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Comparing the 5E Method of Inquiry-based Instruction and the Four-Stage Model of Direct Instruction on Students' Content Knowledge Achievement in an ENR Curriculum

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Abstract

The purpose of this study was to compare the 5E method of inquiry-based instruction (IBI) and the four-stage model of direct instruction (DI) on students' content knowledge achievement. The population for this study was all secondary high school students enrolled in the CASE® Natural Resources and Ecology course and whose teachers completed the CASE® Institute for Natural Resources and Ecology certification between the years 2013 and 2017. This study was quasi-experimental and used a nonequivalent control group, pretest-posttest design. A convenient sample of 13 teachers and 222 students was collected. Each teacher was randomly assigned to deliver a set of 16 lesson plans that utilized either the IBI or DI approach. Lesson plans were grouped into four modules, each lasting approximately two weeks. Prior to the delivery of each module, teachers administered content knowledge pretests. Posttests were administered at the completion of each 2-week module. Students in both groups demonstrated significant gains in content knowledge achievement. ANCOVA statistical procedures were used to compare student achievement for both instructional methods. Results of the ANCOVA indicated that the 5E method of IBI and the four- stage model of DI are equally effective on students' content knowledge achievement.

Keywords: CASE; content knowledge; direct instruction; environmental education; inquiry-based instruction; 5E method

Introduction

The global landscape has been changing at a rapid rate, leading to many complex agricultural and environmental challenges (National Research Council [NRC], 2009). The role of agriculture in providing food, fiber, and natural resources to meet the demands of a growing global population of over 7.5 billion has become paramount. Emerging environmental change, degradation, resource depletion, as well as increasing environmental regulation, have added unique challenges to the future of

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agriculture production (NRC, 2009). In a world facing increasingly complex agricultural and environmental challenges, individuals will need to be educated with the scientific knowledge and problem-solving skills required to address them (Bright & Tarrant, 2002; Ernst & Monroe, 2006).

Experimental research measuring the effectiveness of curriculum design and teaching methods in agricultural education has been vital to establishing a wide body of empirical evidence that has supported best practices in School-based Agricultural Education (SBAE) (Thoron & Myers, 2011). In fact, the American Association of Agricultural Education's National Research Agenda proclaimed "utilizing research to draw a connection between the impact of our academic programs and student preparedness and success is essential for survival and sustainability of agricultural leadership, education, and extension education ..." (Roberts et al., 2016, p. 32). According to Thoron and Myers (2011), a long-standing need has existed for research-based evidence focused on teaching methods and student learning within agriscience. The National Council for Agricultural Education (NCAE) (2015) proposed eight Agriculture, Food, and Natural Resource Career Clusters, including Environmental Service Systems and Natural Resource Systems (ENR). ENR courses have provided SBAE programs with an excellent opportunity for the integration of core sciences into agricultural curricula (Nolin & Parr, 2013). Although the need for ENR courses within SBAE has been well documented (NCAE, 2015), empirical research that has examined the use of specific instructional approaches in ENR, and within SBAE, has been negligible. Learning outcomes of ENR courses should focus on factors that prepare students to understand and manage the complex agricultural and environmental challenges in the world today (NRC, 2009), as well as prepare students for careers in environmental and agricultural disciplines.

The problem that this study addressed was the need for effective teaching methods within SBAE ENR courses that equip students with a basic understanding of science, the environment, and agriculture. According to the NRC (2012), one of the principal goals of science education "has been to cultivate students' scientific habits of mind, develop their capability to engage in scientific inquiry, and teach them how to reason in a scientific context" (p. 41). Science education has been vital in preparing a public who is scientifically literate and able to think critically to solve complex problems (NRC, 2012). Inquiry-based instruction (IBI) has been endorsed as a preferred teaching approach in science education to achieve this goal (Duschl, 2008; Forbes & Davis, 2008; Forbes & Zint, 2010; Hodson, 2003; Minner et al., 2010), but has lacked adequate empirical evidence regarding its effectiveness in public education over alternative teaching methods (Cobern et al., 2010). This study provided empirical evidence comparing the effectiveness of the 5E method of IBI (Bybee et al., 2006) with the four-stage model of direct instruction (Eggen & Kauchak, 2012) in a SBAE ENR course.

Conceptual Framework and Literature Review

The Presage-Process-Product (3P) model (Biggs, 2003) was used as the conceptual framework to guide this study. The 3P model illustrates relationships between presage, process, and product factors in teaching and learning. Presage factors include characteristics of the student, characteristics of the teacher, and characteristics of the learning environment. Process factors include the curriculum and teaching methods used in the learning environment. Lastly, product factors, or learning outputs, are student outcomes that result from the learning experience (Biggs, 2003). Presage, process, and product factors of interest were identified, explored, and analyzed in the context of this study.

Presage Factors

Presage factors exist prior to learning and include preexisting student characteristics. Although many presage factors can impact teaching and learning, characteristics of the student, such as age, race, and gender were determined to be the demographic variables of interest. These demographics are commonly reported in school improvement data and are helpful in identifying educational discrepancies and gaps (Bernhardt, 2018). Instructional materials and teaching methods used must be geared for all students. The disaggregation of learning data by demographics can lead to valuable information about the performance of student subgroups. The goal of teaching and learning is to have all students achieve. Disaggregating student achievement by race and gender enables researchers to identify groups not responding to the process in ways that other students are (Bernhardt, 2018).

Process Factors

Process factors can be described as the learning process, including factors such as learner motivation and learning strategies (Yurdugul & Cetin, 2015). Han (2014) adopted the 3P model as a framework for a literature review and examined delivery methods and instructional strategies as process factors. Similarly, teaching methods were the process factor of interest in this study. The teaching methods under investigation were inquiry-based instruction (IBI) and direct instruction (DI). Specific models of each instructional method were used and will later be explained.

Product Factors

Product factors, or learning experience outcomes, are perhaps the most collected, analyzed, and reported data in teaching and learning. Product factors include both cognitive and non-cognitive student learning outcomes. Desired product factors often guide process factors, as in the case of *Understanding by Design* (Wiggins & McTighe, 2005). Product factors such as improvements in students' critical thinking and problem-solving have recently garnered more attention (Akins et al., 2019; Carlgren, 2013; Perry et al., 2014; Perry et al., 2015), yet content knowledge achievement remains a critical product factor and measure of success for educational programs (Christodoulou, 2013). The importance of content knowledge achievement is evident by learning standards and content knowledge assessments that have become embedded in most educational programs. The product factor investigated in this study was content knowledge achievement and was analyzed according to the instructional method used: IBI and DI. Each instructional method was implemented based upon a specific model.

Model for Inquiry-based Instruction

Inquiry-based instruction is rooted in constructivism. The constructivist approach to learning emphasizes that in order for meaningful learning to occur, individuals must construct their own understanding through active thinking (Cobern et al., 2010). Constructivism itself is not considered a true theory by many, but rather a philosophical viewpoint about the nature of knowledge and learning (Hyslop-Margison & Strobel, 2008). The foundation of the constructivist framework is centered on the works by Piaget (1952), Vygotsky (1978), Dewey (1929), and Bruner (1966). Each of these early contributors influenced the modern view of constructivism (Tobias & Duffy, 2009), which has led to pedagogical implications in education (Hyslop-Margison & Strobel, 2008; Phipps et al., 2008).

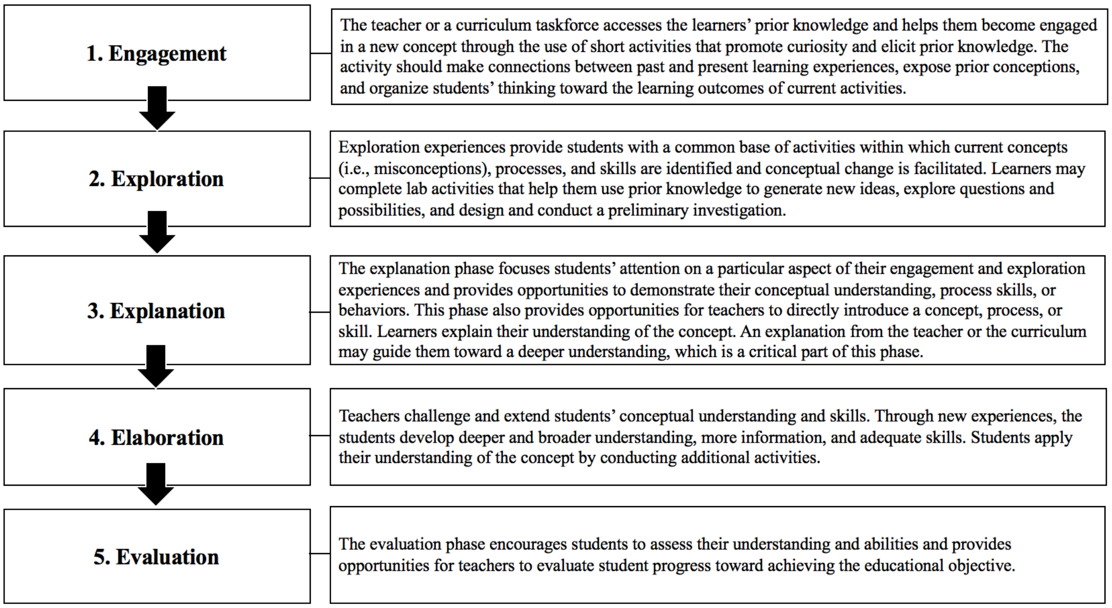
A key principle of the constructivist perspective is that in order for learning to take place, meaningful knowledge must be constructed by the learner, as opposed to being transmitted and absorbed (Cobern et al., 2010). An individual's ability to construct knowledge is dependent upon the behavioral and mental engagement of the learner (Cakir, 2008), as well as the learners' exposure to social interactions and experiences (Schunk, 2012). Engaged exposure to new interactions allows individuals to produce knowledge based upon preexisting beliefs and beliefs stemming from the new interactions (Cobb & Bowers, 1999; Geary, 1995). The theoretical perspective of constructivism has led to varying methods in educational practice that promote students to become actively involved in their own learning. One such method that came to fruition, centered in the epistemological framework of constructivism that permeated education in the 1970s, was IBI (Llewellyn, 2002; Minner et al., 2010). Throughout the nearly next half-century, education reform in science education was centered in the constructivist approaches to learning and touted IBI as *the sine qua non* for science instruction (American Association for the Advancement of Science, 1990; NRC, 1988, 2000).

Despite the popularity of IBI over the last several decades, researchers and practitioners alike have been slow to agree upon a precisely shared understanding of its defining characteristics (Minner et al., 2010). Although multiple perspectives have shaped the definitions of IBI in education (Llewellyn, 2002), scholars have agreed that IBI is a student-centered and teacher-guided approach to learning that places the responsibility for learning upon the student. The focus of instruction shifts to students' learning and thinking processes, as opposed to merely students' acquisition of specific information. The IBI approach assumes that if students are comfortable with the process of learning and are actively engaged, then they will form knowledge about new concepts and will transfer knowledge from other concepts (Doolittle & Camp, 1999; Easterly & Myers, 2011). The student-centered approach to learning can foster students' personal investment in the learning process, which develops students' concentration, enthusiasm, and curiosity toward learning (Minner et al., 2010). Furthermore, IBI commonly engages students in investigating real world problems that require them to reason, obtain information, derive principles, and apply them to possible solutions. During this process students are expected to build on prior knowledge, use logic, and think creatively (Minner et al., 2010).

Atkin and Karplus (1962) were among the first to design teaching methods that were analogous to how scientists invent and use new concepts about nature. Their early work included two processes: *invention* – the initial introduction of a new term, and *discovery* – the following verification or extension of that term. Karplus soon expanded upon this design by including three distinct phases that included exploration, invention, and discovery (Karplus & Thier, 1967). This process of instruction became known as the Science Curriculum Improvement Study (SCIS) Learning Cycle. In the mid-1970s, Karplus again modified the three phases in an effort to make each stage clearer in classroom practice. The phases of the SCIS Learning Cycle became exploration, concept introduction, and concept application. The learning cycle approach emphasized the investigation of phenomena, acquiring evidence to back up claims, and designing and testing experiments. Early studies on the effectiveness of the learning cycle approach reported student increases in content retention, attitudes toward science, and improved scientific reasoning and processing skills, compared to traditional approaches (Abraham & Renner, 1986; Lott, 1983; Raghubir, 1979). The SCIS Learning Cycle was soon revised and expanded by the Biological Sciences Curriculum Study (BSCS). The revised model, referred to as the BSCS 5E Instructional Model, frames a sequence and organization of a program, unit, or lesson to include five phases: engagement, exploration, explanation, elaboration, and evaluation. According to Bybee et al. (2006), each phase contributes to students' better understanding of scientific knowledge, attitudes, and skills. The components of the BSCS 5E Instructional Model are shown in Figure 1.

Figure 1

The BSCS 5E Instructional Model (Bybee et al., 2006)



1. Engagement

The teacher or a curriculum taskforce accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.

2. Exploration

Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.

3. Explanation

The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.

4. Elaboration

Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.

5. Evaluation

The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objective.

Model for Direct Instruction

Direct instruction (DI) can be described as an efficient and explicit teaching method. Although various definitions, criteria, and models for DI exist (Magliaro et al., 2005; Rosenshine, 2008), DI is generally characterized as a teacher-centered approach where instruction is led by the teacher. A key concept of DI is that knowledge is transferred between the teacher and student through modeling and reinforcement (Joyce et al., 2000).

The early model for DI was established by Siegfried Engelmann and his colleagues in the 1960s (Bereiter & Engelmann, 1966). Engelmann believed that all students can learn, given well designed and executed instruction. The theoretical underpinnings of DI posit that students learn most effectively and efficiently through carefully sequenced and unambiguous teacher-led examples (Stockard et al., 2018), followed by individual student practice. Additionally, the DI model places critical emphasis on the sequencing of instruction, recognizing students' prior knowledge, and ensuring student mastery of a concept before advancing forward (Stockard et al., 2018). In the last half century, DI has been one of the most commonly researched instructional methods and has consistently yielded positive student learning outcomes (Coughlin, 2014), including reducing student achievement gaps between sociodemographic groups (Stockard et al., 2018).

Eggen and Kauchak (2012) provided an updated model of DI to teach well defined knowledge and skills. The DI model includes four stages: (a) introduction and review, (b) teacher presentation, (c) guided practice, and (d) independent practice. In the first phase, teachers review prior content, establish student motivation, and overview student learning objectives. In the second phase, teachers provide new knowledge through concrete examples and modeling. During the third phase, students apply the newly taught information through guided activities and the instructor works directly with students through monitoring and scaffolding. Lastly, students complete independent practice, such as homework and evaluation activities. In this last phase, teacher monitoring continues to ensure student mastery of the subject matter.

Purpose

SBAE has been promoted as a discipline centered in experiential and hands-on learning (Phipps et al., 2008). However, it is evident that teacher-centered instructional approaches, such as lecture and demonstration, remain highly used in SBAE (Colclasure & Thoron, 2018; Smith et al., 2015). Despite criticism of DI, some argue that DI taught properly and systematically has its place in the classroom (Kuhn, 2007; Schwartz & Martin, 2004). However, reforms in science education (NRC, 2012) and agricultural education (Hock, 2019; NRC, 2009; Skelton et al., 2018; Thoron & Myers, 2011) have promoted student-centered instruction methods such as IBI. New models and methods of teaching in SBAE, such as the 5E method of IBI, must be empirically compared to more traditional forms of instruction, such as DI. In a review of literature in SBAE, Wells et al. (2015) stressed the need for additional IBI research within all aspects of comprehensive SBAE programs. The purpose of this national study was to compare the 5E method of IBI (Bybee et al., 2006) with the four-stage model of DI (Eggen & Kauchak, 2012) on students' content knowledge achievement. This study was part of a larger study examining the impact of the 5E method on student learning outcomes. The three objectives that guided this study were:

1. Determine changes in content knowledge achievement of high school agriscience students after being exposed to the 5E method of IBI or the four-stage model of DI.
2. Compare the content knowledge achievement of high school agriscience students taught using the 5E method of IBI to the four-stage model of DI.
3. Examine relationships between students' content knowledge achievement and student demographic characteristics.

Methods

Population and Sample

The population for this study included all secondary agriscience students in the United States. The accessible population was all students of agriscience teachers who taught the CASE® Natural Resources and Ecology (NRE) course during spring 2018 and who achieved CASE® certification between the years 2013 and 2017. The CASE® NRE curriculum was selected to serve as a foundational curriculum for this study because it provided a consistent curriculum that was being used by SBAE teachers across the United States. Furthermore, Boone (1988) recommended that professional development be used to ensure that teachers effectively deliver the treatment method. This study followed recommendations by Boone (1988) by identifying teachers who had previously attended professional development in the curriculum and teaching method under investigation. All teachers participating in the study attended a CASE® Institute and received NRE certification. According to CASE® (n.d.), the CASE® Institute for NRE certification lasts approximately nine days and exposes participants to IBI activities, projects, and problems for teaching environmental and natural resource concepts through field and lab experiences.

A sample size of 120 students was calculated to be practically and statistically significant using the Hay's (1973) formula. However, the desired sample size was doubled due to mortality rates as high as 50% seen in similar studies (Dyer, 1995; Myers, 2004; Shoulders, 2012). A convenience sampling method was used, and teachers were recruited to be a part of the study through emails and phone calls. Initial contact was made to each teacher who completed the CASE® Institute for NRE certification between the years 2013 and 2017 (*n* = 167). Four months prior to the anticipated start of the study, a personalized email (Dillman et al., 2014) was sent to each teacher on a listserv provided by CASE®. The email contained (a) why the teacher was selected as a candidate to be a part of the nationwide research study, (b) the expected start date of the study, (c) description and requirements of the study, and (d) a link to complete a short informational survey to assist with the study. After daily survey responses or email replies dropped to zero, follow-up emails were sent to non- responders (Dillman et al., 2014). Three email blasts were sent during a time period of three weeks.

Twenty-one teachers met the following requirements to participate in the study: (a) the teacher completed the CASE® Institute for NRE certification between 2013 and 2017, (b) the teacher planned to teach the CASE® NRE course to high school agriscience students during spring 2018, and (c) the teacher was willing and able to deliver the study's treatment for a duration of eight weeks during the spring of 2018. A follow-up phone conversation was attempted with each of the 21 teachers to discuss the research study in more detail and to solidify each teacher's participation. Seventeen of the 21 teachers were reached after multiple contacts. Four teachers decided they would be unable to participate in the study due to various reasons (e.g., unable to teach learning modules identified in the study, use of a student teacher, maternity leave). Thirteen teachers agreed to participate in the study. Each teacher provided an estimate of the number of students who were expected to be enrolled in their course(s) during spring 2018. The 222 total estimated participants in the study was comparable to the target sample size of 240 students and was deemed sufficient for the study.

Research Design

A quasi-experimental design was most appropriate for this study, as random assignment of subjects to treatment groups was not feasible due to the use of intact classrooms. A nonequivalent control group, pretest-posttest design (Campbell & Stanley, 1963) was used. This design is considered one of the most widely used designs in education research (Ary et al., 2014), despite threats to internal and external validity that include history, maturation, testing, instrumentation, statistical regression, selection, experimental mortality, and diffusion of treatments. The nonrandomized control group, pretest-posttest design used in this study included administration of the same pretest and posttest to both the experimental and control groups. Due to this design, maturation, instrumentation, testing, and history were not serious threats to the study's internal validity (Ary et al., 2014). Regression is only considered a threat with the research design when groups are selected based on extreme scores. This study used random selection to determine which classes received the 5E method of IBI or the four-stage model of DI as the treatment.

This study addressed threats to interaction effects. Interaction effects result in differences in posttest scores due to preexisting group differences rather than the treatment itself. In order to reduce this threat, pretest scores were used as a covariate when comparing posttest scores. The pretest scores were used to establish each student's baseline level of knowledge, and when used as a covariate, adjusted posttest means. Lastly, multiple schools were used ($n = 13$) to reduce the risk of interaction with subjects.

Intact agriscience classrooms were randomly assigned to either the 5E method of IBI or the four-stage model of DI. Both treatments were designed for a duration of eight weeks, with subtle variations expected due to external factors between intact classrooms. The dependent variable under investigation was students' content knowledge achievement. Content knowledge achievement was measured for each of the four learning modules.

Instructional Plans

The instructional content of the study aligned with the existing design for the NRE course by CASE®. According to CASE® (n.d.), the "Natural Resources and Ecology course is a foundational course within the CASE® sequence of courses. The course provides students a variety of experiences in the fields of natural resources and ecology" (para 1.). The lessons that were utilized in this study followed the CASE® recommended sequencing, in which the lesson content appears near the middle of the suggested year-long course. The content utilized in this study was grouped to include the following learning modules: (a) The Energy of Life, (b) Flourishing Fauna, (c) All Natural Flora, and (d) Agricultural Stewardship. The instructional content for each of the modules was designed to be taught for a duration of approximately two weeks. A small amount of supplementary content was added by the researchers to several of the modules in an attempt to make the duration of each module consistent.

The content in each of the four learning modules was segmented into four sections, and detailed instructional plans were constructed for each of the four sections. Each treatment included four modules and 16 instructional plans. The learning objectives and content in each instructional plan were the same for both instructional methods. However, *how* content was taught for each instructional plan varied according to each instructional approach. The BSCS 5E Instructional Model (Bybee et al., 2006) was used as the method of instruction for IBI. Lesson plans using the 5E model were designed according to recommendation and examples from the book *Teaching Science Through Inquiry and Investigation, 12th Ed.* (Contant et al., 2014). Instructional plans for groups receiving DI were designed to follow recommended components in lesson design using DI (Eggen & Kauchak, 2012), including the four stages of implementation: (a) introduction and review, (b) teacher presentation, (c) guided practice, and (d) independent practice. Instructional plans for each treatment were reviewed by a panel of faculty members from the University of Florida in the Department of Agricultural Education and Communication to ensure content validity. The panel of experts concluded (a) content remained consistent between both methods of delivery, (b) lesson plans were designed to appropriately reflect each method of delivery, and (c) lesson plans were practical and easy to follow.

Instrumentation and Procedures

Students' content knowledge achievement was assessed through four researcher-developed posttests for each learning module. Pretests were administered prior to each module's treatment, served as a baseline level of knowledge for each student, and were used as covariates to adjust posttest means. Each content knowledge pretest and posttest included 20 multiple-choice questions. The same questions were used for each module's pretest and posttest. Testing effect threats were reduced by randomizing the ordering of questions within each instrument (Campbell & Stanley, 1963), thereby creating a different sequence of questions for each pretest and posttest. The order of the multiple-choice response options was also randomized for each question.

A total of 80 questions measured students' content knowledge. Thirty-one of the 80 questions came from a CASE® test bank of questions that aligned with the content of this study. The remaining 49 items were researcher developed. The content knowledge questions for each module aligned with the learning objectives in each module's instructional plans. Twenty questions for each module were deemed appropriate to assess the learning outcomes effectively and efficiently within each module's lessons. Each student's posttest scores were shared with the instructor for grading purposes, if desired.

Students' correct and incorrect scores were recorded for each item. Kuder-Richardson 20 (KR20) scores were used to establish reliability coefficients for each of the content knowledge instruments. KR20 scores have been determined to be appropriate for establishing reliability of dichotomous data (Gall et al., 1996; Huck, 2008). A post-hoc reliability analysis using KR20 scores for the content knowledge posttests yielded reliability coefficients of .80, .85, .75, and .82, respectively.

All students in the study received the same multiple-choice questions for each pretest and posttest, however the sequencing of questions and answers varied for each student's test. Teachers administered the tests digitally via a Qualtrics® link. All tests were given during class time and students worked individually, and without resources, to complete them. Students were prompted to record their unique student code before accessing the test, which allowed researchers to match each student's pretest and posttest scores. Pretests were administered before the start of each module and posttests were given directly after the completion of each two-week module. Although the tests were not timed, all students completed them in approximately 20-minutes or less.

Data Analysis

Data collected from this study were analyzed by using the Statistical Package for Social Sciences (SPSS) version 22. Descriptive statistics in the form of means, frequencies, and standard deviations were used to describe the demographic characteristics of high school agriscience students. Objective 1, which sought to determine if significant content knowledge gains were achieved by students exposed to each treatment, was analyzed by comparing students' pretest and posttest scores through paired samples *t* tests. Objective 2 sought to determine if significant differences in content knowledge achievement existed between students exposed to each treatment. A one-way ANCOVA was used for each content knowledge posttest. Pretest scores were used as covariates, which controlled for students' prior content knowledge. Objective 3 sought to determine relationships between variables and was analyzed by using Pearson Product-Moment Correlations and point biserial correlations. The magnitude of correlations was interpreted using the guidelines presented by Davis (1971). Davis described correlations between .01 and 0.09 as *negligible*, between .10 and .29 as *low*, between .30 and .49 as *moderate*, between .50 and .69 as *substantial*, between .70 and .99 as *very high*, and 1 as *perfect*. Ethnicity was dummy coded as one for White and zero for all other ethnicities. Correlations were separately examined for the group receiving IBI and the group receiving DI.

Results

A total of 46.4% (*n* = 84) of the students identified as male, and 33.7% (*n* = 61) identified as female. Thirty-six students did not reveal gender. The group receiving the 5E method of IBI contained 39 males (41.9%) and 34 females (36.6%). Twenty students (21.5%) in the group receiving the 5E method did not indicate gender. Of the 88 students in the group receiving the four- stage model of DI, a majority was male (51.1%, *n* = 45). Twenty-seven students (30.7%) in the DI group indicated being female, however, 16 students (18.2%) did not reveal their gender. Students were asked to share their birthdate in a month-day-year format. Student ages were calculated at the end of the first month of the study when all teachers were delivering the treatment. Students ranged from 14 to 19 years of age. The majority of students was 16 years of age (34.3%, *n* = 62), followed by 15 years of age (24.3%, *n* = 44), 17 years of age (19.9%, *n* = 36), 18 years of age (13.3%, *n* = 24), 14 years of age (7.2%, *n* = 13), and 19 years of age (1.1%, *n* = 2). Overall, students in the DI group were slightly younger in age. More students in the DI group were 14 years of age (11.4%, *n* = 10) and 15 years of age (30.7%, *n* = 27), compared to the IBI group, which consisted of three (3.2%) 14 year-olds and 17 (18.3%) 15 year-olds.

Students were given the option to self-report ethnicity. A total of 143 students (79%) reported ethnicity. A majority of students identified as White, non-Hispanic (58%, *n* = 105), followed by Hispanic or Latino (11%, *n* = 20), Black or African American (3.3%, *n* = 6), and Asian or Pacific Islander (2.2%, *n* = 4). Eight students (4.4%) identified as Other. Students' ethnicities were somewhat similar across treatment groups. The IBI group contained a higher percentage of Hispanic or Latino students (15.1%, *n* = 14) compared to the DI group (6.8%, *n* = 6). Slightly more students in the DI group (5.7%, *n* = 5) identified as Black or African American compared to the IBI group (1.1%, *n* = 1). Two students in each treatment group identified as Asian or Pacific Islander. Table 1 displays student demographic characteristics.

Table 1

Student Participation by Demographics (n = 181)

	Treatment Group					
	IBI (*n* = 93)		DI (*n* = 88)		Total	
	n	%	*n*	%	*n*	%
Gender						
Male	39	41.9	45	51.1	84	46.4
Female	34	36.6	27	30.7	61	33.7
Non-response	20	21.5	16	18.2	36	19.9
Age						
14	3	3.2	10	11.4	13	7.3
15	17	18.3	27	30.7	44	24.3
16	30	32.3	32	36.4	62	34.3
17	22	23.7	14	15.9	36	19.9
18	20	21.5	4	4.5	24	13.3
19	1	1.1	1	1.1	2	1.1
Ethnicity						
Asian	2	2.2	2	2.3	4	2.2
Black	1	1.1	5	5.7	6	3.3
Hispanic	14	15.1	6	6.8	20	11.0
White	50	53.8	55	62.5	105	58.0
Other	5	5.4	3	3.4	8	4.4
Non-response	21	22.6	17	19.3	38	21.0

Note. IBI = Inquiry-based Instruction; DI = Direct Instruction

Data were received from all teachers who started the study. Teachers in 12 of the 13 intact classrooms completed the delivery of the entire treatment. One teacher was only able to complete one of the modules and cited a lack of time to complete the remaining modules. Compared to similar studies (Dyers, 1995; Myers, 2004; Shoulders, 2012), this study had a low teacher mortality rate, however, completion rates for this study's instruments varied considerably. Teachers cited forgetfulness, student test fatigue, student absences, and technology problems as reasons for students not completing instruments. Instrument completion rates for the eight content knowledge assessments were generally above 70%. However, content knowledge completion rates for the DI group were slightly lower and ranged from 59.1% (*n* = 52), as seen in the Module 3 posttest, to 92% (*n* = 81) as seen in the Module 1 posttest. The IBI group had higher instrument completion rates for Modules 2 through 4. Completion rates as high as 91.4% (*n* = 84) and 87.1% (*n* = 81) were recorded.

Due to the design of this study, data were only included for each student who completed a pretest and posttest for each instrument, creating a paired sample. In several instances, teachers forgot to administer pretests and only administered posttests (or vice versa). These students' posttest scores were, therefore, not utilized in the analysis of data for the study's objectives. Completion rates for paired samples were calculated to properly reflect the data available for analysis in this study. As expected, completion rates for students successfully completing both the pretests and posttests were lower than completion rates for individual instruments. Instruments measuring content knowledge had paired sample completion rates between 59.1% (*n* = 111), as seen in Module 3, to 79.0% (*n* = 143), as seen in Module 1. The paired sample completion rates were generally higher for the IBI group compared to the DI group. Paired sample completion rates for the DI group were as low as 47.1% (*n* = 42) and 48.9% (*n* = 43).

Objective 1: Determine changes in content knowledge achievement of high school agriscience students after being exposed to the 5E method of IBI or the four-stage model of DI.

Content knowledge scores were reported by percent of correct answers for 20 questions. The overall pretest mean for Module 1 was 53.04 (*SD* = 19.41, *n* = 143). The IBI group reported a mean of 50.43 (*SD* = 19.75, *n* = 69), and the DI group had a mean score of 55.47 (*SD* = 18.89, *n* = 74). The overall mean score for the Module 2 pretest was 48.65 (*SD* = 21.33, *n* = 111), with the IBI group reporting a mean score of 50.65 (*SD* = 21.47, *n* = 69) and the DI group reporting a slightly lower mean score of 45.36 (*SD* = 20.94, *n* = 42). The overall mean content knowledge pretest scores for Modules 3 and 4 were lower. Module 3 had an overall mean score of 38.13 (*SD* = 14.64, *n* = 107) and Module 4 had an overall mean score of 36.61 (*SD* = 17.09, *n* = 121). Module 3 pretest mean scores for the IBI group (*M* = 37.58, *SD* = 14.77, *n* = 64) and DI group (*M* = 38.95, *SD* = 14.58, *n* = 43) were similar. Lastly, mean pretest scores for the Module 4 content knowledge instrument were 38.36 (*SD* = 18.76, *n* = 67) for the IBI group and 34.44 (*SD* = 14.66, *n* = 54) for the DI group. Table 2 displays pretest mean scores for content knowledge instruments.

Table 2

Pretest Mean Scores for Content Knowledge Instruments

	Treatment Group								
	IBI			DI			Total		
Instrument	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD
Module 1 CK	69	50.43	19.75	74	55.47	18.89	143	53.04	19.41
Module 2 CK	69	50.65	21.47	42	45.36	20.94	111	48.65	21.33
Module 3 CK	64	37.58	14.77	43	38.95	14.58	107	38.13	14.64
Module 4 CK	67	38.36	18.76	54	34.44	14.66	121	36.61	17.09

Note. IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

A content knowledge posttest was administered after the delivery of each module. Student scores for the content knowledge posttests were used to measure content knowledge achievement for the learning objectives identified in each module. The highest overall posttest mean score of 70.87 (*SD* = 20.16, *n* = 143) was calculated for Module 1. The IBI group scored an average of 70.51 (*SD* = 21.73, *n* = 69), and the DI group scored an average of 71.22 (*SD* = 18.72, *n* = 74). Module 2 posttest scores were slightly lower, with a mean score of 68.33 (*SD* = 23.31, *n* = 111). The IBI group reported a mean score of 67.83 (*SD* = 25.97, *n* = 69), and the DI group reported a mean score of 69.17 (*SD* = 18.38, *n* = 42). Posttest scores were the lowest in Module 3, with students obtaining an overall mean score of 52.94 (*SD* = 20.08, *n* = 107). The IBI group had a lower mean score (*M* = 51.56, *SD* = 21.45, *n* = 64), compared to the DI group (*M* = 55.00, *SD* = 17.90, *n* = 43). Lastly, a total mean score of 57.48 (*SD* = 23.25, *n* = 121) was found for the Module 4 content knowledge posttest. The IBI group had a mean score of 58.51 (*SD* = 24.65, *n* = 67), and the DI group had a mean score of 56.20 (*SD* = 21.54, *n* = 54). Table 3 displays posttest mean scores for the four content knowledge instruments used to assess students' content knowledge achievement.

Table 3

Posttest Mean Scores for Content Knowledge Instruments

	Treatment Group								
	IBI			DI			Total		
Instrument	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD
Module 1 CK	69	70.51	21.73	74	71.22	18.72	143	70.87	20.16
Module 2 CK	69	67.83	25.97	42	69.17	18.38	111	68.33	23.31
Module 3 CK	64	51.56	21.45	43	55.00	17.90	107	52.94	20.08
Module 4 CK	67	58.51	24.65	54	56.20	21.54	121	57.48	23.25

Note. IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

The difference between students' content knowledge pretest and posttest scores for each module was calculated to observe if changes in students' content knowledge existed. Mean scores for all modules were higher on posttests compared to pretests. Students exposed to the 5E method had an average gain of 20.07 (*SD* = 18.24, *n* = 69) in Module 1, 17.17 (*SD* = 23.13, *n* = 69) in Module 2, 13.98 (*SD* = 18.56, *n* =64) in Module 3, and 20.15 (*SD* = 22.05, *n* = 67) in Module 4. Lastly, mean gains in content knowledge scores for students exposed to DI were 15.74 (*SD* = 15.56, *n* = 74) in Module 1, 23.81 (*SD* = 19.72, *n* = 42) in Module 2, 16.05 (*SD* = 15.61, *n* = 43) in Module 3, and 21.76 (*SD* = 20.10, *n* = 54) in Module 4. To assess if gains in content knowledge were significant, paired-samples *t* tests were used to compare students' pretest and posttest scores. Results indicated a significant gain in content knowledge at the p <.01 level for both IBI and DI treatments, indicating that both DI and IBI statistically improved students content knowledge achievement. Table 4 displays the results of the paired-samples *t* tests.

Table 4

Paired-samples T Test Between Content Knowledge Pretest and Posttest Scores

Source	*df*	*t*	*p*
IBI Treatment			
Module 1 CK	68	9.141	<.01
Module 2 CK	68	6.167	<.01
Module 3 CK	63	6.027	<.01
Module 4 CK	66	7.479	<.01
DI Treatment			
Module 1 CK	73	8.701	<.01
Module 2 CK	41	7.826	<.01
Module 3 CK	42	6.743	<.01
Module 4 CK	53	7.956	<.01

Note. IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

Objective 2: Compare the content knowledge achievement of high school agriscience students taught using the 5E method of IBI to the four-stage model of DI.

Results of the one-way ANCOVA for the Module 1 posttest indicated no significant effect of instruction type on content knowledge achievement after controlling for students' prior knowledge, *F*(1, 140) = .997, *p* = .32. Results of the Module 2 posttest also indicated no significant effect of instruction type on content knowledge achievement after controlling for students' prior knowledge, *F*(1, 108) = 1.231, *p* = .27. Results of the Module 3 posttest further validated non-significance, *F*(1, 104) = .521, *p* = .47. Lastly, results of the Module 4 posttest concluded that no significant effect of instruction type on content knowledge achievement existed after controlling for students' prior knowledge, *F*(1,118) = .006, *p* = .94. Table 5 displays univariate analysis of treatment effects for content knowledge.

Table 5

Univariate Analysis of Treatment Effects for Content Knowledge

Source	$df_{(between)}$	$df_{(within)}$	*F*	*p*
Module 1 CK	1	140	.997	.32
Module 2 CK	1	108	1.231	.27
Module 3 CK	1	104	.521	.47
Module 4 CK	1	118	.006	.94

Note. CK = content knowledge

Objective 3: Examine relationships between students' content knowledge achievement and student demographic characteristics.

Relationships between student demographic variables and content knowledge achievement were analyzed independently for each treatment group. Results of the Pearson Product-Moment Correlation analysis indicated few trends. For students exposed to the 5E method, a low correlation (*r* = .24) was observed between age and the Module 3 posttest, and a low correlation (*r* = .28) was found between ethnicity and the Module 1 pretest and between ethnicity and the Module 4 posttest (*r* = .26). A moderate correlation (*r* = .34) was also observed between ethnicity and the Module 4 pretest. Analysis showed no significant relationships between the remaining demographic variables (age and gender) and content knowledge achievement for students taught using the 5E method of instruction. For groups exposed to the DI approach, no statistically significant correlations were observed between age and other variables. A moderate correlation was observed between gender and the Module 2 posttest (*r* = .31). Several significant correlations were observed between ethnicity and other variables. Moderate correlations were seen between ethnicity and the Module 1 posttest (*r* = .33), Module 2 pretest (*r* = .37), and the Module 3 posttest *(r* = .37). Analysis showed no significant relationship between the remaining demographic variables and content knowledge achievement for students in the DI group.

Conclusions and Recommendations

This study demonstrated that the 5E method of IBI and the four-stage model of DI are equally effective on students' content knowledge achievement. On average, students increased their content knowledge scores nearly 20% for each two-week learning module after being taught through the 5E method of IBI or the four-stage model of DI. This finding supports the use of the 5E method as an instructional approach to increase students' content knowledge, as much as traditional approaches to instruction. Previous studies reported similar gains in content knowledge achievement after students were exposed to IBI instruction (Geier et al., 2008; Schroder et al., 2007). The results of this research were consistent in some instances with previous research that compared the 5E method of IBI to DI on content knowledge achievement in science education. Lawson et al. (1989) found that students exposed to IBI, using the 5E learning cycle, and students exposed to DI, with employed learning activities, achieved similar gains in content knowledge achievement over a two-week treatment. Results of this study contradicted previous research in agriscience that compared IBI to subject matter instruction (Thoron, 2010). Thoron (2010) found that students exposed to IBI had higher content knowledge achievement compared to students exposed to a subject matter approach.

Findings from this study showed negligible relationships between high school agriscience students' age or gender and content knowledge achievement when taught using IBI or DI. This study also reported that some relationships existed between student's ethnicity and content knowledge achievement for both treatment groups. Relationships between student achievement and ethnicity have been documented and can be linked to the many barriers that minority students face in the United States educational system (National Center for Education Statistics, 2016). Meta-analysis on previous educational research has indicated that DI can reduce achievement gaps between sociodemographic groups (Stockard et al., 2018). However this study demonstrated fewer significant associations between ethnicity and achievement in the IBI group compared to the DI group, illustrating that minority students taught through the 5E method of IBI were just as successful as students taught through the four-stage model of DI.

We acknowledged limitations to this study and offered suggestions for future research. When analyzing IBI, the multiple perspectives that shape the definition of IBI (Llewellyn, 2002; Minner et al., 2010) should be considered. In this study, IBI was represented through the 5E method (Bybee et al., 2006), and DI was represented through Eggen and Kauchak's (2012) four-stage model. Other models of IBI could offer students the ability to conduct more authentic inquiry involving localized issues (Ernst & Monroe, 2006; Forbes & Zint, 2010). Future research comparing IBI and DI could include a larger distinction between teacher-centered and student-centered methods and activities and could explore other models of IBI.

Time and student test fatigue were acknowledged as constraints in this study. As part of the larger study, students were exposed to a combination of twelve instruments in an eight-week period, and test fatigue was evident by lower completion rates and reduced time commitments to complete instruments occurring later in the study. Caution should be taken when designing experimental studies that require students to complete a multitude of assessments over a relatively short duration.

A defining characteristic of the constructivist approach to learning is that in order for meaningful learning to occur, individuals must construct their own understanding through active thinking (Cobern et al., 2010). Individuals who make meaning of content may be more likely to retain content knowledge for a longer duration compared to students who learn through rote memorization (Baker & Robinson, 2018). Future research that compares IBI to other approaches of instruction may consider testing students' long-term content knowledge retention. IBI has also shown benefits for developing students' scientific reasoning (Thoron & Myers, 2012), reducing classroom management problems (Lieberman & Hoody, 1998), increasing student engagement (Powers, 2004), and increasing students' perceptions of agriculture (Thoron & Burleson, 2014). Future research that examines methods of IBI in SBAE may consider investigating additional learning outcomes beyond content knowledge achievement.

Despite the call for teachers to use more student-centered teaching approaches, such as IBI, teacher-centered approaches remain highly used in SBAE (Colclasure & Thoron, 2018; Smith et al., 2015). Blythe et al. (2015) conducted focus groups to describe perceptions of National Agricultural Teacher Ambassador Academy participants' transition to IBI. The researchers identified that agriculture teachers perceive implementing IBI to be time consuming and initially lack self-confidence transitioning to IBI. Furthermore, teachers reported that students initially struggled transitioning to IBI, however, after time both students and teachers felt more comfortable and students reported learning more from IBI compared to other teaching methods. Preservice teacher training and continuing professional development on IBI must be provided for teachers to successfully implement it in their classrooms (Blythe et al., 2015; Thoron et al., 2011). It is recommended to conduct further research that examines teacher professional development on IBI, specifically with the 5E method, that establishes stepwise procedures to implement IBI.

Additional research that investigates why teachers utilize certain teaching methods over others would be beneficial. Prior meta-analysis research indicated that DI has led to significant gains in student content knowledge achievement (Coughlin, 2014). Perhaps teachers are uncertain if new teaching strategies such as the 5E method of IBI will reduce students' content knowledge achievement over teaching methods they currently use. This study indicates that content knowledge achievement is equivalent when students are taught by the 5E method of IBI or the four-stage model of DI. We recommend that teachers use a variety of teaching methods that are selected purposefully based upon their teaching situation. Due to the scientific nature of ENR Agriscience courses, findings from similar research, and our findings from this study, we recommend practitioners to use the 5E method of IBI in ENR Agriscience courses. Additional experimental research in SBAE comparing various models of IBI to other teaching methods, using various curricula, is recommended to further identify outcomes of IBI.

References

Abraham, M. R., & Renner, J. W. (1986). The sequence of learning cycle activities in high school chemistry. *Journal of Research in Science Teaching, 23*(2), 121-143. https://doi.org/10.1002/tea.3660230205

Akins, J. L., Lamm, A. J., Telg, R., Abrams, K. Myers, C., & Raulerson, B. (2019). Seeking and engaging: Case study integration to enhance critical thinking about agricultural issues. *Journal of Agricultural Education, 60*(3), 97-108. https://doi.org/10.5032/jae.2019.03097

American Association for the Advancement of Science (1990). *Science for all Americans: Project 2061*. Oxford University Press.

Ary, D., Jacobs, L. C., Sorenson, C., Walker, D. A. (2014). *Introduction to research in education* (9th ed.). Cengage Learning.

Atkins, J. M., & Karplus, R. (1962). Discovery or invention? *Science Teacher, 29*(5), 45-51.

Baker, M. A., & Robinson, J. S. (2018). The effects of two different pedagogical delivery methods on students' retention of knowledge over time. *Journal of Agricultural Education, 59*(1), 100-118. https://doi.org/10.5032/jae.2018.01100

Bereiter, C., & Engelmann, S. (1966). *Teaching disadvantaged children in the preschool*. Prentice Hall.

Bernhardt, V. L. (2018). *Data analysis for continuous school improvement* (4th ed.). Routledge.

Biggs, J. (2003). *Teaching for quality at university* (2nd ed.). Open University Press.

Blythe, J. M., DiBenedetto, C. A., Myers, B. E. (2015). Inquiry-based instruction: Perceptions of National Agriscience Teacher Ambassadors. *Journal of Agricultural Education, 56*(2), 110-121. http://doi.org/10.5032/jae.2015.02110

Boone, H. N., Jr. (1988). *Effects of approach to teaching on student achievement, retention and attitude* [Doctoral dissertation, The Ohio State University].

Bright, A. D., & Tarrant, M. A. (2002). Effect of environment-based coursework on the nature of attitudes towards the Endangered Species Act. *The Journal of Environmental Education, 33*(4), 10-19. https://doi.org/10.1080/00958960209599149

Bruner, J. (1966). *Toward a theory of instruction*. Harvard University Press.

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

Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education, 3*(4), 193-206. https://files.eric.ed.gov/fulltext/EJ894860.pdf

Campbell, D. T., & Stanley, J. C. (1963). Experimental and quasi-experimental designs for research on teaching. In N. L. Gage (Ed.), *Handbook of research on teaching* (pp. 171-246). Rand McNally.

Carlgren, T. (2013). Communication, critical thinking, problem solving: A suggested course for all high school students in the 21st century. *Interchange, 44*, 63-81. https://doi.org/10.1007/s10780-013-9197-8

CASE (n. d.) Natural Resources and Ecology. https://case4learning.org/index.php/curriculum/case-courses/natural-resources-and-ecology

Christodoulou, D. (2013). Minding the knowledge gap: The importance of content in student learning. *American Educator, 38*(1), 27-33. https://eric.ed.gov/?id=EJ1023875

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational Researcher, 28*(2), 4-15. https://doi.org/10.3102/0013189X028002004

Cobern, W. W., Schuster, D., Adams, B., Applegate, B., Skjold, B., Undreiu, A., Loving, C. C., & Gobert, J. D. (2010). Experimental comparison of inquiry and direct instruction in science. *Research in Science & Technological Education, 28*(1), 81-96. https://doi.org/10.1080/02635140903513599

Colclasure, B. C., & Thoron, A. C. (2018, October 5). *Factors associated with agriculture teachers' perceived use of instructional methods* [Paper presentation]. 2018 North Central Region American Association for Agricultural Education Conference.

Contant, T. L., Bass, J. E., & Carin, A. A. (2012). *Teaching science through inquiry and investigation* (12th ed.). Pearson Education, Inc.

Coughlin, C. (2014). Outcomes of Engelmann's Direct Instruction: Research syntheses. In J. Stockard (Ed.), *The science and success of Engelmann's Direct Instruction* (pp. 25-54). NIFDI Press.

Davis, J. A. (1971). *Elementary survey analysis.* Prentice-Hall.

Dewey, J. (1929). *My pedagogical creed*. Progressive Education Association.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed- mode surveys: The tailored design method* (4th ed.). John Wiley and Sons.

Doolittle, P. E., & Camp, W. G. (1999). Constructivism: The career and technical education perspective. *Journal of Vocational and Technical Education, 16*(1), 23-46. https://eric.ed.gov/?id=EJ598590

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education, 32*, 286-291. https://doi.org/10.3102/0091732X07309371

Dyer, J. E. (1995). *Effects of teaching approach on achievement, retention, and problem solving ability of Illinois agricultural education students with varying learning styles* [Doctoral dissertation, the University of Illinois at Urbana-Champaign]. Illinois Digital Environment for Access to Learning and Scholarship. https://www.ideals.illinois.edu/handle/2142/19661

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. https://doi.org/10.5032/jae.2011.02036

Eggen, P., & Kauchak, D. (2012). *Strategies and models for teachers: Teaching content and thinking skills* (6th ed.). Pearson Education.

Ernst, J., & Monroe, M. (2006). The effects of environment-based education on students' critical thinking skills and disposition toward critical thinking. *Environmental Education Research, 12*(3-4), 429-443. https://doi.org/10.1080/13504620600942998

Forbes, C. T., & Davis, E. A. (2008). Exploring preservice elementary teachers' critique and adaptation of science curriculum materials in respect to socioscientific issues. *Science & Education, 17*, 829-854. https://doi.org/10.1007/s11191-007-9090-z

Forbes, C. T., & Zint, M. (2010). Elementary teachers' beliefs about, perceived competences for, and reported use of scientific inquiry to promote student learning about and for the environment. *The Journal of Environmental Education, 42*(1), 30-42. https://doi.org/10.1080/00958961003674673

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction*. Longman.

Geary, D. C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist, 50*(1), 24-37. https://doi.org/10.1037/0003-066X.50.1.24

Geier, R., Blumenfeld, P., Marx, R., Krajcik, J., Fishman, B., & Soloway, E. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922-939. https://doi.org/10.1002/tea.20248

Han, J. H. (2014). Closing the missing links and opening the relationships among the factors: A literature review on the use of clicker technology using the 3P model. *Educational Technology & Society, 17*(4), 150-168. https://eric.ed.gov/?id=EJ1045546

Hays, W. L. (1973). *Statistics for the social sciences.* Holt, Rinehart, and Winston.

Hock, G. (2019, March). Facilitating effecting inquiry-based instruction. The Agricultural Education Magazine, 1-28. https://www.naae.org/profdevelopment/magazine/current_issue/2019%2003%20--%20Mar%20Apr.pdf

Hodson, D. (2003). Time for action: Science education for an alternative future*. International Journal of Science Education, 25*(6), 645-670. https://doi.org/10.1080/09500690305021

Huck, S. W. (2008). *Reading statistics and research* (5th ed.). Pearson Education, Inc.

Hysolp-Margison, E. J., & Strobel, J. (2008). Constructivism and education: Misunderstandings and pedagogical implications. *The Teacher Educator, 43*(1), 72-86. https://doi.org/10.1080/08878730701728945

Joyce, B., Weil, M., & Calhoun, E. (2000). *Models of teaching* (6th ed.). Allyn & Bacon.

Karplus, R., & Thier, H. D. (1967). *A new look at elementary school science*. Rand McNally.

Kuhn, D. (2007). Is direct instruction an answer to the right question? *Educational Psychologist, 42*(2), 109-113. https://doi.org/10.1080/00461520701263376

Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). *A theory of instruction: using the learning cycle to teach science concepts and thinking skills*. https://eric.ed.gov/?id=ED324204

Lieberman, G., & Hoody, L. (1998). *Closing the achievement gap: Using the environment as an integrated context for learning*. http://www.seer.org/extras/execsum.pdf

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

Lott, G. W. (1983). The effect of inquiry teaching and advanced organizers upon student outcomes in science education. *Journal of Research in Science Teaching, 20*(5), 437-451. https://doi.org/10.1002/tea.3660200507

Magliaro, S. G., Lockee, B. B., Burton, J. K. (2005). Direct instruction revisited: A key model for instructional technology. *Educational Technology, Research, and Development, 53*(4), 41-55. https://doi.org/10.1007/BF02504684

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*(4), 474-496. https://doi.org/10.1002/tea.20347

Myers, B. E. (2004). *Effects of investigative laboratory integration on student content knowledge and science process skill achievement across learning styles* [Doctoral dissertation, The University of Florida]. University of Florida Institutional Repository.

National Center for Education Statistics (2016). *Status and trends in the education of racial and ethnic groups 2016*. https://nces.ed.gov/pubs2016/2016007.pdf

National Council for Agricultural Education. (2015). *Agriculture, food, and natural resources (AFNR) career cluster content standards.* https://www.k12.wa.us/sites/default/files/public/careerteched/clusters/agriculture/afnrstandards.pdf

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

National Research Council (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*. National Academy Press.

National Research Council. (2009). *Transforming agricultural education for a changing world*. National Academic Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* National Academic Press.

Nolin, J. B., & Parr, B. (2013). Utilization of high stakes high school graduation exam to assess the impact of agricultural education: A measure of curriculum integration. *Journal of Agricultural Education, 54*(3), 41-53. https://doi.org/10.5032/jae.2013.03041

Perry, D. K., Paulsen, T., & Retallick, M. S. (2015). The impact of a capstone farm management course on critical thinking abilities. *Journal of Agricultural Education, 56*(2), 13-26. https://doi.org/10.5032/jae.2015.02013

Perry, D. K., Retallick, M. S., & Paulsen, T. H. (2014). A critical thinking benchmark for a department of agricultural education studies. *Journal of Agricultural Education, 55*(5), 207-221. https://doi.org/10.5032/jae.2014.05207.

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). *Handbook of agricultural education in public schools* (6th ed.). Thomson Delmar Learning.

Piaget, J. (1952). *The origins of intelligence in children* (M. Cook, Trans.). International Universities Press.

Powers, A. (2004). An evaluation of four place-based education programs. *The Journal of Environmental Education, 35*(4), 17-32. https://doi.org/10.3200/JOEE.35.4.17-32

Raghubir, K. P. (1979). The laboratory-investigative approach to science instruction. *Journal of Research in Science Teaching, 16*(1), 13-18. https://eric.ed.gov/?id=EJ196929

Roberts, T. G., Harder, A., & Brashears, M. T. (Eds.) (2016). *American Association for Agricultural Education national research agenda: 2016-2020*. http://aaaeonline.org/resources/Documents/AAAE_National_Research_Agenda_2016-2020.pdf

Rosenshine, B. (2008). *Five meanings of direct instruction*. Center on Innovation & Improvement. http://www.centerii.org/search/Resources/FiveDirectInstruct.pdf

Schroder, C. M., Scott, T. P., Tolson, H., & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*, 1436-60. https://doi.org/10.1002/tea.20212

Schunk, D. H. (2012). *Learning theories: An educational perspective*. Allyn & Bacon.

Schwartz, D., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction, 22*, 129-184. https://doi.org/10.1207/s1532690xci2202_1

Shoulders, C. W. (2012). *The effects of a socioscientific issues instructional model in secondary agricultural education on students' content knowledge, scientific reasoning ability, argumentation skills, and view of the nature of science* [Doctoral dissertation, The University of Florida]. ProQuest Dissertations Publishing.

Skelton, P., Blackburn, J. J., Stair, K. S., Levy, N., & Dormody, T. J. (2018). Agriscience education through inquiry-based learning: Investigating factors that influence the science competence of middle school students. *Journal of Agricultural Education, 59*(1), 223-237. https://doi.org/10.5032/jae.2018.01223

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. https//doi.org/10.5032/jae.2015.04183

Stockard, J., Wood, T. W., Coughlin, C., & Khoury, C. R. (2018). The effectiveness of direct instruction curricula: A meta-analysis of a half century of research. *Review of Educational Research, 88*(4), 479-507. https://doi.org/10.3102/0034654317751919

Thoron, A. C. (2010). *Effects of inquiry-based agriscience instruction on student argumentation skills, scientific reasoning, and student achievement* [Doctoral dissertation, The University of Florida]. University of Florida Institutional Repository.

Thoron, A. C., & Burleson, S. E. (2014). Students' perception of agriscience when taught through inquiry-based instruction. *Journal of Agricultural Education, 55*(1), 66-75. https://doi.org/10.5032/jae.2014.01066

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

Thoron, A.C., & Myers, B.E. (2012). Effects of inquiry-based agriscience instruction on student scientific reasoning. *Journal of Agricultural Education, 53*(4), 156-170. https://doi.org/10.5032/jae.2012.04156

Thoron, A. C., Myers, B. E., & Abrams, K. (2011). Inquiry-based instruction: How is it utilized, accepted, and accessed in schools with National Agriscience Teacher Ambassadors? *Journal of Agricultural Education, 52*(1), 96-106. https://doi.org/10.5032/jae.2011.01096

Tobias, S., & Duffy, T. M. (2009). The success or failure of constructivist instruction. In S. Tobias & T. M. Duffy (Eds.). *Constructivist instruction: Success of failure* (1-10). Routledge

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wells, T., Matthews, J., Caudle, L., Lunceford, C., Clement, B., & Anderson, R. (2015). The infusion of inquiry-based learning into school-based agricultural education: A Review of literature. *Journal of Agricultural Education, 56*(4), 169-181. https//doi.org/10.5032/jae.2015.04170

Wiggins, G. P., & McTighe, J. (2005). *Understanding by Design*. Association for Supervision and Curriculum Development.

Yurdugul, H., & Cetin, N. M. (2015). Investigation of the relationship between learning process and learning outcomes of e-learning environments. *Eurasian Journal of Educational Research*, (58), 57-74. https://doi.org/10.14689/ejer.2015.59.4