Journal of Agricultural Education, 57(3), 87-100.
doi: 10.5032/jae.2016.03087

Part of What We Do: Teacher Perceptions of STEM Integration

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Abstract

This study explored three high school agriculture teachers' perceptions of science, technology, engineering, and mathematics (STEM) integration through interviews. The approach was constructivist and data were analyzed according to the framework of integrated STEM education presented in a National Academy of Sciences report. Each participant agreed to complete three interviews that first investigated past experiences, then present perceptions, and lastly reflections on meaning. A total of about six hours of interview data were analyzed using the constant comparative method. Teacher perceptions were outlined individually and then compared. The teachers shared similar perceptions related to time constraints, the effects of STEM integration, concerns about rapport with students, how agricultural education has changed, and curricular resources. Perceptions aligned well with the framework of integrated STEM education because teachers described increased student interest, motivation, and career-readiness due to agriculture programs, and these perceptions were in some cases supported by non-agriculture teachers. Misconceptions of STEM education included incomplete definitions of engineering education and viewing the use of instructional technology as STEM education. Teacher educators may benefit from increased insight into the perceptions of veteran teachers.

Keywords: STEM; AG-STEM; teacher perceptions; science; technology; engineering; mathematics

Introduction

Science, technology, engineering, and mathematics (STEM) education has sought to produce graduates with the complex skills required for careers in science, policy, business, and industry. Simultaneously, calls for education reform that increase meaningful, situated, contextualized, and interdisciplinary learning in STEM have created a challenge for administrators and teachers at all levels (Kezar & Elrod, 2012; National Research Council [NRC], 2004; Sadler, 2011). A report entitled *Rising above the Gathering Storm* described stagnation in STEM education, the importance of improving it, and how improvements would lead to a better future (Committee on Prospering in the Global Economy of the 21st Century [CPGEC], 2007). While progress has been made, many indicators have remained stagnant or declined

Between 1970 and 2003, the U.S. ranked 20th worldwide in the proportion of those under 24 years old with degrees in natural science or engineering. The percentage of STEM degrees out of all undergraduate degrees has historically been about 17% in the U.S. (Kuenzi, 2008). International standardized tests indicated problems earlier in the pipeline as well. In 2009, U.S. middle and high school students ranked outside the top 20 in science and math literacy by the Program for International Student Assessment (Fleischman, Hopstock, Pelczar, & Shelley, 2010). Statistics such as these have motivated many initiatives to improve and increase the STEM pipeline (Gonzalez & Kuenzi, 2012).

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Federal policies have attempted to solve problems of achievement and underrepresentation as well as assure STEM career opportunities, though projections indicated a shortage of qualified graduates (CPGEC, 2007). In particular, predictions suggested an increasing shortage of agricultural STEM professionals (Goecker, Smith, Smith, & Goetz, 2010). Between 2015 and 2020, nearly 20,000 annual job openings in food, agriculture, renewable natural resources, or the environment will be in STEM areas. Such STEM careers are pivotal in maintaining a globally competitive economy and providing higher average lifetime income to workers (Carnevale, Smith, & Melton, 2011). Increasing achievement and enrollments in STEM fields have also been connected to positive socioeconomic outcomes due to increased innovation (CPGEC, 2007).

Of particular interest to agricultural educators is the notion that agricultural careers will require more knowledge and abilities related to STEM (Association of Public and Land-Grant Universities, 2009; CPGEC, 2007; NRC, 2009). Coincidentally, both agricultural and STEM education have emphasized experiential education, knowledge in the context of real-world issues, and problem solving skills (Ejiwale, 2012; Wardlow & Osborne, 2010). This close match suggests that agricultural education may be particularly well-suited to addressing STEM achievement.

In fact, research has indicated agricultural education programs are capable of increasing science and mathematics achievement (Chiasson & Burnett, 2001; Conroy & Walker, 2000; Parr, Edwards, & Leising, 2006; Ricketts, Duncan, & Peake, 2006). Therefore, agriculture teacher educators need an understanding of how current teachers perceive STEM integration to inform professional development and teacher preparation programs. Teacher perceptions can also lead to further research and curricular resources.

For the purposes of this research, “STEM education includes approaches that explore teaching and learning among any two or more of the STEM subjects, and/or between a STEM subject and one or more other school subjects” (Sanders, 2009, p. 21). Therefore, throughout this study, teaching agriculture with or through one or more STEM disciplines was considered STEM education. The act of preparing and implementing such an approach was the operational definition of STEM integration. The multidisciplinary aspect of the definition led the National Academy of Engineering (NAE) and NRC (2014) to refer to it as integrated STEM (iSTEM) education. Further, iSTEM education must involve a real-world context

Conceptual Framework

STEM Integration in K-12 education: Status, prospects, and an agenda for research sought to clarify the nature of iSTEM education and provide a framework for implementation and research (NAE & NRC, 2014). A conceptual model listed key aspects of STEM integration, implementation, goals, and outcomes. The nature and scope of STEM integration can be clarified by the disciplinary emphasis, type of STEM connections, and the duration, size, and complexity of the program. Variables related to implementation include instructional design, educator supports, and adjustments to the learning environment (NAE & NRC, 2014). The goals for students are STEM literacy, 21st century competencies, workforce readiness, interest, engagement, and making connections between disciplines. The goals for teachers include increased STEM content knowledge and pedagogical content knowledge. Outcomes for students include learning, interest in STEM, STEM course taking and persistence, development of STEM identity, and STEM-related employment. Outcomes for teachers include changes in practice.

The authors of this paper interpreted the NAE and NRC (2014) report as a key work about the theory and practice of iSTEM education. Additionally, the report’s review of literature tentatively indicated effective iSTEM education improves interest and achievement in STEM, especially among underrepresented groups (NAE & NRC, 2014). Therefore, this claim is a theoretical proposition, and it is significant because increasing achievement and interest directly addresses the problems described in the introduction. This study considered how narrative data provided by agriculture teachers supported or disagreed with the conceptual model and theory provided in the NAE and NRC (2014) report.

Theory related to iSTEM education has evolved from previous scholarship related to integrated curricula (NAE & NRC, 2015). Integrated curriculum "cuts across subject-matter lines, bringing together various aspects of the curriculum into meaningful association to focus upon broad areas of study. It views learning and teaching in a holistic way and reflects the real world, which is interactive" (Shoemaker, 1989, p. 5). Agriculture is one such broad area of study that reveals associations between STEM disciplines. The explanation for why the iSTEM approach should increase interest and achievement is rooted in the argument that contextualized learning oriented towards real-world issues and activities motivates students.

Overall, the epistemological approach was constructivist. Two assumptions were participants built their knowledge through the collection of their experiences and understanding was subjective and dependent on point of view. The goal was to accurately portray the participants' experiences of STEM integration in multiple ways.

Purpose

The purpose of this research was to explore and describe teacher perceptions of STEM and STEM integration qualitatively in order to provide insight to teacher educators and researchers. In doing so, we sought to answer two questions:

1. Do agriculture teachers consider the nature and scope of integration, implementation of iSTEM education, goals, and outcomes in a way that is consistent with the theory provided in NAE and NRC (2014)?
2. Do agriculture teachers perceive a positive effect on students' interest and achievement in STEM?

Method

Data were gathered via interviews and analyzed through the conceptual framework of iSTEM education. The semi-structured interviews were completed according to an interview guide. Two in-person interviews were followed by an e-mail interview. The constant comparative method was appropriate to analyze the narrative data (Glaser, 1964). A purposive sample allowed for the selection of participants with maximally varied traits. The programs offered differing curricular paths across multiple geographic contexts in the Southeast.

Due to the small sample and sampling method, the transferability of this research is limited to similar situations, and readers may judge the applicability of the information as they deem appropriate. Cases within an acceptable travel radius were purposively selected for maximum variation, which served to increase transferability by including a spectrum of contexts (Merriam, 2009). The population density of the community as well as the curriculum frameworks provided two variables whose spectrums were well represented by the cases. Pseudonyms are used to protect the identities of the participants.

The data collection procedure can be summarized in four steps:

1. Interview each teacher twice, at least two weeks apart, using the semi-structured interview guide.
2. After each interview, begin the first round of analysis to identify themes.
3. Consult other researchers to shape analysis.

4. Send a preliminary analysis to each teacher, then complete a third and final interview via e-mail as member checking and reflection on meaning.

Several processes were used to ensure credibility, dependability, and confirmability. First, practice interviews and observations were completed before the case study began (Merriam, 2009). During analysis, data triangulation has been the most successful strategy to assure the credibility of a study (Merriam, 2009). Triangulation was completed by comparing and contrasting teachers' statements from three individual interviews over the course of several months. Investigator triangulation was also completed by consulting other researchers and decreased the influence of researcher subjectivity. The interview database served to create an audit trail. Respondent validation was also employed to increase dependability and confirmability of the findings (Richards, 2009; Seidman, 2012). A preliminary analysis was sent to the teachers by email in order to ensure it accurately reflected their realities.

This semi-structured interview process followed the suggestions of Seidman (2012). The three interviews series explored past experiences, current experiences, and then reflection on meaning. An interview guide was followed, but follow-up questions assured participants' answers shaped the content of the interviews. The interview guide concerned formative experiences with agricultural education, teacher preparation, progression as a teacher, sources of curriculum, experiences with STEM integration, and changes to their perceptions over the course of the study. The interviewer attempted to use the word STEM sparingly to prevent excessive cueing. These following questions served as the guide, with the first two questions being the focus of the first interview and the latter three being the focus of the second:

1. "Were you in middle or high school agriculture education programs? What were they like?"
2. "In your teacher preparation program, how was the balance of technical agriculture courses to teaching courses?"
3. "How do you think students' traditional academic skills are affected by your program?"
4. "What value is there in teaching science, technology, engineering, and mathematics through agriculture?"
5. "What challenges or difficulties are there with teaching STEM?"

The final interviews were completed by e-mail, and the teachers were asked to discuss the preliminary analyses of the first two interviews and improve their accuracy. IRB approval was attained for this protocol and pseudonyms are used to protect identities.

The analysis process employed the constant comparative method as described by Glaser (1964). Data were transcribed and then analyzed in WeftQDA v1.0.1. Themes were developed based on the variables of interest and the most relevant, repeated, or insightful statements within the interviews. Transcripts were reviewed at least three times. All quotes marked with a certain theme were also reviewed separately, so all comments related to the theme could be considered simultaneously. The constant comparative method involves an iterative process of revisiting the data and reconsidering implications to increase validity.

Findings

> "Ag teachers have been addressing STEM for years and years. From what I can see, my lesson plans haven't changed because of STEM. I've been doing STEM my whole life. I just didn't call it STEM. It was part of what we did. It was part of our program, it was part of our curriculum." – Mr. Olsen

The findings are presented below through individual reports and then compared in the conclusions section. The themes that developed during the analysis were: STEM knowledge, perceptions of STEM, perceptions of STEM integration, rapport and STEM, curriculum resources, troubleshooting, jargon, STEM and careers, we have been doing this, changes in agricultural education, student engagement, perceptions of student perceptions, importance of technology, and ability levels. Commonalities among the cases were veteran teachers with at least 15 years of experience and active involvement with the FFA. However, each case had different curricular paths and contexts that were purposively chosen for maximum variation. These are briefly described, then followed by individual reports discussing teacher perceptions of STEM, their STEM education, and STEM integration.

Ms. Aiken's program involved animal and veterinary science and horticulture curriculum frameworks. Situated in a small city with both suburban and rural areas, Ms. Aiken taught the most demographically diverse student population of the three teachers. The facilities included a livestock pavilion, land lab, and greenhouse. A second agriculture teacher had recently been hired and a separate biotechnology program that was not focused on agriculture existed at the school.

Mr. Greer taught classes within biotechnology and horticulture frameworks in a rural town. The facilities included a biotechnology lab, greenhouse, and land lab. A second agriculture teacher taught courses for the animal science framework. The recent addition of the biotechnology program and lab had a clear influence on Mr. Greer's STEM perceptions.

Mr. Olsen's program utilized animal science and agricultural mechanics curriculum frameworks. The facilities included a large workshop and land lab for plants and livestock. This program was located in the least populated town. The middle school and high school shared a campus, and a second agriculture teacher ran a middle school program.

Ms. Aiken

Ms. Aiken perceived STEM as an important but difficult aspect of teaching agriculture. Her chief concern regarding teaching STEM was the varying ability level of students, which was particularly a challenge in the introductory class. The class provided students with a science credit, and she said:

> It seems like I'll get a lot of seniors that haven't met their science requirement for one reason or another and a lot of times those are very low level kids that get put in that class. And they want to think that it's going to be a piece of cake and they don't have to do anything, and so I've got a mixture of grade levels. And all the way through kids that are advanced placement kids. So, it is a challenge. Yes, I use those advanced placement kids a lot of time to - if we do groups and stuff - sometimes, to be the leader and to help me teach at points, which is good for those kids. But, I need to challenge them more.

Concerning her teacher preparation, she said science and mathematics were her strengths. Ms. Aiken's knowledge of STEM was further demonstrated by her ability to list diverse STEM topics. Furthermore, she actively pursued professional development opportunities in these areas:

> And yes, I want lesson plans and things that I can take directly from a workshop to class. Or, I want to gain knowledge that I can take and add to what I've already been teaching with what's going on in the world today. Or what's the latest in research and chemicals. I went to a canine workshop at national convention on industry certifications. Back when they were just talking about identifying markers and identifying proteins and genes and all that good stuff, I got a lot of good information from that. I've been to workshops on emerging pathogens and environmental pollution and things like that. Integrated pest management – I've taken courses in that.

She also used a subscription-based website and other internet resources to add new pieces to her curriculum each year. Textbooks were used minimally.

Yet, she felt that STEM education was a new term to describe an old phenomenon that agriculture teachers have been working with for quite some time. She discussed the many time consuming responsibilities of teachers, which was a more acute problem for agriculture teachers:

> The morning is usually taken up with kids working on teams or meetings, meetings all the time. So, that is totally not a time to do anything. And then my planning period, that's 50 minutes, and a lot of times I have to do all the record keeping, bookkeeping that's required for FFA or the department – whether we're ordering feed or getting a purchase order done. We really need a secretary. Every department needs a secretary or farm manager. Because what we're doing here, we have to manage a beef cattle operation, have to manage the horticulture operation. And after school, I'm working show teams till 5, so then I go home and eat supper and its grade papers.

She seemed concerned that policies related to STEM education may lead to additional stress and wasted time rather than tangible improvements in teaching and learning.

She also described the difficulties of doing hands-on STEM activities in large groups:

> Probably the worst thing that's happened from the beginning of my teaching until now is at the beginning, we'd have classes of 10 or 15 at most. And you could do a lot more individualized learning with those kids and spend a lot more time with them. Now, I have 35 in a class and that is not good. It's very difficult to do the hands-on with that many kids and actually be able to move around and talk to them. If you figure a 50-minute period, you can't even spend 2 minutes per kid because you're over 50 minutes. And you've still got to take attendance on the computers that are supposed to be quicker, which I think actually take longer.

Therefore, benefits of using and learning about technology in agriscience could be contrasted to the drawbacks of some educational technologies and trends. In general, she felt that "we have a lot more restrictions now than we did in the past," especially concerning liability, submission of lesson plans, and home SAE visits. She also stated:

> Computers are supposed to make things easy, but if we have to type in word for word every lesson plan you did, you spend more time writing these things up than you do teaching. That's crazy. Why?

She also mentioned how planning lessons in advance sometimes "doesn't work. Because, ok, well, the pipe broke out there and we've got to go fix it now. Or that cow is sick or they've broken through the fence, so now we've got to go deal with that."

In closing, Ms. Aiken emphasized the transferrable nature of STEM knowledge. She noted this in her education as well as in her teaching. She said:

> Whether it's the reproductive tract or the chemicals that we use, progesterone or estradiol, or whatever we may be using, all that comes into play in teaching the students about the functions, reproductive functions, not only in animals, but all this can be related to humans.

Math was integrated through medical calculations, supply orders, and even questions about calculating pay. Technology also played an important role in the animal science classes:

> With laws on being able to identify animals' origin, where they came from - we always tag our animals in the ears and we keep excellent, excellent medical records

> of anything. We actually have a wand that, once we get these ear tags in them, then we can just wave the wand as the tag goes by and all the identification and everything comes up on our computer.

Mr. Greer

Mr. Greer perceived STEM as inseparable from agricultural curriculum. He stated that technology was the driving force behind change in agriculture and agricultural education. While he admitted a dislike of math, he described high levels of math integration. This can be explained because he realized the power of numbers to represent the real world:

> Well, I planned to utilize that population chart and I know that there's math there. I just know, so many times in the textbook, they look right past all that beautiful information that's there that could actually answer so many of their questions that I want them to look at it.

Therefore, even teachers with partially negative perceptions of a subject may effectively integrate it into their curriculum. Mr. Greer's other thoughts on math integration included:

> I like to think that we reinforce because a lot of times I think kids believe math is just I have to know it. So, we try to show them ways they can use it, like fertilizer percentages, parts per million. Those are algebraic expressions. Those are real. I struggle with geometry, but we will learn to measure a piece of property by pacing it. Making our garden, we make it square. Well, we use the Pythagorean Theorem.

When discussing his university experience, Mr. Greer noted "there has to be a nice equilibrium" between STEM courses and pedagogical courses. He added that the balance has depended on the student's background. The changing nature of agricultural education was also mentioned:

> When I came through Jr. High and High School, ag class – the boys, mostly guys – and we would go out and water plants. We would trim hedges, mow grass, we would pick oranges. There was no classroom instruction… I'd never had a class notebook for ag.

However, his hands-on skills and interest in agriculture were increased by the classes.

He acknowledged that STEM integration can be challenging and a learning experience for the teacher. He had recently begun teaching a series of biotechnology classes. He incorporated a biotechnology lab curriculum package with online materials, his own lessons, and horticultural lab work. The process of STEM integration could be time consuming:

> And I guess the planning of it takes so long, it takes a lot of work up front to really plan out a good STEM unit. It takes a lot of work and a lot of preparation and I think that's why some teachers may not like it.

But he also noted the benefits of STEM integration. When asked how his class affected students' achievement in other classes, Mr. Greer said that other teachers had even detected the effect:

> I know in talking to the teachers in science, biology. In biotechnology, if they are in 10th grade when we do DNA - oh wow, it just reinforces that material that they're receiving in biology about DNA. And I've heard it from the teacher side: They say, "Did you just do a unit on...?" I say yes, "I sure did." Oh, the kids seemed to be engaged, they had a good conversation, they knew a lot more background than I initially thought, I just want to make sure... and I say yes, I just covered that.

He believed that rigorous STEM teachers can prove themselves through certifications or competitions.

Lastly, Mr. Greer described how overcoming obstacles as a class using STEM can build rapport:

> I think they just want to know that you care enough about it that you're not going to give up. If you have a break in an irrigation line, you don't say oh well, can't do that anymore guys, it's broken. We had lots of irrigation line breaks, I had animals get out, fences were down, freezes came – and if you care about it, you problem solve.

Therefore, STEM problem solving in order to maintain agricultural projects was an opportunity to demonstrate both knowledge and values.

Mr. Olsen

Mr. Olsen described himself as "an old school agriculture teacher" and suggested the research would be better off at another school if the desire was to see "fancy PowerPoints" and other instructional technology. However, he went on to describe a project that used vibration to settle a local farm's manure slurry to prepare it for vermiculture. The project exemplified how programs can partner with a local industry and use STEM skills to solve problems.

As indicated by the following quote, Mr. Olsen perceived STEM integration as naturally occurring:

> I didn't go, oh I gotta start throwing more lessons in there on math and more lessons in there on science. I've been teaching science and math my whole life! I guess people need to get in the classrooms and see what we're doing, and then they would understand.

This statement also demonstrated his view that STEM was a new educational phrase that hasn't necessarily impacted his teaching. Although, he noted that agriculture teachers in general added more science and math "to be able to keep up with the standards that the state has now." He went on to discuss how agriculture classes are electives, so students have different expectations than for required academic classes. A tension existed between making classes enjoyable for students and ensuring significant STEM learning. While both were important to Mr. Olsen, building rapport with students and cultivating their interest in agriculture was his first priority.

For instance, he suggested that too much math may lessen rapport with students. While he still integrated quantitative thinking through data collection, measurement, the Forestry CDE, and economics, these activities were periodically completed as a whole class. Science, technology, and engineering were all integrated more consistently. He also discussed disciplines beyond STEM that were taught:

> Well, we cover a lot of science. We cover a little bit of math. We do a lot on history, the history of agriculture. We do a lot on economics and the importance of agriculture. So, we hit all the curriculums a little bit. We do speeches, so you get your public speaking and leadership skills. And well, it's got to be entertaining because it's an elective.

He stated this type of integration made STEM topics fun and positively affected students STEM perceptions. He even said that, "You could teach five periods of ag every day, and it would make sense to the kids because it's real life stuff, it's hands on."

Many sources of STEM integration were discussed by Mr. Olsen. He saw FFA Career Development Events, which he would introduce in class and teach after school, as an avenue of STEM integration:

> Plus, the contests are so much more in depth than what our curriculum is. Our forestry contest – seriously, if I taught forestry for a year, I could teach the contest because it would take a year to learn everything on the contest.

He highlighted the agricultural mechanics classes as relevant to STEM, particularly engineering. He felt outsiders didn't always understand the value of the classes:

> They don't see it as - we don't call it ag mechanics STEM, we call it ag mechanics and they think that kids are down here changing oil. Well, there's a whole lot more to it. We do plumbing, we do electrical, we do welding, we do oxygen acetylene, we do brazing, we do woodwork, and it's all the math and science and trigonometry and geometry for designing and building the things we build.

Mr. Olsen regularly employed the engineering process of "delimiting an engineering problem, developing solutions, and optimizing the design solution" (Brunsell, 2012, p. X). His class even designed and constructed objects for the school, such as band stands.

Conclusions

Overall, perceptions were consistent with the framework for iSTEM education in the report by NAE and NRC (2014). With an emphasis on the scientific discipline of agriculture, teachers integrated knowledge, concepts, and skills across all four STEM subjects. A sense of the nature and scope of integration as well as how it was implemented was provided by the individual case reports. All three teachers noted how programs began integrating more science and technology since their time in middle and high school, and they recognized the role of teacher preparation programs and state standards in accomplishing this.

Teacher perceptions were influenced by the history of their educational experiences. Teachers integrated STEM into agriculture curriculum using their own ideas, online resources, and materials from teacher preparation and professional development programs. The framework of iSTEM education suggested implementation is connected to changes in practice and increased STEM content knowledge that enable more effective programs (NAE & NRC, 2014). The interviews provided support for this because all three teachers described changes in their practice over time, but also in the practice of agricultural education since their participation as secondary students.

STEM-related preparation and professional development enabled and encouraged the teachers in these cases to integrate more STEM. Evidence of this statement was triangulated in several ways. Mr. Olsen integrated the engineering design process and explained the scientific reasons behind livestock management decisions based on his STEM knowledge. Ms. Aiken stated workshops were an important source of new STEM-integrated lessons and spontaneously made connections between agriculture and STEM in conversation with students. Mr. Greer used his notebooks from university agriscience courses to create his original curriculum and engaged in professional development before offering the biotechnology track. Furthermore, all three teachers discussed how their teacher education program emphasized science and technology in agriculture curricula, and they maintained this emphasis in various ways according to the curriculum frameworks associated with their programs. For sources of STEM integration ideas, the teachers perceived online curricula as the easiest way to integrate new STEM lessons, but discussed the lessons they had developed themselves most passionately.

Perceptions of engineering and mathematics were more diverse than those of science and technology. The two teachers who had few or no engineering education experiences lacked explicit integration of engineering. Only Mr. Olsen, who taught agricultural mechanics, discussed engineering during interviews without prompting. The other teachers integrated the engineering design process through troubleshooting broken equipment, but they did not necessarily perceive this as engineering integration. Two teachers shared negative perceptions of mathematics. Mr. Greer stated he disliked mathematics, but emphasized the importance and beauty of it as a way of knowing and condensing information.

Each teacher-participant valued STEM knowledge and skills for making contributions to society, especially agricultural production. Another commonality was the perception that technology has had an incredible influence on agriculture, and teachers must educate students about it. This recognition of the significance of technology was sometimes paired with a misperception that STEM education includes the use of instructional technologies. Instructional technology can be used to teach both STEM and non-STEM subjects, whereas technology education requires learning about technology.

Despite valuing STEM, the teachers wondered whether STEM was simply a new educational phrase that might not gain long-term significance. An underlying perception identified across all three cases was the worry that too much STEM-integration could lessen rapport or student interest. Despite these reservations, the teachers shared the iSTEM framework's goals for students: STEM literacy, workforce readiness, increased interest, and making connections to between agriculture and STEM disciplines. They saw these goals as connected to the state's education standards.

All three teachers provided anecdotal evidence supporting the theoretical proposition that iSTEM education positively affects student achievement. Mrs. Aiken cited interacting with students for several years of agriculture coursework as providing a unique opportunity to facilitate and observe growth in students. Evidence from Mr. Greer included non-agriculture teachers reporting increased achievement and engagement among agriculture students in science courses. Furthermore, each teacher referenced students who had obtained STEM careers in agriculture. Additionally, the NAE and NRC (2014) described extracurricular programs as providing students with unique opportunities to develop interest and positive STEM identities, and the teachers described the FFA in similar terms.

Although each teacher discussed the diverse ability levels of students and mentioned the challenges presented by learning disabilities and poverty, information indicating a greater effect on these students could not be triangulated. However, GPA and attendance requirements for participation in CDEs and other events were described as extrinsic motivators for achievement because "students can't go and do these activities - they can't get out of class or get out of school unless they have a good GPA." Mrs. Aiken, who taught at the school with the highest surrounding population density, shared several stories of students from underrepresented populations "coming alive" in an educational environment that valued hands-on skills and activities.

Lastly, teachers perceived the management of an agricultural operation as a sign of STEM competence. They perceived an increase in student motivation in other STEM classes caused by the hands-on and contextualized learning in their classrooms. They also emphasized that disciplines beyond STEM were taught by their programs. Although one teacher discussed collaborating with other teachers, team teaching or facility sharing was not described in the other cases. A separate, non-agriculture-specific biotechnology program was offered at one school but had no connection to the agricultural program. This may be due in part to the time intensive nature of teaching and managing an agricultural education program. The teachers viewed students learning hands-on STEM skills through assistance with management of the agricultural operation as a key aspect of agricultural education that connected STEM knowledge to real-world competence.

Implications and Discussion

STEM disciplines have been responsible for key advancements in human society (Carnevale et al., 2011). Recent policy initiatives have sought to improve STEM education because it will be critical to ensuring economic well-being, public and environmental health, security, new industries, and a globally improved standard of living (CPGEC, 2007). Teacher preparation programs should ensure preservice teachers have accurate definitions and conceptions of STEM integration. Familiarity with the framework for iSTEM education (NAE & NRC, 2014) may be helpful. While this qualitative research may only be transferrable to cases with similar curriculum and teacher variables, the insights provided by a thorough examination of teachers' perceptions can have theoretical and practical value. The views shared by the participants have implications concerning teacher preparation, research, curriculum, and the nature of STEM integration in agriculture programs.

STEM integration in agriculture was perceived as supportive of students' learning in other classes. Not only could the teachers provide evidence of increased achievement and engagement in traditional subject area classes, the field trips and extra-curricular activities provided additional interest and motivation for high achievement. Similarly, the teachers connected hands-on activities to both rapport and motivation in other classes. In each case, rapport and experiential, contextualized learning were used to increase students' interest in STEM and motivate them.

Rapport with students was the most listed characteristic of effective agriculture teachers in a Delphi study completed by Roberts and Dyer (2004). Yet, two of the teachers suggested that too much STEM integration might decrease rapport, especially because:

> It's got to be entertaining because it's an elective. And if it's not fun, the kids won't take it. If they won't take it, your program dies real quick. If my program was nothing but work, work, work, really tough stuff, eventually. . . [trails off].

Further research could clarify how the method and level of STEM integration interact with student rapport in agriculture classrooms. Certain periods within programs may be more appropriate for building rapport than STEM integration or vice versa. Cases in which agriculture classes are required rather than elective may involve less tension concerning students' reaction to STEM integration.

While teachers' perceptions affected the nature and scope of integration in their classrooms, the relationship was complex. Negative perceptions of a discipline were overcome when it was still seen as important and useful. The ability of teacher perceptions to affect student perceptions has been broadly discussed in the literature (Balschweid, 2002; Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011), yet little is known about phenomenon related specifically to teacher STEM perceptions and how they are expressed. Previous studies focused primarily on science or mathematics integration rather than a multi- or interdisciplinary approach including all four STEM subjects.

The call for the integration of science into agriculture curricula that began in the 1980s (NRC, 1988) has been addressed in these cases through the combined efforts of teachers and teacher educators. Agriculture provides a meaningful context for hands-on, object-based, and other experiential learning that connects traditional academic subjects. All three teachers described their adolescent experiences as students in agricultural education as involving little STEM integration and almost exclusively hands-on activities. Therefore, given the progression toward teaching and learning science through agriculture, an important implication may be that institutions and teacher educators can influence the future of STEM integration. The teachers in these cases demonstrated a commitment to lifelong learning through extracurricular engagement, professional development, and continually updating their curricula.

The lesser amount of engineering and mathematics integration described by the teachers suggested the two disciplines may need more attention from teacher educators and researchers. The mathematics abilities of some preservice teachers has been identified as a barrier to mathematics integration (Stripling & Roberts, 2012). Less attention to engineering in STEM education has been identified as a problem of STEM education and research in general (Coppola & Malyn-Smith, 2006). Preservice teachers whose specializations involve these topics should complete rigorous coursework requirements in mathematics, agricultural engineering, and STEM integration.

In conclusion, the data suggested the three teachers perceived value in STEM integration in a way consistent with the NAE and NRC (2014) framework, though they worried it was a catchphrase more than a useful concept. Despite this, the teachers proudly told stories of students entering STEM careers, such as agricultural research and nursery management. Consistent with other findings (Myers & Washburn, 2008), the most mentioned challenges were time constraints and the diverse ability levels of students. Yet, many systemic changes beyond individual teaching practices need to occur to support STEM learning across all student ability levels (Basham, Israel, & Maynard, 2010). In the meantime, teacher educators, researchers, and policy makers should engage in dialogue and collaboration with stakeholders to ensure high quality STEM education within school-based agricultural education programs.

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