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Agriscience Education Through Inquiry-Based Learning: Investigating Factors that Influence the Science Competence of Middle School Students

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Abstract

Inquiry-based teaching methods have been found to enhance students' abilities to understand the process of scientific inquiry. The purpose of this study was to determine if middle school students taught through an inquiry-based teaching approach consisting of scientific skill development, scientific knowledge, and scientific reasoning were more likely to meet their respective science grade level expectation. Participants consisted of predominantly Hispanic sixth and eighth grade students enrolled in school enrichment programs through the MMSAEEC. Inquiry-based instruction was integrated within science classes using lessons in soil pH and water quality. Overall, sixth grade students scored highest on items related to science skill, while the eighth grade students scored highest on the science knowledge portion of the instrument. Regarding the sixth grade students, science reasoning and science skill were found to be significant predictors of grade level expectation, while science skill was significant for the eighth grade data. It is recommended that teachers incorporate inquiry-based learning strategies into their classrooms to encourage students to ask questions and refine their ability to think critically and solve problems. Further research is needed to clarify the role of science comprehension and the associated sub-dimensions with the ability to predict grade level expectation.

Keywords: agriscience, inquiry-based learning, science competence, science comprehension

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Introduction

According to a report published by the National Science Board (NSB) (2015), upwards of 26 million workers, from sub-baccalaureate through doctoral levels of education, are employed in jobs that require significant knowledge in the science, technology, engineering, and math (STEM) fields. This represents nearly one-fifth of all jobs in the United States (NSB, 2015). Additionally, a 17% increase in STEM employment opportunities has been projected by the year 2020 (White

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House Initiative on Educational Excellence for Hispanics [WHIEE], n.d.). Currently, there is a shortage of qualified employees for current STEM positions and not enough students are pursuing education in STEM to provide an adequate workforce to meet future growth in the field (WHIEE, n.d.). Even more alarming is the lack of representation of minorities in STEM (National Science and Technology Council, 2013). Clearly, it is imperative to build student interest in STEM fields in a way that will encourage the eventual pursuit of a STEM career.

Research has indicated that attitudes and interests of students as young as middle school aged can be positively influenced by the integration of STEM (Wyss, Heulskamp, & Siebert, 2012). This integration has been especially important as a method of developing student engagement in the science fields (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). Science, in particular, often disengages students with scientific concepts that fail to connect to their daily lives (Diaz & King, 2007). As an alternative, educational reform has suggested a more hands-on approach to science integration that engages students in active learning, problem solving, and exploration (Satchwell & Loepp, 2002). Career and technical education (CTE) programs, such as agricultural education, can enable students to learn science skills by embedding content in authentic contexts (Conroy & Walker, 2000; Pearson, Young, & Richardson, 2013; Roberts & Ball, 2009; Roegge & Russel, 1990; Zirkle, 2004). Additionally, teaching science in context further develops students' critical thinking and problem solving skills (Phipps, Osborne, Dyer, & Ball, 2008; Myers, 2004; Thoron & Myers, 2011; Thoron & Myers, 2012).

Inquiry-based teaching methods have also been found to enhance a student's ability to conduct experiments and help them gain a better understanding of the process of scientific inquiry (National Research Council [NRC], 2007). Inquiry-based instruction is rooted within the constructivism paradigm popularized by educational philosophers such as Piaget, Vygotsky, and Dewey (Doolittle & Camp, 1999). In fact, Dewey (1910/1997) outlined steps of reflective thinking, which align very closely to the scientific methods utilized in modern inquiry-based learning. Effective inquiry-based learning is derived from scientific thinking and realistic problem solving and its flexible approach allows teachers to modify the structure of lessons based on particular educational goals (NRC, 2000). As a student-centered approach to learning, inquiry-based instruction begins with students' current knowledge, then proceeds with instructor support in developing knowledge of scientific inquiry (NRC, 2000). This differs from traditional teaching methods that focus on the teacher as an expert (NRC, 2000; Parr & Edwards, 2004). Problem-solving and higher-order thinking skills are enhanced when students are encouraged to expand their knowledge through active engagement and reflection (NRC, 2000; Von Secker & Lissitz, 1999).

Following the NRC's (2000) publication on the scientific inquiry teaching method, the prominence of inquiry-based science instruction increased in an effort to reform science education in the U.S. (Thoron & Meyers, 2011). Inquiry-based methods align well with CTE and agricultural education courses as these subjects have been shown to be an innovative means for improving core content achievement by allowing students to apply these concepts to real-world situations (Parr, Edwards, & Leising, 2008; Pearson, Young, & Richardson, 2013; Young, Edwards, & Leising, 2008; Thoron & Meyers, 2011). Thoron and Meyers (2011) conducted a quasi-experimental study to determine the effects of an inquiry-based approach versus a subject matter approach on high school students' achievement in agriscience instruction. This study found that students who were taught using the inquiry-based teaching method scored higher on content knowledge assessments than students taught using the subject matter approach (Thoron & Meyers, 2011).

Teachers should purposefully select methodologies when integrating STEM content into the context of agriculture (Baker, Brown, Blackburn, & Robinson, 2014). When successfully implemented in the classroom, inquiry-based teaching can lead to an authentic learning experience that encourages students to think critically (Parr & Edwards, 2004; Thoron, Meyers & Abrams, 2011). However, successful inquiry-based teaching requires adequate professional development and teacher training (Thoron et al., 2011; Thoron and Meyers, 2011). Teacher in-service programs, such as the National Agriscience Teacher Ambassador Academy (NATAA), teach educators to utilize pedagogy that encourages students to engage in scientific thought, conduct detailed observations, and ask open-ended questions (Thoron et al., 2011). Thoron et al. (2011) interviewed NATAA teacher participants after they received inquiry-based instructional training to gain a deeper understanding about their perceptions of implementing these techniques into their classrooms. They found that implementing inquiry-based instruction in the classroom was an individual process for each teacher and that inquiry-based instruction was a more rewarding teaching method, despite increased lesson preparation time (Thoron et al., 2011). Additionally, focus group respondents indicated the use of inquiry-based teaching methods helped the teachers form positive associations with other instructors and administrators. Overall, this method was regarded as an asset to agriscience teachers, especially when combined with adequate preservice training and professional development that allowed them to implement this strategy in their classrooms (Thoron et al., 2011).

The Memorial Middle School Agricultural Extension and Education Center (MMSAEEC) in Las Vegas, NM is an agriscience education program developed by the New Mexico State University (NMSU) Cooperative Extension Service in partnership with the public school system to integrate inquiry-based and experiential learning methods into the classroom (Skelton & Seevers, 2010; Skelton, Seevers, Dormody, & Hodnett, 2012; Skelton, Stair, Dormody, & Vanleeuwen, 2014). The mission of this sixth through eighth grade STEM education program is to prepare students to think critically about complex concepts and become aware of careers in the STEM fields (Skelton & Seevers, 2010; Skelton et al., 2012; Skelton et al., 2014). The program employs the skills of a NMSU faculty member to deliver instruction, conduct classroom based experimental studies, plan field trips, and provide demonstrations (Skelton & Seevers, 2010; Skelton et al., 2012; Skelton et al., 2014). The MMSAEEC seeks to achieve its mission through contextualized instruction and hands-on learning within the subjects of agriculture and natural resources (Skelton & Seevers, 2010; Skelton et al., 2012; Skelton et al., 2014).

Studies by Skelton, Dormody, & Lewis (In Press) and Skelton et al. (2014) have been conducted to measure the science achievement and comprehension of middle school students participating in the MMSAEEC program. Skelton et al. (2014) conducted a quasi-experimental study to determine if there was a difference in student achievement in science, as well as agriculture and natural resources. This study also analyzed differences in student interest in STEM careers between the MMSAEEC program and two comparison middle schools. Student achievement in science, and agriculture and natural resources was determined from New Mexico standardized test scores. A comparison of performance on the science standardized test indicated that the MMSAEEC students' overall test scores were higher than the comparison schools in overall science comprehension, as well as the sub-dimensions of science and people, scientific investigations, and physical science. However, the life science and earth science sub-dimension scores were not significantly different (Skelton et al., 2014). Overall, MMSAEEC students had improved performance and higher scores; however, interest in STEM careers was not significantly different between the groups. In fact, all students indicated a similarly strong interest; however, the MMSAEEC students were twice as likely to be interested in agricultural careers (Skelton et al., 2014).

One important factor of the MMSAEEC program is the demographics of the students involved. Overall, 88% of students in the program are Hispanic, a demographic that is underrepresented in STEM (Lopez et al., 2005). Hispanics represent nearly 20% of the U.S.

population, however they represent less than two percent of the total STEM workforce (WHIEE, n.d.). Although Hispanics in [State] have not traditionally been considered a minority within the state, the overall Hispanic community in the U.S. is a minority group that has shown a lack of educational attainment. The drop-out rate for Hispanic students, age 25 years or less, is 27% and is attributed to issues such as language barriers, needing to work to supplement their family's income, and a lack of family support for education (Gasbarra & Johnson, 2008).

There is also a socioeconomic trend within the Hispanic community in which 23% of the population lives below the poverty level, with an average family income of $34,396 (Lopez et al., 2005). However, as the population of Hispanics is projected to increase in the U.S., their buying power and their overall economic contribution is projected to increase (Lopez et al., 2005). It will be important to increase engagement in STEM careers through education that also prepares Hispanic students for employment (Gasbarra & Johnson, 2008; Lopez et al., 2005).

The shortage of Hispanics in STEM and science related fields has been associated with several factors, including (a) the methods that are used to teach science in schools, (b) the lack of qualified instructors teaching these subjects, and (c) under-funded schools that are deficient in proper supplies to effectively teach these subjects (Gasbarra & Johnson, 2008). There is a need for Hispanic students to have access to more hands-on STEM education that can provide better access to education for this community (Gasbarra & Johnson, 2008). In order develop interest in STEM careers, alternative methods of teaching science may be necessary to reach diverse populations and actively engage learners.

Conceptual Framework

Experiential and inquiry-based learning programs employ a process by which knowledge is created through experience (Kolb, 1984). Through this process, experiential learning creates an environment for students to carry out investigations in a real-world context. According to Kolb (1984), effective engagement in curriculum requires: (a) concrete experience; (b) reflective observation; (c) abstract conceptualization; and (d) active experimentation. The conceptual framework for this study is developed from the interaction of these four principles through a model of application involving scientific knowledge, scientific skills, and scientific reasoning developed by Skelton et al., (2012) (see Figure 1). The interconnection of all three concepts forms a broader contextual understanding and improves science comprehension (Skelton et al., 2012).

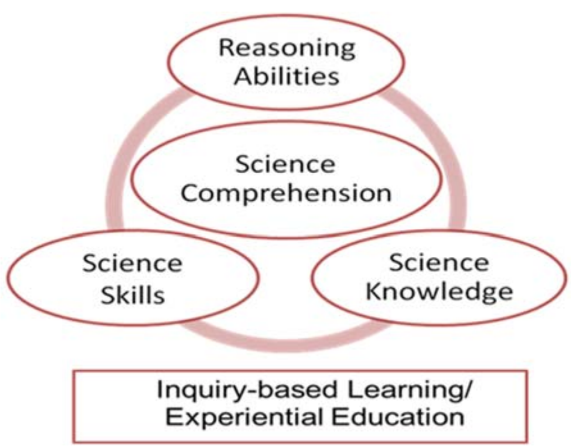

Figure 1. A conceptual model for improving science comprehension (Skelton et al., 2012).

The content of the program is based on the New Mexico public school grade level expectation (GLE), STEM curriculum, as well as the 4-H Science, Engineering, and Technology curriculum (Skelton & Seevers, 2010). The teaching methods used within this program are based on a conceptual model consisting of inquiry-based activities and the experiential learning process (Skelton et al., 2012; Skelton et al., 2014). The combination of inquiry and experiential learning provides an opportunity for higher level thinking skills to be developed and be retained by students (Skelton et al., 2014). The process model begins with science skill and/or knowledge development or acquisition, and proceeds to higher order thinking skills that allow students to demonstrate mastery of the content and then form scientific conclusions (Skelton et al., 2012).

The purpose of this research aligns closely with the AAAE National Research Agenda, specifically Research Priority Area 3: Sufficient Scientific and Professional Workforce that Addresses the Challenges of the 21st Century, as well as Research Area Priority Area 4: Meaningful, Engaged Learning in All Environments (Roberts, Harder, & Brashears, 2016). Deepening our understanding of how core content integration influences the achievement of minority students enrolled in agricultural education programs can assist the profession in meeting the demand for a scientifically prepared workforce that is well represented by all ethnic and racial groups.

Purpose and Objectives

The purpose of this study was to determine if middle school students taught via an inquiry-based teaching approach consisting of scientific skill development, scientific knowledge and scientific reasoning, were more likely to meet their respective science grade level expectation (GLE). The following research objectives guided the statistical analyses of the study:

1. Determine the level of science comprehension (i.e., science knowledge, science skill, and science reasoning) by grade level.
2. Determine whether science comprehension subdimension scores (i.e., science knowledge, science skill, and science reasoning) can predict if students are more likely to meet their respective science GLE.

Methodology

Research Design

This study represents data collected as part of a larger study (Skelton et al., In Press). Participants in this study consisted of six classes of 6th grade students and five classes of 8th grade students enrolled in school enrichment programs through the MMSAEEC. Students in 6th grade received enrichment as part of their earth science curriculum which consisted of soil pH. Students in 8th grade received programming targeted at analyzing water chemistry. These topic areas fit within the New Mexico standardized science curriculum and were identified as ideal areas for inquiry-based teaching. MMSAEEC programs are designed as educational enhancements, similar to 4-H school enrichment programs, and are delivered through the traditional classroom. Broadly, the experiments examined the relationships between plant growth and soil pH (6th grade) and plant growth and water quality (8th grade). Researchers spent the first week teaching basic principles and applications for testing pH of solutions (i.e., litmus paper, pH paper, meters) and water chemistry (i.e., dissolved oxygen, pH, total dissolved solids, nitrate, ammonia-nitrogen, phosphorous, electrical conductivity, and chlorine). During this process, content was introduced, techniques were demonstrated, and students practiced collecting data. Then, using a guided-inquiry approach, students were provided with a problem to investigate and the materials necessary to carry out the investigation. In teams of 3, the students developed hypotheses and devised their own procedures to test their hypotheses. Following their procedures, the students designed conducted their own experiments. Upon completion of the experiments, they were required to explain the problem, their hypothesis, procedures utilized, and present conclusions to their classmates (Skelton et al., In Press).

In order to measure science comprehension, an instrument was developed that reflected the New Mexico agriculture, food, and natural resource content and performance standards. Pre-test and post-test assessments were designed to measure change in scientific knowledge, science skill development, and scientific reasoning ability (see Table 1). Skelton et al. (In Press) offers an in-depth discussion of the pre-test and post-test differences. Overall science comprehension was determined as a result of each program treatment through the aggregation of the sub-dimension scores. For each grade level, a researcher-created instrument, consisting of nine multiple-choice items, was developed with three questions measuring each sub-dimension. A panel of experts established face and content validity of the instruments. The panel made no recommendations, therefore the instrument was utilized as presented.

Table 1

Pretest Scores of Students Enrolled In MMSAEEC (Skelton et al., 2016)

Grade Level	*M*	*SD*
Sixth Grade (*n* = 88)		
Science Knowledge	0.75	0.75
Science Skill	1.82	0.88
Science Reasoning	1.06	0.79
Science Comprehension Total	3.62	1.57
Eighth Grade (*n* = 43)		
Science Knowledge	1.86	0.86
Science Skill	0.98	0.87
Science Reasoning	1.23	0.84
Science Comprehension Total	4.07	1.88

Note. Categories of knowledge, skill, and reasoning comprised of three items each.

Regarding the sixth grade students, 77 (87.50%) were of Hispanic origin and 41 (46.59%) were female. A total of 36 (83.72%) of the eighth grade students were of Hispanic origin and 19 (44.18%) were female. Additionally, student Measure of Academic Proficiency and Progress (MAPP) scores were obtained from Las Vegas City Schools to determine if students were at or below their respective GLE (see Table 2). The MAPP is administered three times per year to track students' academic progression. For this study, the students' mid-year test data was utilized, as it was administered during the same time of year as the study's intervention.

Table 2

Personal Characteristics and Grade Level Expectations of Students Participating in MMSAEEC (Skelton et al., 2016)

Grade Level	*F*	%
Sixth Grade (*n* = 88)		
Hispanic Origin	77	87.50
Gender (Female)	41	46.59
At Grade Level Expectation	36	40.90
Below Grade Level Expectation	52	59.10
Eighth Grade (*n* = 43)		
Hispanic Origin	36	83.72
Gender (Female)	19	44.18
At Grade Level Expectation	29	67.40
Below Grade Level Expectation	14	32.60

Data Analysis

Data associated with objective one were analyzed via descriptive statistics, specifically the mean, standard deviation, and percentage. Logistic regression was utilized to meet the needs of objective two. Logistic regression is appropriate when the outcome variable is categorical in nature (Field, 2009). Specifically related to this study, the outcome variable was whether or not the students met their respective GLE. Due to the exploratory nature of this study, the alpha level utilized to determine statistical significance was set at 0.10. Nagelkerke's R^2 was employed to determine the practical significance of the regression model. The value of Nagelkerke's R^2 ranges between zero and one, making its interpretation similar to the classical R^2 utilized to measure effect size in multiple regression (Field, 2009; Nagelkerke, 1991).

Findings

Objective one of this study sought to determine overall science comprehension of students after participating in an inquiry-based science program. Sixth grade students had an overall science comprehension mean of 6.35 (SD = 1.52) out of a possible nine items (see Table 3). The highest mean was in the area of science skill (M = 2.48; SD = 0.66). The lowest mean was for science reasoning (M = 1.76; SD = 0.71).

Table 3

Performance on the Science Comprehension Examination Post-Test for 6th Grade (n = 88)

Test Category	M	%	SD
Science Knowledge	2.11	70.33	0.82
Science Skill	2.48	82.67	0.66
Science Reasoning	1.76	58.67	0.71
Science Comprehension Total	6.35	70.56	1.52

Note. Categories of knowledge, skill, and reasoning comprised of three items each.

Regarding performance of the eighth grade students, the overall mean of science comprehension was 6.05 (SD = 1.59) out of a possible nine items (see Table 4). The highest mean was in the area of science knowledge (M = 2.37; SD = 0.76) and the lowest was science reasoning (M = 1.74; SD = 0.79).

Table 4

Performance on the Science Comprehension Examination Post-Test for 8th Grade (n = 88)

Test Category	M	%	SD
Science Knowledge	2.37	79.00	0.76
Science Skill	1.93	64.33	0.94
Science Reasoning	1.74	58.00	0.79
Science Comprehension Total	6.05	67.22	1.59

Note. Categories of knowledge, skill, and reasoning comprised of three items each.

Objective Two sought to determine if science comprehension sub-scores could predict science GLE. Prior to employing logistic regression, the Hosmer and Lemshow Goodness of Fit (HLGF) Test was calculated to determine how well the model fits the data. Table 5 lists the results of the HLGF by grade level. Regarding the sixth grade data, the HLGF was determined not to be statistically significant at the $\alpha = .05$ level, indicating the model fit the data well (see Table 5). Similarly, the HLGF was calculated prior to analyzing data associated with the eighth grade students. The HLGF for this group was determined to not be statistically significant at the $\alpha = .05$ level (see Table 6).

Table 5

Results of the Hosmer and Lemeshow Goodness of Fit Test for 6th Grade

	χ^2	*df*	*p*
Step 1 – 6th Grade	4.54	7	0.72
Step 1 – 8th Grade	6.87	8	0.55

The regression model associated with the sixth grade data predicted 70.5% of the cases correctly versus 59.1% predicted in the initial constant model. Nagelkerke's R^2 was calculated to determine the significance of the overall model. Specifically, Nagelkerke's R^2 was 0.36 for the data associated with the sixth grade students. Science knowledge was determined to not be statistically significant ($p = 0.45$). Both science skill (Wald = 3.11; $p = 0.08$) and science reasoning (*Wald* = 10.84; $p = 0.00$) were determined to be statistically significant at the $\alpha = 0.10$ level (see Table 6). The science skill and science reasoning odds ratios were 2.38 and 4.17, respectively.

Table 6

Logistic Regression of 6th Grade Test Areas on Grade Level Expectation

Variable	*B*	*SE*	*Wald*	*df*	*p*	*Odds Ratio*
Science Knowledge Score	0.26	0.34	0.58	1	0.45	1.29
Science Skill Score	0.87	0.49	3.11	1	0.08	2.38
Science Reasoning Score	1.43	0.43	10.84	1	0.00	4.17

Note. α = .10

The regression model associated with the eighth grade data predicted 74.4% of the cases correctly versus 67.4% in the initial constant model (see Table 7). Nagelkerke's R^2 was calculated to be 0.25 for the overall model. Science skill was the only sub-score determined to be statistically significant (*Wald* = 6.05; $p = 0.01$) at the $\alpha = 0.10$ level. The science skill odds ratio was 3.20.

Table 7

Logistic Regression of 8th Grade Test Areas on Grade Level Expectation

Variable	*B*	*SE*	*Wald*	*df*	*p*	*Odds Ratio*
Science Knowledge Score	-.045	0.53	0.70	1	0.40	0.64
Science Skill Score	1.16	0.47	6.05	1	0.01	3.20
Science Reasoning Score	-.064	0.53	1.46	1	0.23	2.30

Note. α = .10

Discussion and Implications

Objective one sought to determine the level of science comprehension by grade level. Regarding the sixth grade students, there was a 31.5% increase in the number of correct items on the post-test instruments (Skelton et al., 2016). Eight-grade students completing the water chemistry unit demonstrated a 40.79% increase in the items they answered correctly (Skelton et al., 2016). The overall score on the 9-item science comprehension instrument could be considered low average (i.e., roughly 70% correct) for both sixth and eighth grade students. The sixth grade students performed best on items related to science skill, while the eighth grade students scored highest on the science knowledge portion of the instrument (Skelton et al., 2016). Results from this study indicate that the inquiry-based methods used in this program were beneficial to overall science comprehension of both grade levels. This is consistent with several prior studies that have investigated the merits of inquiry-based learning (Parr et al., 2008; Pearson et al., 2013; Young et al., 2008; Thoron & Meyers, 2011).

The purpose of objective two was to determine if the science comprehension sub-dimensions (i.e., science knowledge, science skill, and science reasoning) could predict whether students would meet their respective GLE, as measured by the MAPP. Regarding the sixth grade students, science skill and science reasoning were found to be statistically significant predictors. Per analysis of the odds ratios of these sub-dimensions, it was determined that the higher students scored, the more likely they were to meet their GLE. Science knowledge was not a significant predictor of GLE of the sixth grade students.

Regarding the eight-grade students, science skill was found to be a statistically significant predictor. Analysis of the odds ratio indicated that as scores in the science skill sub-dimension increased students were more likely to meet their GLE. The sub-dimensions of science knowledge and science reasoning were not significant predictors for this group of students.

In both the 6th grade program and the 8th grade program, over 85% of students were identified as being Hispanic and over 45% of the students were female (Skelton et al., 2016). An increase in science comprehension, especially for students that are typically identified as underrepresented in the science field is an important finding (NRC, 2007; Barron, 2003). Active learning has been recognized as being one of the most influential factors to student success, being even more impactful than student background and previous academic performance (Barron & Darling-Hammond, 2008). Identifying specific ways that inquiry-based learning can be used to help all learners advance in science fields can not only be beneficial for students, but could inform the development of impactful pre-service teacher education and in-service professional development opportunities.

Recommendations

Active learning and engagement in hands-on learning strategies have been identified as effective methods of science instruction (Rutherford & Ahlgren, 1990; Barron & Darling-Hammond, 2008). Results from this research demonstrate that inquiry-based learning strategies benefit students and it is recommended that teachers should incorporate inquiry-based learning strategies as a regular part of their classroom instruction. However, integration can be a challenge, particularly because teachers may not have received formal training in how to incorporate inquiry-based learning within the agriscience classroom (Linn, Slotta, & Baumgartner, 2000). Because successful inquiry-based learning requires extensive student support and teacher training, adequate planning is crucial for successful integration (Rosenfeld & Rosenfeld, 1999).

Guskey's Model of Teacher Change (2002) describes successful professional development as being a complex process that requires more than just individual training sessions. This model describes ideal professional development as having four key stages: (a) learning about the professional development topic in depth; (b) putting the professional development to practice; (c) determining how students learn as a result of the change in teaching methods; and (d) addressing any change in behavior that results from implementation. Professional development in inquiry-based learning cannot stop after introducing the concept, but rather, should allow teachers to learn about the topic, implement inquiry-based learning and then analyze how inquiry-based learning can impact their classroom. The MMSAEEC program should be utilized to teach agriculture teachers across New Mexico to better incorporate inquiry-based and experiential learning. Studies that actively analyze inquiry-based learning in programs, such as this one, may be helpful for teachers to learn about inquiry-based teaching strategies and better understand how to incorporate this teaching method into their content.

Because agriscience is often known for the experiential nature of its programs (Achieve, Inc., 2015), actively including hands-on and inquiry-based learning strategies may be an excellent opportunity for agriscience and science teachers to develop partnerships that can benefit both teachers and students. Through active partnerships, teachers can provide opportunities for students to better understand scientific principles within the context of agriculture. Similar partnerships have been discussed related to the integration of mathematics into agricultural education (Parr et al., 2008; Young et al., 2008). Pearson et al. (2013) partnered science and CTE teachers together to develop a community of practice whereby they developed curriculum maps and ensured each lesson was science enhanced. Utilizing these types of partnerships could create stronger collegial relationships and ensure students receive the most accurate, up-to-date science content delivered in the context of CTE.

Regarding future research, further investigation is warranted into the predictive power of the science comprehension subdimensions. This exploratory study utilized a small sample and liberal alpha value in determining significance; therefore, future studies should utilize large samples of students and utilize a more conservative alpha value to determine statistical significance. We also worked with limited variance for both the independent variables, which were measured by only three indicators each, and the dependent variable (GLE) which was a dichotomous variable in this study. Expanding the number of indicators measuring the three-science comprehension sub-dimensions before regressing them on overall science score instead of a dichotomous GLE variable could give us a clearer picture of the potential of the model. It is also recommended that future experimental research should be conducted to determine precisely how inquiry-based learning influences student science comprehension. Within the MMSAEEC future studies should include a delayed post-test to understand the long-term effects of this educational model. While this study analyzed science knowledge within a small aspect of science education, larger studies that address more aspects of science and CTE would be beneficial to teacher education programs. Additionally, other models of inquiry-based education should be studied to identify which methods are most effectively integrated within agriscience programs.

It is also recommended that in addition to studying the overall benefits of inquiry-based learning on student achievement, specific aspects of science integration should be examined. The ability to generate accurate hypotheses, for example, has been connected to the development of efficient and effective problems solvers (Blackburn & Robinson, 2016; Johnassen, 2000). In MMSAEEC and other similar program models, a better understanding of student achievement in areas such as these could help to increase understanding of student success in STEM programs.

Lastly, specific research should be conducted to more closely examine inquiry-based learning models on students from diverse backgrounds. Programs such as MMSAEEC that work with a large number of students from traditionally underrepresented populations can provide unique opportunities to study both student achievement and student interest in STEM. Longitudinal research, in particular, should be conducted to determine if programs like these do increase the number of diverse students that enter the STEM workforce. In a study conducted by Oakes (1990), three factors were determined to be necessary for underrepresented students to pursue careers in science: (a) students' opportunities to learn science and math; (b) their achievement in science and math; and (c) the students' decisions to pursue careers in these areas. The MMSAEEC model as designed by Skelton et al. (2016) provides opportunities within each of these three areas, therefore, this program and similar models should be investigated to determine the long-term impact of successful student achievement in science and math, student interest in these areas, and their decision to eventually pursue careers in these fields.

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