known and unknown through contextualized learning. The contextual bridge between agricultural education and STEM concepts is well established; agriculture teachers rate the importance of integrating STEM concepts high and have an awareness of shifts in educational structure mandating integration STEM concepts (Myers & Dyer, 2004; Smith, Rayfield, & McKim, 2015). Stubbs and Myers (2015) reported integration of STEM concepts as an essential component of a quality agricultural education program.

Experiential learning theory is based on the premise that learning is a dynamic interaction between the learner, methods through with information is gathered, and methods by which information is processed in the mind (Kolb, 1984, 2015). The resulting model is the cyclical process of the experiential learning cycle. This cycle includes two sets of dialectically opposed modes of learning: Active Experimentation (AE) and Reflective Observation (RO) related to transforming experience, and Concrete Experience (CE) and Abstract Conceptualism (AC) related to grasping experience. Through ELT, Kolb outlines two distinct modes of grasping experience; apprehension, based on concrete experiences, and comprehension, based on abstract conceptualization (Kolb, 2015), and highlights that individuals will have a preference between the opposing modes of learning (Kolb, 2015).

There are those who argue learning preference cannot be used as a standalone assessment of learning ability (Pashler, McDaniel, Rohrer, & Bjork, 2008). Others have noted the importance of understanding individual student learning factors in education (Brokaw & Merz, 2000; Claxton & Murrell. 1987; Coffield, Moseley, Hall, & Ecclestone, 2004a, 2004b; Duff, 2004; Dunn and Dunn, 1989; Felder & Silverman, 1988; Fleming, 2001; Gregorc, 1979; Kolb, 1985, 2015; Tomlinson, 1999). Sousa (2011) noted, “there is little argument that people have various internal and external preferences when they are learning” (p. 59). Due to the close tie between *Kolb’s Learning Style Inventory (KLSI)* and ELT, we used this instrument as an assessment of student learning preference for grasping information.

Several researchers have examined sequence of instruction in general (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Reigeluth, Merrill, Wilson, & Spiller, 1980; Scandura, 1983; Webb, 1997). These concepts of sequencing instruction have often included only the sequencing of concepts and topics, rather than sequencing the modes of learning or type of instruction. The concept of sequencing an initial exposure to instructional information from a specific end of the ELT continuum has not been fully examined. Baker, Brown, Blackburn, and Robinson (2014) conducted an initial examination into presentation order of concepts within the context of experiential learning theory for post-secondary students using agriculture as the context. While their findings failed to reveal significant differences between order of abstraction and type of reflection, they recommended further research in this area, specifically within the secondary classroom.

Research into effective methods for integrating STEM concepts into agricultural education within the framework of ELT may yield important results related to instruction for individual students. Cognitive sequencing may play an important role in allowing students to grasp abstract concepts as applied in a contextual setting (Garlick, 2010; Marzano, et. al., 2001; Reigeluth, 1983). This research was conducted to fill the gap in the knowledge base by analyzing cognitive sequencing in STEM education concepts through the pedagogical approach of ELT, allowing for the most effective sequences for students based on learning preferences to be revealed, and giving agricultural education students access to the most efficacious methods for learning STEM content.

Purpose and Objectives

The purpose of this portion of a larger study was to determine the effect of cognitive sequence of instruction and student learning preference for grasping information on student learning of STEM concepts in agricultural education. To guide the research, the following objectives were developed:

1. Describe the effect an interaction between student learning preference for grasping information and cognitive sequence of instruction has on student change scores on STEM content assessments.
2. Describe the variance of student change scores attributed to student preference for grasping information.
3. Describe the variance of student change scores attributed to cognitive sequence of instruction.

This quasi-experiment was developed to test the following null hypothesis:

Ho: There is no interaction between student preference for grasping information and cognitive sequence of instruction for student change scores on STEM-based content assessments in agricultural education

Methods and Procedures

This study was conducted using a quasi-experimental design, utilizing students enrolled in Principles of Agriculture, Food, and Natural Resources (AFNR) courses in Texas as the functional experimental units. Quasi-experimental research was popularized by Campbell and Stanley (1963) and can be defined as "an experiment in which units are not randomly assigned to conditions" (Shadish et. al., 2002, p. 511). The experiment used a repeated measures crossover design including a control group (Campbell & Stanley, 1963; Shadish, et. al., 2002) to allow for multiple data collection points from each student.

Sites were recruited through purposive selection based on the diversity of school population, regional differences, location in relation to [University], and teacher qualities including commitment to project and teaching history. Fraenkel, Wallen, and Hyun (2006) noted that purposive sampling is sometimes necessary in quasi-experimental educational research due to the need for collaboration between researchers and school personnel. Of twelve identified sites, four were successful in completing authorization and data collection for both experimental rounds. The final population included students enrolled in the Principles of Agriculture, Food, and Natural Resources courses at four high schools in Texas, $n = 121$. Experimental treatments were randomly assigned to each site, as shown in Table 1. According to Shadish, et. al. (2002) quasi-experimental research may require groups of experimental units to be randomly assigned to a treatment collectively, if they are pre-organized into logistically viable groups.

Table 1

Experimental Treatment Profiles by Site

		Round One				Round Two		
Site		Curriculum	Sequence			Curriculum	Sequence	
1	O_1	--	--	O_2	O_3	--	--	O_4
2	O_1	Water	AC-CE	O_2	O_3	Soil	CE-AC	O_4
3	O_1	Soil	AC-CE	O_2	O_3	Water	CE-AC	O_4
4	O_1	Soil	CE-AC	O_2	O_3	Water	AC-CE	O_4

Two units of experimental curricula were developed for this study. Each unit was developed in two formats; one cognitively sequenced with each new concept beginning with a concrete experience and moving toward abstract conceptualization, and another with each new concept beginning with abstract conceptualization and moving toward a concrete experience. It is important to note that the unit topics were selected because of the presence of many abstract science concepts, which could allow cognitive sequencing to be examined in STEM contexts. To ensure curricula met the rigorous requirements for use as experimental treatments and to establish content and face validity, they were designed with guidance from a cognitive psychologist and agricultural curriculum developers. Gagne's nine events of instruction (1965) were held constant during each round of testing except "presenting the stimulus" which varied based on which mode of grasping experience was presented first. Gagne (1965) theorized that by following the nine events of instruction, external learner variables can be controlled in test groups. Each test site received both content areas, sites were randomized as to which content area and cognitive sequence they would receive first. The crossover design allowed each student to experience both units of instruction and both cognitive sequences.

Experimental treatments for this study were designed to be instructed exactly as developed, using provided lesson plans, worksheets, laboratories, and information. Completing this research within the parameters of the study design relied on teachers at each experimental site instructing the curricula exactly as designed. The possibility of deviation from the intended curricula posed a limitation to this study. To overcome this limitation and ensure fidelity of treatment, extensive training and instruction on the use of the curriculum materials was provided to teachers and agreements of compliance were signed and collected from teachers administering the experimental treatments.

Three instruments were used in this study; content knowledge assessments for both the water and soil science units, and *KLSI v 3.1*, which was used to determine student preference for grasping experience in study participants. Unit assessments were developed to directly assess each of the unit objectives with exam questions at multiple levels of cognition. Linkages between individual instrument items and objectives, along with cognitive levels of exam items were established during instrument development. According to Frisbie (1988), the most appropriate method for determining the reliability of a typical teacher-made test using multiple question formats is through the employment of a *KR-20* coefficient. Resulting coefficients (*KR-20*) were 0.75 for the water science pretest and 0.78 for the water science posttest. For the soil science tests, the resulting reliability coefficients (*KR20*) were 0.81 for the pretest and 0.86 for the posttest. Reliability coefficients for teacher-made tests are considered to be acceptable at a minimum level of 0.65

(Frisbie, 1988), therefore the reliability of both unit assessments were deemed acceptable for the intended purpose of this study.

The paper version of the *KLSI v. 3.1* instrument was used to determine the learning style preference for respondents in regard to grasping information. The format of *KLSI v. 3.1* is a forced-choice response to 12 instrument items. Each item contains a statement prompt and asks respondents to rank their preferences for four answer choices, which correspond to the four learning modes of Kolb's (1984) experiential learning theory (ELT). Respondent rankings are ordinal from 4 "most like me" to 1 "least like me" (Kolb & Kolb, 2013). Validity of the *KLSI v. 3.1* has been widely established for use in the field of education (Kolb & Kolb, 2005), and was determined to be acceptable for the purposes of this study. Previous measures of reliability for the four learning KLSI learning modes range from $\alpha = 0.77$ to $\alpha = 0.84$ (Kolb & Kolb, 2005), and reliability was determined to be suitable for use in this study. To maintain group sizes large enough for statistical examination, student preference for concrete experience or abstract conceptualization was classified dichotomously, using the cut scores provided with the *KLSI v 3.1* manual (Kolb & Kolb, 2005). This decision is similar to the decision to use a bipolar classification of preference for grasping and transforming information by Baker (2012).

This quasi-experiment was conducted in the fall semester of 2015. Data were collected in two phases: collection of student characteristics, and collection of STEM assessment knowledge. The first phase of data collection was the collection of information related to participant demographic and classification variables. Per Institutional Review Board requirements, parental consent and student assent were obtained by each student in the Principles of AFNR courses for each participating school. Consent and assent were obtained for n = 121 of the students for an overall inclusion rate of 94.5% of all students (N = 128). We travelled to sites to collect information regarding student demographic characteristics and to administer the *KLSI v. 3.1* instrument to students.

The final phase of data collection was completed by the agriculture teachers who participated in the study. Prior to teaching each unit, teachers administered a pretest, and at the completion of each unit of experimental curricula, a posttest was administered. These assessments included no names, only a unique identifier for each student. Tests were hand-scored once by the teacher according to the predefined answer key, and again by the research team to ensure scoring was consistent and correct. Scores on the pre and posttests were added to the encrypted spreadsheet, and a change from pretest to posttest score was calculated.

Initial data were analyzed with an omnibus multivariate analysis using IBM SPSS v. 23. A multivariate analysis of variance was determined to be the optimal statistical tool for interpreting information from this study (Meyers, Gamst, & Guarino, 2012; Stevens, 2009). Tabachnick and Fidell (2007) mentioned the need to carefully examine the use of MANOVA in crossover designs, as the variation in treatment across measures may be due to the effects of crossing treatments, rather than true interaction when assumptions are violated. After running a MANOVA analysis, two of the assumptions of MANOVA were violated, and the decision was made to examine the two units of instruction separately using two univariate ANOVAs (Howell, 2012; Mayers, 2013; Tabachnick & Fidell, 2007). The resulting univariate analyses yielded two ANOVAs from the same data set. The alpha level for significance was adjusted using Bonferroni's adjustment (Meyers, et. al., 2013; Stevens, 2009; Tabachnick & Fidell, 2007), resulting in an adjusted alpha level of $p < 0.02$ for determining significance.

Findings

Prior to analyzing the results related to the research objective, data were analyzed using ANOVA to determine if statistically significant differences existed in the four test sites on the pretest measures. An initial examination of prior knowledge was necessary to interpret subsequent differences which may have existed based on teacher or school factors rather than the independent variables. No significant differences ($F(3,117) = 1.22$, $p = 0.30$, $\eta_p^2 = 0.03$) were found in the pretest water science assessment scores between students at the sites. The ANOVA examination of the raw scores on the soil science unit exams revealed statistically significant differences ($F(3,117) = 5.10$, $p = 0.02$, $\eta_p^2 = 0.15$) in the means between sites on the soil science pretest assessment. Post hoc analysis showed differences only between sites three and four. The nature of this study allowed for an examination of change from pretest to posttest (Shadish, et. al., 2002), and as such, the differences in pretest scores were noted for examination in the outcomes of hypothesis testing, but deemed no threat to the analysis of findings related to the objectives.

To begin the analysis related to the research objectives, the descriptive results of change from pretest to posttest on both the water science and soils science unit assessments were calculated and are shown in Table 2.

Table 2

Means and Standard Deviations of Change in Score for Water Science and Soil Science Units by Independent Variable Group

		Water Science Unit		Soil Science Unit	
Variable	Category	*n*	*M* (*SD*)	*n*	*M* (*SD*)
Grasping Preference	Apprehension	85	41.82 (24.57)	85	47.69 (26.62)
	Comprehension	36	30.53 (28.93)	36	32.31 (23.84)
Sequence of Respective Unit	AC to CE	72	43.69 (17.97)	31	33.81 (16.87)
	CE to AC	31	48.45 (31.04)	72	57.64 (19.52)
	Control	18	0.33 (3.24)	18	1.06 (2.56)

Note: The crossover design allowed for students receiving the water science unit in the AC to CE sequence to receive the opposite treatment for the soil science unit, which accounts for the differences in *n* between sequences

Following an analysis of the descriptive means, the means for each of the units of instruction were compared by using univariate analyses. The results of the omnibus ANOVA examination for the water science unit revealed significant differences ($p \leq 0.02$) in the dependent variable. Significant differences were found for both preference for grasping experience ($F(1,115) = 11.07$, $p = 0.01$, $\eta_p^2 = 0.09$) and cognitive sequence of instruction ($F(2,115) = 60.65$, $p = 0.01$, $\eta_p^2 = 0.51$). These findings were superseded by the finding of a single statistically significant ($F(2,115) = 38.19$, $p = 0.01$, $\eta_p^2 = 0.40$) interaction involving both preference for grasping experience and cognitive sequence. Based on the guidelines set forth by Cohen (1977), this difference had a large effect size $\eta_p^2 \geq 0.14$, and showed a high level of power. Based on the findings, the null hypothesis was rejected, and it was determined that interactions between cognitive sequence and preference for grasping experience did exist. Results of the omnibus ANOVA are shown in Table 3.

Table 3

ANOVA Table for the Effect of Preference for Grasping Knowledge and Cognitive Sequence on Change in Pre and Posttest Scores on Water Science Unit Assessments

	SS	*df*	*MS*	*F*	*p*	η_p^2	1-β
Grasping	2922.20	1	2922.20	11.07	0.01*	0.09	0.91
Sequence	32014.49	2	16007.24	60.65	0.01*	0.51	1.00
Grasping*Sequence	20160.22	2	10080.11	38.19	0.01*	0.40	1.00
Error	30352.84	115	263.94				
Total	262248.00	121					

Note: Significant alpha level was determined *a priori* at an adjusted level of $p \leq 0.02$ to account for analysis of both units of instruction

The analysis of the soil science unit yielded similar results, which are shown in Table 4. A significant difference ($F(2,115) = 69.17$, $p = 0.01$, $\eta_p^2 = 0.55$) was found related to student preference for grasping information which was superseded by a significant interaction ($F(1,115) = 17.58$, $p = 0.01$, $\eta_p^2 = 0.23$) between sequence of instruction and preference for grasping information.

Table 3

ANOVA Table for the Effect of Preference for Grasping Knowledge and Cognitive Sequence on Change in Pre and Posttest Scores on Water Science Unit Assessments

	SS	*df*	*MS*	*F*	*p*	η_p^2	1-β
Grasping	93.95	1	93.95	0.41	0.53	0.01	0.10
Sequence	32028.74	2	16014.37	69.17	0.01*	0.55	1.00
Grasping*Sequence	8138.91	2	4069.46	17.58	0.01*	0.23	1.00
Error	26624.92	115	231.52				
Total	310351.00	121					

Note: Significant alpha level was determined *a priori* at an adjusted level of $p \leq 0.02$ to account for analysis of both units of instruction

Following the results from the ANOVA analyses, simple main effects tests were conducted to further investigate the interaction. The results of the simple main effects tests revealed that, for both units of instruction, students had significantly higher scores in the unit sequenced to begin with their preferred method of grasping information. The resulting profile plots for both units are shown in Figures 2 and 3.

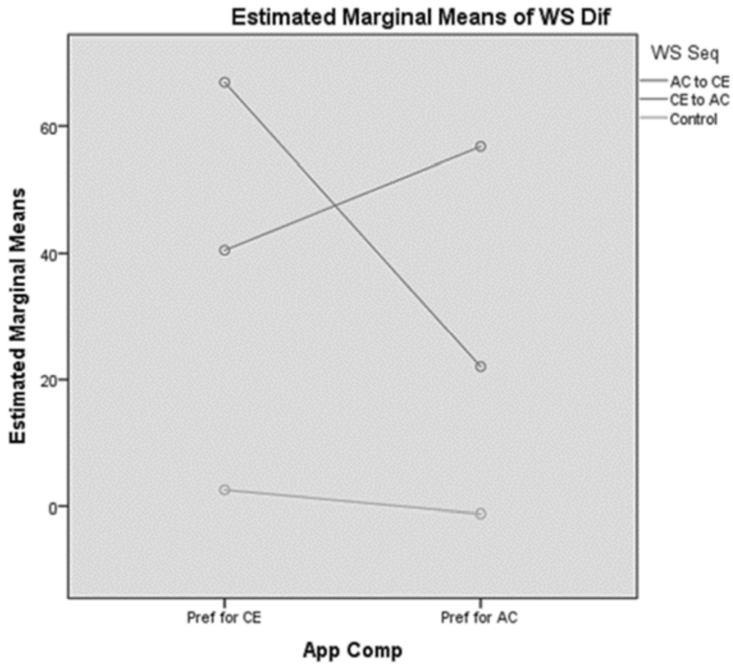

Figure 2. Profile plot for water science unit

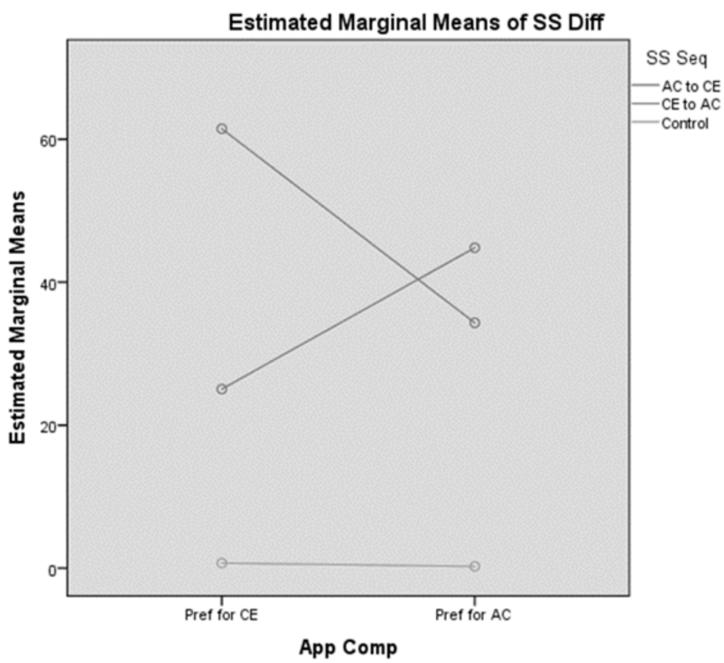

Figure 2. Profile plot for soil science unit

Conclusions/Implications

This study was an exploratory examination of cognitive sequencing of STEM concepts in agricultural education, in an effort to gain insight into how the cognitive principle of sequencing instruction might play a role in student understanding of STEM concepts. The study was developed using the foundational underpinnings of experiential learning, which is already at the foundation of agricultural education (Baker, 2012; Roberts, 2006). Through this examination, we can begin to frame methods for instruction which might help agricultural educators better guide students through the abstract STEM concepts they are being asked to teach (Myers & Dyer, 2004). The findings of this study lend support to the fact that it is not only what agricultural educators are teaching in regards to STEM concepts in agricultural education, it is how they are teaching it that may make the critical difference for students.

The results of this study highlight the importance of cognitive sequencing as a factor related to change in score from pretest to posttest. By using a crossover design, each student could be evaluated in relation to their preference for grasping experience and their performance on purposively sequenced units. For the n = 121 students involved in this study, differences were evident. The results reveal that sequencing of instruction resulted in greater changes in assessment scores as an interaction with preference for grasping experience. Student differences based on cognitive sequence have direct implications for agricultural educators as they work to instruct STEM concepts.

Three main findings emerge from this study: students in this study who preferred to grasp experience through apprehension had higher change scores from pretest to posttest when the units were sequenced to begin with a concrete experience, students who preferred to grasp experience through comprehension had higher change scores when the units were sequenced to begin with abstract conceptualization, and students performed with higher change scores in the unit cognitively sequenced to match their preferred learning style, regardless of unit content.

Many of the concepts in STEM education are abstract in nature (Maltese, et. al., 2014), and the hands-on nature of agricultural education and other CTE courses have been seen as a platform for delivering these concepts (Stone, 2010). For students who prefer to grasp information through apprehension, the presentation of abstract concepts through abstract conceptualization, which is common in traditional education (Reigeluth, 2013), may not provide the stimulus they need to effectively grasp the new information.

The majority of students in this study (n = 86) had a preference for grasping experience through apprehension. If the proportion of students who prefer apprehension over comprehension is similar in the total population of agricultural education students to the proportion in this study, there could be a large number of students who would benefit from a sequencing instruction to begin with concrete experiences. Providing students preferring apprehension over comprehension a concrete experience at the beginning of the instruction allows them to have an experience to tie the abstract concepts to (Garlick, 2010; Kolb, 2015). According to Kolb (2015) those who prefer concrete experience (apprehension) have "a concern with the uniqueness and complexity of present reality as opposed to theories and generalizations" (p. 105).

Students with a preference for grasping experience through comprehension were found to have higher changes in scores when new concepts were presented with an abstract conceptualization focus first. What implications does this have for agricultural education? The traditional model of curriculum design, which includes instruction in abstract concepts followed by concrete application of those abstractions is well-suited for students who prefer to grasp experience through comprehension (Reigeluth, 2013). These students are more suited to learning abstract concepts through traditional educational methods.

Students with both types of preferences exist in an agricultural education classroom, so which of the cognitive sequences is better suited for development of curriculum materials?

Sequencing instruction based on individual student preferences for grasping information has close ties to the literature related to differentiated instruction. Tomlinson (1999) stated the importance of tailoring educational practices to meet the needs of each student. The findings of this study give an example of just how critical differentiated instruction is when dealing with STEM concepts in agricultural education classes. Students in this study showed drastically higher scores when they were given the opportunity to grasp information in a sequence tailored to their preference. This small change to educational methods may have broad-reaching effects, not only for STEM concepts in agricultural education, but for education as a whole.

It is important to note that, within the confines of ELT, the entire learning cycle must be completed in order for learning to occur. Students who have a preference for apprehension are not likely to learn only through the concrete experience, it must be supplemented by reflective observation, abstract conceptualization, and active experimentation in order for the intent of ELT to be met (Baker, 2012; Kolb, 2015).

Recommendations

These conclusions serve as a starting point for a discussion on how our practices can best meet the needs of our students. Agricultural education is charged with providing context to abstract STEM concepts (Myers & Dyer, 2004). To this point, there has been little research on the best ways to deliver this content effectively (Stone, 2010). Perhaps by returning to our ELT roots (Roberts, 2006; Baker, et. al. 2012) and differentiating our instruction based on individual learning preferences (Tomlinson, 1999) through cognitive sequencing, we can stimulate the change our field needs to meet the challenge.

Because both preferences for grasping information exist in a secondary agricultural education classroom, it is recommended to alternate and combine instruction in STEM concepts from both apprehension and comprehension of the prehension dialectic. Careful attention should be paid during the design of instruction to ensure that students are receiving exposure to the complete learning cycle as defined through ELT. In-service teachers should be properly instructed in methods that allow them to teach using the full ELT cycle. Professional development should be created and presented to in-service teachers to highlight the effects of cognitive sequencing based on learning style.

The results of this study yield promising areas for investigation in a secondary agricultural education classroom. Cognitive sequencing may be the most feasible method educators can use to tailor learning to the preferences of each student. With professional development instruction, teachers could learn methods for varying the sequencing of concepts in their classrooms. Varied instruction could be as simple as splitting the class based on learning preferences and setting up learning stations that would allow instruction take place beginning with a concrete experience for students who prefer to grasp through apprehension and beginning with the explanation of abstract concepts for those who prefer to grasp through comprehension. With minimal effort on the part of the teacher, all students could be instructed in the sequence that matches their preferences. In-service should include instruction on how to present new concepts using both an apprehension and comprehension beginning point.

One of the largest reflective comments from the teachers who delivered the experimental units was that delivering instruction beginning with a concrete experience felt unnatural. It stands to reason; these teachers were likely students who learned in a traditional education model with concepts sequenced from AC to CE (Reigeluth, 2013). They most likely learned to teach from instructors who modelled and shared an AC to CE method for learning (Reigeluth, 2013). We recommend continued emphasis on both sequencing instruction and the design of lessons using ELT for preservice agricultural educators to help them understand that variation can exist. Pre-service teachers should be made aware of the potential effects of cognitive sequencing on student learning. We recommend teacher educators consider adding lesson plan formats that include identification of each component of ELT. They should also be given the opportunity to develop lessons which are not sequenced in a traditional AC to CE format.

Additional research is needed to completely understand the role sequencing of instruction might play in both STEM education and agricultural education as a whole. Although this examination looked specifically at abstract STEM concepts, an examination of the Examining the role of the transformation dimension, replicating this study with engineering and mathematics concepts, and examining units of instruction with alternating or combined sequences of instruction are all recommended areas for continued exploration. We also recommend a replication of this study in fields outside of agricultural education, to test the interdisciplinary reach of instruction purposively sequenced based on ELT.

Experiential learning theory is a valuable tool which many believe may be at the very core of agricultural education. Attention to this theory as a systematic method for instruction, rather than a suggested principle could yield the understanding of how to integrate content and STEM concepts more effectively for all students. This study is the initial examination of a much larger concept. Combining purposively sequenced instruction with the foundations of ELT could bridge the gap between abstract concepts and knowledge for agricultural education students, and may allow agricultural educators to effectively integrate STEM concepts for all students.

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