© Journal of Agricultural Education
Volume 53, Number 2, pp 58–69
DOI: 10.5032/jae.2012.02058

Effects of Inquiry–based Agriscience Instruction and Subject Matter–based Instruction on Student Argumentation Skills

Andrew C. Thoron, Assistant Professor
Brian E. Myers, Associate Professor
University of Florida

The purpose of this study was to determine the effect of inquiry–based agriscience instruction on student argumentation skills. Argumentation is defined as the student's ability to establish a claim, provide a rationale for steps taken, provide and justify data, recognize alternate conclusions, and provide evidence why the conclusion is correct or the best solution. Developing argumentation skills can aid in developing the next generation of scientists, and help individuals who are not scientists, distinguish evidence from bias. This quasi–experimental study investigated the effect of two teaching methods on student argumentation skills. Inquiry–based instruction was compared to the subject matter approach in 15 agriscience education classes in seven secondary schools across the United States. Univariate analysis of covariance, detected a statistically significant difference between groups on argumentation skills. Those students taught through inquiry–based instruction had higher argumentation skill than students taught through the subject matter approach.

Keywords: agriscience students; inquiry; inquiry–based; argumentation; argumentation skills; quasi–experimental

Introduction

Research has indicated that the amount of student learning that occurs in a classroom is directly proportional to the quality and quantity of student involvement in the educational program (Cooper & Prescott, 1989). Chiasson and Burnett (2001) reported that agricultural education helped connect student involvement in content, citing a greater gain in science scores. However, high school teachers dominate classroom conversation, consuming nearly 70% of classroom time (Cooper & Prescott). Inquiry–based instructional approaches reverse this trend, placing students first in the learning process and teachers in the role of learning facilitator. The facilitating teacher manages interactions and keeps teams focused on progress, encouraging students to work toward answering the overall learning outcomes set forth through their plan of action (Cooper & Prescott). The National Research Council [NRC] (1996, 2000) defined scientific inquiry as the study of the natural world and explanations that are based on evidence. Furthermore, Anderson (2002) argued that scientific inquiry is the ability to understand and support investigations with evidence. In addition, Keil, Haney, and Zoffel (2009) stated inquiry–based instruction contains multiple dimensions of teaching and learning and leads learners to develop deeper understandings while connecting content knowledge to solving a situation.

Explanations of results and conclusions based on evidence, when students are taught through inquiry–based instruction, leads to a need to investigate tools that take into account (measure) students' abilities to produce evidence–based claims, form conclusions, and supply recommendations based on their understanding of the investigation. Investigation of argumentation skills is the study of logic, and producing correct inferences based on a given context (Driver, Newton, & Osborne, 2000). At first glance, the term argumentation may lead one to believe individuals will verbally argue their point–of–view in a heated exchange. While an argument between individuals can exist, argumentation skills are the development of logical explanations and categorization of opposing assertions, weights of evidence, and determination of merit for each assertion with regard to evidence (Kuhn, 1992). Argumentation skills can be expressed through writing or discussion (Driver et al., 2000).

Rogers (1948) wrote that student contact alone with science does not develop the ability to think critically. In pointing out the need for argumentation skills, Schwab (1962) argued that science education is merely a presentation of conclusions that are taught as empirical and absolute truth – a simple unproblematic collection of facts (Geddis, 1991). Claxton (1991) described that the way teachers are taught to present science does not reward rebuttals based on one's scientific reasoning. While facts are important to know, and some unquestioned scientific concepts exist, scientists assess alternatives, consider evidence, interpret text, evaluate the appropriateness of design, and discriminate conclusions when formulating their final analysis and arguments (Latour & Woolgar, 1986). Baron (1991) and Cerbin (1988) wrote that pure traditional teaching creates learners that lack the ability to develop arguments with adequate evidence. Furthermore, Norris and Phillips (1994) indicated that students are not encouraged to argue their strengths and weaknesses, and they called for the science education community to focus on argumentation skills.

Kuhn (1992) conducted a study on argumentation of 160 individuals ranging from ninth grade students through adult. Kuhn determined that individuals of all ages use false claims and weak arguments to present their beliefs. The development of argumentative practice is foundational to scientists and is "essential to enhance the public understanding of science..." (Driver et al., 2000, p. 287). Kuhn determined that individuals with low argumentation skills simply dismiss factors as irrelevant if findings do not support their point of view. Several studies indicate that students have difficulty distinguishing between evidence and bias (Baron, 1991; Perkins, Farady, & Bushey, 1991; Toplak & Stanovich, 2003). A United States population less aware of the food and fiber industry may present a serious threat to production practices.

Jimenez–Aleixandre, Bullgallo–Rodriguez, and Duschl (1997), in a study of high school discussion groups that used genetics problems as the context, found that students had difficulty incorporating claims and scientific evidence. Jimenez–Aleixandre et al. determined that the traditional science classroom does not regularly provide context for the construction of students' ability to develop argumentation skills. Zohar and Nemet (2002) conducted an experimental study on the topic of human genetics with ninth grade students, one group using traditional methods (control) and the other, an interactive curriculum. They found that the treatment group was able to transfer reasoning abilities through the context of genetics to everyday life applications. Additionally, the treatment group referred to correct, biological evidence through argumentation at an increased frequency when compared to the control group.

Development of argumentation skills of students has been examined in an educational context. Previous studies focused on the development of argumentation skills; however, few studies examined a teaching method's effect on student argumentation skills. Kuhn (1993) provided evidence that an agriscience student who has greater argumentation skills will create more thoughtful science–based arguments. In summary, it can be posited that the development of argumentation skills for agriscience students will lead to more thoughtful, evidence–based answers for citizens unaware of how the food and fiber industry operates. Additionally, agriscience students who subsequently do not seek careers in agriculture will be able to make educated decisions based on the scientific arguments of the agricultural industry.

Theoretical/Conceptual Framework

Constructivism is the guiding philosophical perspective used in this study. The constructivist approach to teaching and learning has been highlighted in research and in practice in numerous educational contexts (Bransford, Brown, & Cocking, 2000; Hamlin, 1992; Lampert, 1992; Myers & Dyer, 2006; Newcomb, McCracken, & Warmbrod, 1993; NRC, 2000; Phipps, Osborne, Dyer, & Ball, 2008; Schunk, 2004). Schunk stated, "…the rise of constructivism has been theory and research in human development, especially the theories of Piaget and Vygotsky" (p. 285). As an epistemology, constructivism is concerned with the role of the learner and teacher as a facilitator. Constructivism incorporates cognitive theories which place emphasis on learners' information processing as a central cause of learning, yet constructivism digs deeper to capture the complexity of human learning (Schunk, 2004). Constructivism shifts the focus from "how knowledge is acquired" to "how it [knowledge] is constructed" (Schunk, 2004, p. 285). Piaget's Theory of Cognitive Development (1972) and Vygotsky's Sociocultural Theory (1978) combined to form the theoretical basis for the study from a constructivist philosophical perspective.

The model for this study (Figure 1) depicts interactions that occur in an inquiry–based classroom. Because this study is part of a larger study, there was more than one outcome investigated. Static attributes were variables that were collected during the investigation, and the teaching and learning process describe the inquiry–based process.

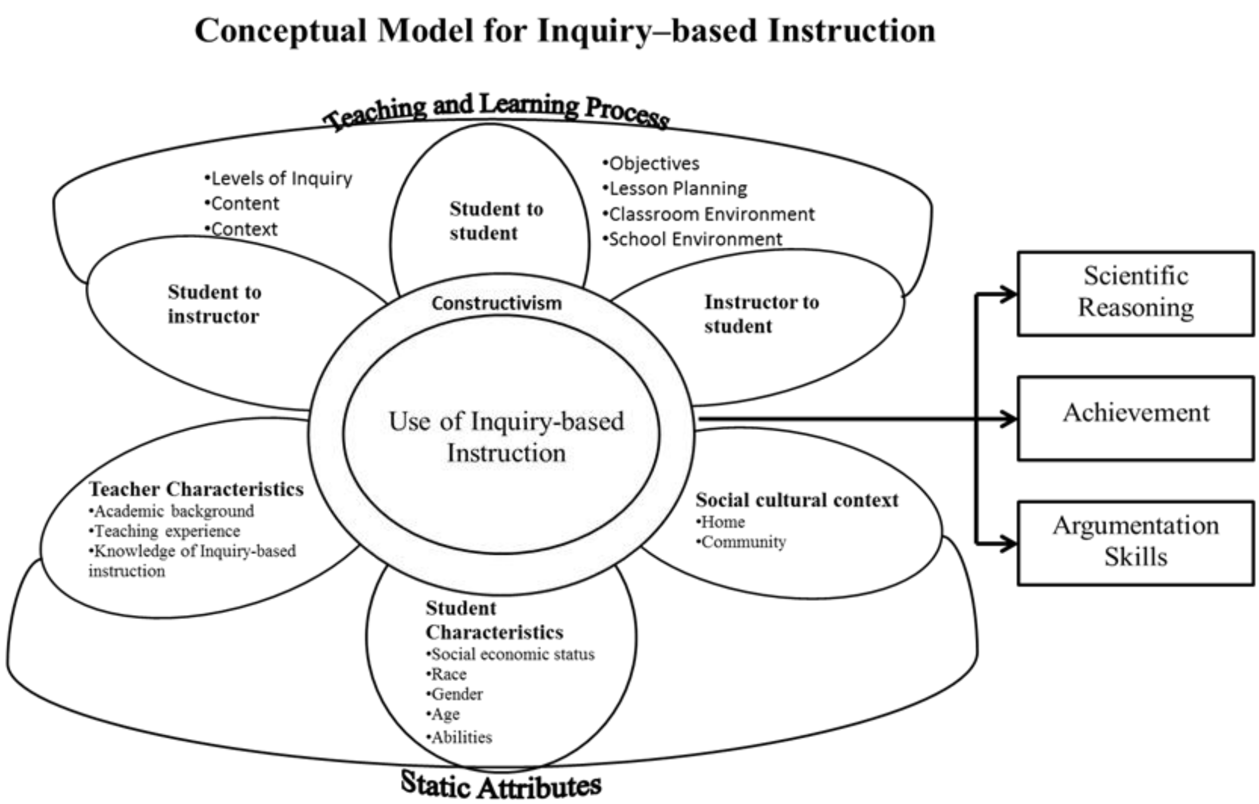

Figure 1. Conceptual model for the effects of inquiry–based instruction.

Purpose/Objectives/Hypotheses

The purpose of this study was to determine the effects of teaching method on high school agriscience students' argumentation skills. The specific objectives guiding the study were to:

1. Describe the population of the study.
2. Ascertain the effects of inquiry–based instruction on argumentation skills of high school agriscience students.
3. Examine the relationship between argumentation skills, ethnicity, gender, year in school, and socio–economic status of high school agriscience students.

The null hypothesis, H_o: no significant difference in student argumentation skills based upon the teaching method (inquiry–based teaching or subject matter approach), guided the analysis of the second objective.

Methods

The population of this quasi–experimental design comprised students at ten high schools offering agriscience education in the United States (*N* = 437). The accessible population was students of the ten National Agriscience Teacher Ambassador Academy (NATAA) participants. A purposive sample was selected according to the ability of the teacher to utilize the integrated agriscience curriculum and inquiry–based instruction and subject matter approach to teaching.

The content and context of the lessons for both the subject–matter and inquiry–based lessons were deemed appropriate by a panel of experts. Seven units of instruction that addressed the soil and plant science portion of the National Agriscience Content Standards for an agriscience course in the United States (CAERT, 2008) were selected by the researcher from the Animal, Plant, and Soil Science curriculum developed by the Center for Agricultural and Environmental Research and Training, Inc. (CAERT, 2008). The instructional plans were evaluated for content validity by a panel of experts from the Agricultural Education and Communication Department and the School of Teaching and Learning at the University of Florida. The panel determined that the inquiry–based and subject matter lessons were suitable for the grade levels and deemed the lessons appropriate.

The independent variable in this study was the teaching method used in the agriscience classes. Intact treatment groups were randomly selected to receive either inquiry–based instruction or the subject matter approach to learning. The dependent variable in this study was student argumentation skill. The greatest threat in this design type is that the differences found in the posttest are due to preexisting group differences, rather than due to the treatment (Gall, Borg, & Gall, 1996). The use of multiple classroom settings in this study reduced the risk of interaction of subjects, and the use of pretests of content knowledge addressed these concerns.

To ensure that teachers involved in this study were exhibiting the correct teaching methodology (fidelity of the treatment), teachers were asked to audiotape each class period during the study. The Science Teaching Inquiry Rubric (STIR) (Bodzin & Cates, 2002) was used to analyze the level of inquiry–based instruction. The STIR has been reported to have an overall correlation of r =.58 with a perfect correlation between two raters of r =1.00, establishing the STIR as an effective analysis tool (Bodzin & Beerer, 2003). The researcher determined *a priori*, based on a study conducted by Thoron and Myers (2010), that students missing more than 25% of the instructional time during the study would be removed. Additionally, students who did not receive the treatment, due to inappropriate delivery of the treatment, would be removed from the sample.

All students were administered a pretest to establish a base line before each of the seven replications to measure content knowledge levels in the subject matter to be taught (soil and plant science). All sections were taught the same content by the same teacher and according to their randomly assigned group were taught with the same teaching method the entire twelve weeks (inquiry or subject–matter). Pretest instruments were developed by the researcher using content knowledge questions in the form of multiple choice items. The instruments contained a specific number of questions based on the determined percentage of time to be spent teaching each objective of the unit. The testing instruments were validated by a panel of agriscience education and inquiry education experts. Prior to the study a coefficient alpha for the dichotomous data of the content knowledge achievement exams were calculated through a pilot test to assess reliability of the instruments (Campbell & Stanley, 1963). Reliability coefficients for the content knowledge achievement instruments were calculated using Kuder–Richardson 20 (KR20) for dichotomous data (Gall et al., 1996). The seven instruments were determined to have a coefficient alpha of: .94, .93, .91, .86, .87, .89, and .91 respectively.

A scoring rubric developed by Schen (2007) was utilized in the assessment of student argumentation skills. The researcher scored each student response, assigning a score based on the quality of the response in the categories of claim made, grounds used, warrants given, counterargument generated, and rebuttal offered. A panel of experts consisting of faculty from the Agricultural Education and Communication Department and the Educational Psychology Department at the University of Florida evaluated the researcher–developed rubric for face and content validity and determined that the rubric was valid. After completion of the researcher–scored response, an expert selected a random sample (subject–matter and inquiry–based teaching) for a double blind review to obtain inter–rater reliability. The inter–rater reliability for the argumentation skills scores yielded a Cronbach's alpha of .81.

Findings

This study is part of a larger study conducted by the researcher. The results address the objectives and hypothesis of the study in determining the influence of teaching method, gender, ethnicity, social economic status, and year in school on student argumentation skills. Objective one sought to describe the population of the study. The total group consisted of 437 students, ten teachers, totaling twenty–one intact classes, from ten schools across the United States. Three teachers opted out of the study noting health related issues or teaching reassignment. As a result of teachers being unable to deliver instruction, three schools totaling 109 students were removed from the study. Twenty–three students were removed from the study due to missing 25% or more of instruction.

Audio recordings of the administered units were scored using the STIR rubric (Bodzin & Cates, 2002) to determine the level of inquiry investigation by students in the inquiry–based treatment group and that inquiry was not being delivered in the traditional treatment group. It was determined that all seven teachers effectively delivered inquiry–based and subject matter instruction. After removal of participants unable to complete the study and students missing more than 25% of the instructional time, the data sample was 305 students. This equates to a 30.21% mortality rate for this study. Previous experimental studies in agricultural education using intact classes reported similar or higher mortality rates (Boone, 1988; Dyer, 1995; Flowers, 1986; Myers, 2004) and Jurs and Glass (1971) described mortality rates may be as high as 50%.

Participant ethnicity was categorized into groups of White (non–Hispanic) (*n* = 249, 81.6%), Black (*n* = 13, 4.3%), Hispanic (*n* = 31, 10.2%), and Other (*n* = 12, 3.9%). The ethnicity of each of the treatments was similar to the ethnicity of the entire sample. A majority (58.0%) of the participants in this study were male. The treatment groups were similar to each other as inquiry–based instruction contained 57.6% male and subject matter (SM) contained 58.5% male participants. Inquiry–based instruction yielded 170 participants and subject matter contained 135 students.

Of the 305 participants who reported grade level data, 48.5% (*n* = 148) were in the ninth grade. The remainder of the participants were either in tenth grade (*n* = 134, 44.0%), or eleventh grade (*n* = 23, 7.5%). There were no twelfth–grade students in the study. Grade level distribution by treatment groups varied little from that of the overall sample. Slightly more than 50% of the students in the inquiry–based group were in the ninth grade as compared to approximately 45% in the subject matter group. Thus, treatment groups were similar in terms of grade level.

Socio–economic status (SES) was determined by eligibility to participate in the national free and reduced school lunch program (Stone & Lane, 2003). Therefore, SES was categorized in groups of ineligible to participate, eligible to receive reduced lunch, and eligible to receive free lunch. A majority of the students participating in this study (*n* = 221, 72.5%) were ineligible to participate in the national school lunch program with 16.7% (*n* = 51) eligible to receive a reduced price in the school lunch program and the remainder (*n* = 33), 10.8% eligible to receive free lunch. The two treatment groups were similar in terms of SES.

Objective two sought to ascertain the effects of inquiry–based instruction on argumentation skills of high school agriscience students. Each student's content knowledge achievement was determined using the researcher–developed content knowledge achievement instruments. The maximum possible score on these instruments was 100. Pretest data were collected from 305 participants (100%). Inquiry–based instruction treatment group achieved similar mean content knowledge scores and similar standard deviations as the subject matter treatment group (see Table 1).

Table 1
Participant Mean Content Knowledge Pretest Scores (n = 305)

	Treatment Group					
	IBI		SM		Total	
Instrument	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	35.57	11.68	36.64	12.80	36.04	12.18
2	35.72	12.78	36.09	14.20	35.88	13.41
3	31.20	11.06	31.79	12.40	31.46	11.66
4	36.19	13.88	35.17	12.96	35.74	13.47
5	35.82	11.89	35.97	12.77	35.89	12.27
6	33.72	13.78	35.02	13.83	34.30	13.79
7	29.27	11.74	30.07	12.75	29.63	12.18

Note. IBI = Inquiry–based instruction; SM = Subject Matter

The student argumentation skills instrument was used to determine the argumentation skills of students following the treatments (subject matter and inquiry–based instruction). The student argumentation skill ability of participants was measured post–treatment using a rubric developed by Schen (2007). The response rate for the argumentation instrument was 86.2%. The overall mean score of the argumentation skill instrument was 5.97 (SD = 1.79) of a possible 10 (see Table 2). The mean argumentation score was higher for the inquiry–based instruction (*M* = 6.44, *SD* = 1.74) than for subject matter instruction (*M* = 5.39, *SD* = 1.68).

Table 2
Participant Mean Student Argumentation Skill Scores

	Treatment Group					
	IBI (*n* = 147)		SM (*n* = 116)		Total (*n* = 263)	
Instrument	*M*	*SD*	*M*	*SD*	*M*	*SD*
Argumentation Skills	6.44	1.74	5.39	1.68	5.97	1.79

Note. IBI = Inquiry–based instruction; SM = Subject Matter

Objective three sought to examine the relationship between argumentation skills, ethnicity, gender, year in school, and socio–economic status of high school agriscience students. Prior to any inferential analysis of the data, all variables were examined for correlations. Terminology proposed by Davis (1971) was used to indicate the magnitude of the correlations. Pearson Product Moment correlations were used to determine the relationships between the variables (see Table 3). Negligible correlations between all variables were found with the exception of the correlation between treatment and argumentation skill score. The relationship between the argumentation skill score and treatment r = .30 was found to be moderate.

Table 3
Correlations Between Variables

Variable	1	2	3	4	5	6
1. Argumentation Skills Score	—	.03	.16	.05	.14	.30
2. Grade		—	.03	.04	.06	.04
3. Gender			—	.03	.11	.01
4. Ethnicity				—	.05	.01
5. SES					—	.05
6. Treatment						—

Note. Treatment = Teaching method utilized

The null hypotheses states there is no significant difference in student argumentation skills based on teaching method. Students' argumentation skill score was calculated by the use of Schen's (2007) rubric. Students taught using inquiry–based instruction achieved a higher mean argumentation skill score (M = 6.44) than students taught using the subject matter approach. The univariate analysis of covariance [$F(127) = 30.23$, $p \leq .001$, $r^2 = .29$] revealed significant differences in argumentation skills at the alpha level of .05 between students taught by the two teaching methods (see Table 4). Based on these findings, the null hypothesis of no significant difference in student argumentation skills between the two groups was rejected.

Table 4
Univariate Analysis of Treatment Effects for Argumentation Skills

Source	*df*	*F*	*p*	r^2
AS	2	30.23	≤.001	.29

Note. AS = Argumentation Skills

Conclusions

Based on the results of this study there are three conclusions.

1. *Demographics:* A majority (81.6%) of the students involved in this study were White, non–Hispanic. A majority (58%) of the students in the study were male. Nearly half (48.5%) of the students were in the ninth grade. The second largest grade level represented was the tenth grade (44%) followed by the remainder of the sample in the eleventh grade (7.5%). A majority of the students participating in the study did not qualify for free or reduced lunch programs (72.5%), while just over one–quarter of the students were in lower socioeconomic groups. There were negligible variations across all the demographics for inquiry–based and subject matter treatment groups. Thus equivalency of treatment groups was established; the random assignment of subjects to treatment group was effective.
2. *Relationships of variables:* Student demographic variables yeilded low to negligible relationships with argumentation skill and treatment. However, treatment and argumentation skills had a moderate relationship.
3. *Argumentation skills:* Student scores were calculated using Schen's (2007) rubric. Students taught using inquiry–based instruction achieved a mean score of 6.44 while students taught through the subject matter approach achieved a mean score of 5.97. Therefore, students in the inquiry–based instruction scored higher than students in the subject matter group. A univariate analysis of covariance revealed significant differences in argumentation skills at the alpha level of .05 between students taught by the two teaching methods thus the null hypothesis was rejected. It was concluded that inquiry–based instruction was more effective than subject matter instruction in developing argumentation skills.

Discussion/Implications

The findings of this study support the work of Keil, Haney, and Zoffel (2009) they found that inquiry–based instruction contains multiple dimensions of teaching and learning and leads learners to think critically without being critical or concerned with arriving only at a correct answer. It can be concluded that inquiry–based instruction continues to focus on the ability to explain the process examined in the development of learner answers (Keil et al., 2009). Furthermore, inquiry–based instruction seeks to capitalize on current student experiences and transfer those experiences to new learning situations (NRC, 2000).

Some research has reported that learners have difficulty distinguishing evidence from bias/fairness (Baron, 1991; Perkins, Farady, & Bushey, 1991; Toplak & Stanovich, 2003). Using inquiry–based instruction can increase argumentation skills, which are a direct link to reasoning patterns and the ability to support their conclusions based on scientific data. Baron (1991) and Cerbin (1988) found that a pure traditional lecture–based teaching strategy creates learners who lack the ability to develop arguments with adequate evidence. While conclusions from this study cannot refute or support Boron's and Cerbin's claims, this study provided evidence that inquiry–based instruction is more effective than the subject matter approach in the development of argumentation skills. The findings of this study indicated that inquiry–based instruction increases the students' ability to link evidence with claims. Inquiry–based instruction may lead to learners being able to be prepared for post–secondary education or workplace careers (Kuhn, 1992) through the formation of stronger argumentation skills.

This study supports that inquiry–based instruction is more supportive of the students' ability to satisfy the needs of individuals entering careers in agriculture, attending major universities, or pursuing other postsecondary education endeavors. The NRC (1996) reported that employees in a highly competitive market must have the ability to reason and provide developed arguments for or against the conclusions they reached as they are solving problems; inquiry–based instruction can help strengthen those arguments.

Driver et al. (2000) wrote that argumentation ability is central to foundational practices of science. Inquiry–based instruction may lead to better qualified scientists and an enhanced public understanding of science. Development of students with better argumentation skills will help supply agriculturists to formulate better arguments that are supported by fact and yet enable agriculturists to understand and assess counter claims to differing solutions to a problem.

Recommendations

This study provides evidence of the effectiveness of inquiry–based instruction for school–based agriscience education across the United States. Teacher educators will find the study useful in the selection of teaching methods. The results of this study could assist agricultural educators by identifying key components to adapting curricula to inquiry–based instruction and the role that quality professional development has on student argumentation in agriscience. Based on the findings of this study, the following recommendations were made for teacher educators and curriculum developers in secondary school education:

1. Because inquiry–based instruction is an effective method that promotes argumentation skills when delivered to secondary school agriscience students, teacher educators should model inquiry–based instruction and incorporate argumentation skills.
2. Teacher educators should provide in–service education opportunities for current teachers on inquiry–based instruction and student argumentation development.
3. Inquiry–based curricula and lesson plans that use this form of instruction should be developed to further the use of this teaching method.
4. Teacher educators should provide direct instruction for the development of higher scientific reasoning and argumentation skills in their preservice program and provide professional development for in–service teachers.

Based on the findings of this study, the following recommendations were made for practitioners in secondary school agriscience education:

1. Strong consideration should be given to attend the NATAA professional development workshops and learn inquiry–based instruction.
2. Agriscience courses should include direct instruction on argumentation skills. This instruction should include a focus on the development of the argumentation instrument in combination of agricultural contextual problems that students support with research data they collect or review from basic agriculture and science journals.

While this study provides conclusions regarding its objectives and hypothesis, the study also developed recommendations for further research, including:

1. More experimental studies are needed in agricultural education investigating the best methods to teach agriscience education. Replication of this study involving a different group of teachers and different content focus will add to the body of knowledge for the profession.
2. A model for inquiry–based instruction integration is worthy of development due to the identified effectiveness of this teaching method.
3. Replication of this study comparing inquiry–based instruction with other teaching methods may provide insight into how to best teach agriscience.
4. This study examined the effect of the teaching methods on argumentation skills following instruction. This study should be replicated to investigate the effects of these treatments on long–term retention of content knowledge achievement, argumentation skills, and scientific reasoning.
5. This study did not assess student attitude toward the methods of instruction or the change in attitude toward science when learning under inquiry–based instruction. Further research should be conducted to determine how these teaching methods affect student attitude, motivation, and self–efficacy.

References

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1–12. doi: 10.1023/A:1015171124982

Baron, J. (1991). Beliefs about thinking. In J. F. Voss, D. N. Perkins, & J. W. Segal (Eds.), *Informal reasoning and education* (pp. 169–186). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bodzin, A., & Beerer, K. (2003). Promoting inquiry–based science instruction: The validation of the Science Teacher Inquiry Rubric (STIR). *Journal of Elementary Science Education, 15*(2), 39–49. doi: 10.1007/BF03173842

Bodzin, A., & Cates, W. (2002). Inquiry *dot* com. Web–based activities promote scientific inquiry learning. *The Science Teacher, 69*(9), 48–52.

Boone, H. N., Jr. (1988). *Effects of approach to teaching on student achievement, retention, and attitude* (Unpublished doctoral dissertation). The Ohio State University, Columbus, OH.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school.* (2nd Ed.). Washington, DC: National Academy Press.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi–experimental designs for research.* Boston, MA: Houghton Mifflin.

Center for Agricultural and Environmental Research and Training (CAERT). (2008). *Ag Literacy Lesson Plan Library.* Retrieved from http://www.caert.net/estore1/sample.asp

Cerbin, B. (1988). *The nature and development of informal reasoning skills in college students.* Paper presented at the National Institute on Issues in Teaching and Learning, Chicago, IL. (ERIC Document Reproduction Service No. ED298805)

Chiasson, T. C., & Burnett M. F. (2001). The influence of enrollment in agriscience courses on the science achievement of high school students. *Journal of Agricultural Education, 42*(1), 61–71. doi: 10.5032/jae.2001.01061

Claxton, G. (1991). *Educating the enquiring mind: The challenge for school science.* Harverster, UK: Wheatsheaf.

Cooper, J., & Prescott, S. (1989, March). *Cooperative learning: Kids helping kids, teachers helping teachers.* Materials packet for higher education component of AACTE symposium. (ERIC Document Reproduction Service No. ED310 067)

Davis, J. A. (1971). *Elementary survey analysis.* Englewood, NJ: Prentice–Hall.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287–312. doi: 10.1002/(SICI)1098–237X(200005)

Dyer, J. E. (1995). *Effects of teaching approach on achievement, retention, and problem solving ability of Illinois agricultural education students with varying learning styles*(Unpublished doctoral dissertation). University of Illinois at Urbana–Champaign, Champaign, IL.

Flowers, J. L. (1986). *Effects of problem solving approach on achievement, retention, and attitudes of vocational agriculture students in Illinois* (Unpublished doctoral dissertation). University of Illinois at Urbana–Champaign, Champaign, IL.

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

Geddis, A. (1991). Improving the quality of classroom discourse on controversial issues. *Science Education, 75,* 169–183. doi: 10.1002/sec.3730750203

Hamlin, C. (1992). Reflexivity in technology studies: Toward a technology of technology (And Science)? *Social Studies of Science, 22*(3), 511–544. doi: 10.1177/0306312792022003004

Jimenez–Aleixandre, M. P., Bullgallo–Rodriguez, A., & Duschl, R. A. (1997, March). Argument in high school genetics. *Paper presented at the National Association for Research in Science Teaching,* Chicago, IL.

Jurs, S. G., & Glass, G. V. (1971). Experimental mortality. *Journal of Experimental Education, 40,* 62–66.

Keil, C., Haney, J., & Zoffel, J. (2009). Improvements in student achievement and science process skills using environmental health science problem–based learning curricula. *Electronic Journal of Science Education, 13*(1), 1–18. Retrieved from http://ejse.southwestern.edu

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review, 62*(2), 155–178.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*(3), 319–337. doi: 10.1002/sce.3730770306

Lampert, M. (1992). Practices and problems in teaching authentic mathematics in school. In F. Oser, A. Dick, & J.–L. Patry (Eds.), *Disseminating new knowledge about mathematics instruction* (pp. XX). Hillsdale, NJ: Erlbaum.

Latour, B. W., & Woolgar, S. (1986). An anthropologist visits the laboratory. In B. Latour & S. Woolgar (Eds.), *Laboratory life: The construction of scientific facts.* (pp. 83–90). Princeton, NJ: Princeton University Press.

Myers, B. E. (2004). *Effects of investigative laboratory integration on student content knowledge and science process skill achievement across learning styles* (Unpublished doctoral dissertation). University of Florida, Gainesville, FL.

Myers, B. E., & Dyer, J. E. (2006). The influence of student learning style on critical thinking skill. *Journal of Agricultural Education, 47*(1), 43–52. doi: 10.5032/jae.2006.01043

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

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

Newcomb, L. H., McCracken, J. D., & Warmbord J. R. (1993). *Methods of teaching agriculture.* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Norris, S. P., & Phillips, L. M. (1994). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching, 31*(9), 947–967. doi: 10.1002/tea.3660310909

Perkins, D. N., Farady, M., & Bushey, B. (1991). Everyday reasoning and the roots of intelligence. In J. F. Voss, D. N. Perkins, & J. W. Segal (Eds.), *Informal reasoning and education* (pp. 83–106). Hillsdale, NJ: Lawrence Erlbaum Associates.

Phipps, L. J., Osborne, E. W., Dyer, J. A., & Ball A. L. (2008). *Handbook on agricultural education in public schools.* (7th ed.). Clifton Park, NY: Thomson Delmar.

Piaget, J. (1972). *The psychology of the child*. New York, NY: Basic Books.

Rogers, E. M. (1948). Science in general education. In E. J. McGrath (Ed.), *Science in general education.* Dubuque, IA: William C. Brown Co.

Schen, M. S. (2007). *Scientific reasoning skills development in the introductory biology courses for undergraduates*(Unpublished doctoral dissertation). The Ohio State University, Columbus, OH.

Schunk, D. H. (2004). *Learning theories: An educational perspective.* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Schwab, J. J. (1962). *The teaching of science as enquiry.* Cambridge, MA: Harvard University Press.

Stone, C. A., & Lane, S. (2003). Consequences of a state accountability program: Examining relationships between school performance grains and teacher, student, and school variables. *Applied Measurement in Education*, *16*(1), 1–26.

Thoron, A. C., & Myers, B. E. (2010). The effect of using vee maps verses standard laboratory reports on achieving content knowledge. *Journal of Agricultural Education, 51*(3), 12-22. doi: 10.5032/jae.2010.03012

Toplak, M. E., & Stanovich, K. E. (2003). Associations between my side bias on an informal reasoning task and amount of post–secondary education. *Applied Cognitive Psychology, 17,* 851–860. doi: 10.1002/acp.915

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

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*(1), 35–62. doi: 10.1002/tea.10008

ANDREW C. THORON is an Assistant Professor of Agricultural Education in the Department of Agricultural Education & Communication at the University of Florida, 407 Rolfs Hall, Gainesville, FL 32611, athoron@ufl.edu

BRIAN E. MYERS is an Associate Professor of Agricultural Education in the Department of Agricultural Education & Communication at the University of Florida, 307A Rolfs Hall, Gainesville, FL 32611, bmyers@ufl.edu