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The emphasis for STEM integration in school-based agricultural education (SBAE) classrooms is imperative, resulting in a need for teacher educators to generate a positive view on the integration. Specifically, SBAE teacher aspirants need to be prepared to deliver relevant agricultural curriculum grounded in STEM. The purpose of the study was to evaluate the content knowledge and interest in STEM-related careers for secondary students enrolled in SBAE programs in [State]. Pre-service SBAE teachers at Oklahoma State University were charged with delivering a sustainable bioenergy unit of instruction to their students. This study resulted in a statistically significant improvement in students' STEM knowledge as a result of teaching the content and laboratory experiences (p < .01). Mean scores increased three letter grades and by almost 30 percentage points. Unfortunately, minimal differences existed in student interest in STEM as a result of the experience. Future research needs to explore the preparedness of SBAE teachers to develop, teach, and evaluate the impact in all four content areas (i.e., science, technology, engineering, and math). In addition, the results of this study should be used to guide in the evaluation of state standards compared to national SBAE standards.

Keywords: human capital, teacher preparation, STEM

Introduction

The United States was once considered a leader in STEM education; the loss of this classification can be attributed to a lack of K-12 student interest in STEM and STEM careers (Watson et al., 2022). Individuals ranging from the business sector to government have advocated for the integration of additional STEM concepts within education (Ferand et al., 2020; Roberts et al., 2020). STEM integration within school-based agricultural education (SBAE) appears to focus more heavily on science and mathematics while deemphasizing technology and engineering (Eck et al., 2021b; Wang & Knobloch, 2020). Yet, SBAE teachers have a genuine desire to integrate each curricular area of STEM into their classes so long as they are appropriate for the varying levels of student ability

(Stubbs & Myers, 2016). Regardless, SBAE is not currently successfully connecting science to real world application (McKim et al., 2017).

As the emphasis for STEM integration in various classrooms becomes more apparent, it is important that teacher educators generate a positive view on the subject. According to Margot and Kettler (2019), “teachers’ years of experience are inconsistently related to their perceptions of STEM integration or education, and teachers’ value or interest in STEM may mediate the relationship” (p. 5). Essentially, those who value STEM education and are self-efficacious within the subject tend to implement STEM concepts in their curricula more readily than those who are not as self-efficacious or do not value STEM as highly (Margot & Kettler, 2019). Therefore, assessing how teacher education programs prepare pre-service teachers, especially in regard to developing STEM based lesson plans, is an important consideration (Whisenhunt et al., 2021).

Ultimately, teacher preparation programs in agricultural education seek to prepare teacher aspirants to make a substantial impact on future generations through the delivery of SBAE (Eck et al., 2021c). Coupling this potential impact with the identification of SBAE as an effective platform to facilitate STEM integration and address the nationwide STEM workforce demands (Haynes et al., 2021; Swafford 2018) allows SBAE teacher aspirants the unique opportunity to make purposeful connections between STEM and agriculture. This becomes increasingly important considering the significant shortage of STEM workers in the United States (Watson et al., 2022). Therefore, if SBAE teachers can make these purposeful connections, the ability to highlight careers within the various agricultural sectors improves (Stubbs & Myers, 2016). Additionally, the comprehension and application of STEM concepts increase, furthering the connection for a future workforce, as research has shown that implementing STEM within SBAE programs can increase students’ science and math achievement (Stubbs & Myers, 2016). Unfortunately, SBAE teachers have been found to lack the necessary science content knowledge to effectively integrate it in their classes (Baker et al., 2015).

It is possible that a teacher’s preparedness and teaching self-efficacy can lead to increased student engagement and achievement, especially as it relates to teaching STEM concepts in the context of agriculture, aligning with the call to increase STEM integration in primary and secondary schools (Watson et al., 2022). Unfortunately, the current level of STEM integration is lacking in preservice SBAE teacher planning (Wang & Knobloch, 2018; Whisenhunt et al., 2021), regardless of the potential connections between STEM integration and AFNR curriculum as outlined in the American Association for Agricultural Educations National Research Agenda (Andenoro et al., 2016). Are SBAE teachers prepared to make the purposeful, relevant connections to STEM, which are essential to meet the demands of a changing agricultural workforce? SBAE teacher preparation programs become the pivotal component of addressing this question; therefore, it is imperative that they prepare SBAE teacher aspirants to develop and deliver high quality and relevant agricultural curricula grounded in STEM principles. We propose that one potential avenue is through the inclusion of purposeful STEM integration within the pre-service teacher preparation program.

Literature Review

A primary component of pre-service SBAE teacher preparation programs include instructional methods and/or course design to help prepare students to develop and deliver instructional material (Greiman & Bedtke, 2008). The delivery of instructional lesson plans aid in effective teaching strategies which increase student engagement and learning (Whisenhunt et al., 2021). Research has shown that students who are taught by teachers who use highly structured lesson plans tend to exhibit higher levels of comprehension, retention, and academic achievement when compared to students who are taught the same curricula by teachers who refrain from using highly structured lesson plans (Sung, 1982). Wang and Knobloch (2020) noted, “beliefs influence practices, and teachers’ beliefs are predictive indicators of certain instructional practices, such as inquiry” (p. 58). All too often however, pre-service SBAE teacher lesson plans omit clear connections to STEM integration (Eck et al., 2021b).

Further supporting curriculum development, the Agriculture, Food, and Natural Resources (AFNR) curriculum standards were developed by the National Council for Agricultural Education (2015) as a baseline for STEM integration across the agricultural career pathways (The Council, 2015; Swafford, 2018). Unfortunately, the adoption and use of AFNR standards is not mandatory; therefore, the standards are used or adapted as states see fit (The Council, 2015). Regardless, the inclusions of such standards helps SBAE teachers provide rigorous and relevant instruction while meeting community and program demands through purposeful career connections (Judson et al., 2020; Swafford, 2018). Specifically, “the career pathway content standards outline technical knowledge and skills required for future success within this discipline” (The Council, 2015, p. 2).

Following the essential coursework preparing pre-service SBAE teachers is the student teaching internship, which serves as a culminating experience for students to implement their course content in a structured, real-world environment, ultimately impacting their intent to enter the SBAE teaching profession (Eck et al., 2020b; 2021a). The student teaching internship has been identified by both teacher educators and state staff in agricultural education to be a valuable preparatory experience for preservice teachers prior to entering the profession (Greiman & Bedtke, 2008; Whisenhunt et al., 2021). Although various institutions have different standards and assignments that must be completed within the program, all require their preservice teachers to demonstrate the appropriate pedagogical knowledge necessary for teaching (Whisenhunt et al., 2021). Part of that pedagogical knowledge is developing lesson plans that incorporate standards-based curricula (Eck et al., 2021b; Sorensen et al., 2018).

This training becomes increasingly important considering the connection between K-12 student completion rates and their awareness of, curiosity about, and interest in STEM and STEM careers (Watson et al., 2022). Work in K-12 education (Krishnamurthi et al., 2014) has shown positive effects of STEM based educational programs on students’ STEM knowledge, along with their personal curiosity and confidence. Additionally, career awareness and interest have been connected to the inclusion of STEM curricula within K-12 classrooms (Reinhold et al., 2018). All are leading to a need for increased STEM integration in classrooms and the preparedness of teachers to deliver the essential components.

Theoretical and Conceptual Framework

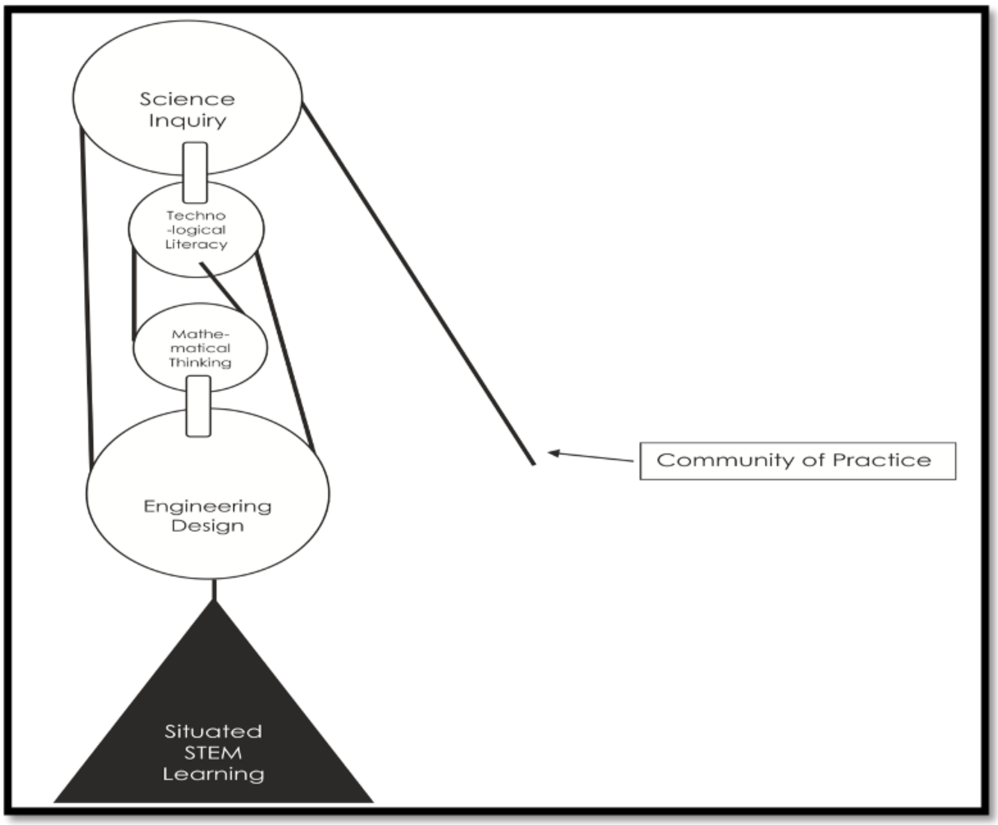
The study was undergirded by the human capital theory, which includes the education, training, skills, and experiences of an individual necessary for employability and general wellbeing (Becker, 1964; Little, 2003; Schultz, 1971; Smith, 2010, Smylie, 1996). Although human capital can be general or specific (Smith, 2010), it often focuses on future employability (Becker, 1964). Within the context of this study, STEM-focused agricultural careers become the target through purposeful STEM integration delivered by pre-service SBAE teachers.

A conceptual model (see Figure 1), derived from Kelley and Knowles (2016), was used to illustrate five different areas of "situated learning, engineering design, scientific inquiry, technological literacy, and mathematical thinking as an integrated system" (p. 3). Kelley and Knowles (2016) identified that engineering design offered students a foundation to a systematic approach to solve problems in the STEM fields. For students to methodically encounter, identify, execute, and propose findings, teachers must be competent in inquiry-based practices (Kelley & Knowles, 2016).

Technological literacy has different meanings to different individuals. Instead of viewing technological literacy for face value, Kelley and Knowles (2016) identified it as volition. "Technology as volition is the concept that [it] is driven by the human will and as a result is embedded within our culture driven by human values" (Kelley & Knowles, 2016, p. 6). The incorporated mathematical thinking in the model included the integration of mathematical analysis and evaluation as an integral STEM practice essential for making relevant connections between content knowledge and potential future career skills (Kelley & Knowles, 2016). The concept of a community of practice can allow SBAE teachers to partner community experts in STEM careers alongside students in engineering and technological practices that help students conceptualize real-world STEM education applications (Kelley & Knowles, 2016).

Figure 1

A Graphic of Conceptual Framework for STEM Learning



Note. Adapted from "A Conceptual Framework for Integrated STEM Education," by T. R. Kelley and J. G. Knowles, 2016, *International Journal of STEM Education*, *3*, Article 11 (https://doi.org./10.1186/s40594-016-0046-z). Copyright 2016 by the *International Journal of STEM Education*. Reprinted with permission.

Although integral STEM education occurs in multiple content areas, we propose this as a potential model for SBAE to further the development of career specific human capital (Smith, 2010). This study focuses on the delivery of a sustainable bioenergy unit of instruction that is grounded in STEM education, with purposeful integration of STEM throughout the curriculum being delivered to secondary agricultural education students, situated in STEM learning (see Figure 1). Specifically, the sustainable bioenergy curriculum serves as a situated STEM learning experience, where the student teaching cohort serves as the community of practice. The sustainable bioenergy unit included five lessons (i.e., bioenergy history and biodiesel, bioplastics, plant growth readings, ethanol and fermentation, and oil extraction) which highlighted science using inquiry-based instruction (i.e., science inquiry), provided students an opportunity to integrate agricultural and science-based technologies (i.e., technological literacy), required calculations and conversions using mathematical formulas (i.e., mathematical thinking), and employed engineering design principles (i.e., engineering design) when making bioplastics. The community of practice depicted in Figure 1 represents the cohort of pre-service SBAE teachers at Oklahoma State University during the spring 2021 semester. They were trained together on the sustainable bioenergy curriculum and served as a resource and sounding board for each other during the student teaching experience. Combined, this provides the pre-service SBAE teachers with a model for inclusion of purposeful STEM integration within their respective student teaching centers as recommended by Kelley and Knowles (2016) for situated STEM learning.

Purpose/Objectives

The purpose of the study was to evaluate the human capital development of students enrolled in SBAE programs in Oklahoma related to STEM content knowledge in agriculture. Two research objectives guided the study:

1. Determine the change in content knowledge of SBAE students prior to and after being taught using a sustainable bioenergy curriculum; and
2. Identify SBAE students' career interest in STEM prior to and after being taught using a sustainable bioenergy curriculum.

Methods

SBAE students in Oklahoma whose program served as a clinical teaching site for pre-service SBAE teachers at Oklahoma State University (n = 8) during the spring 2021 semester served as the study's accessible population (Privitera, 2020). The pre-service teachers participated in a two-hour bioenergy curriculum training prior to their clinical teaching experience. The training provided an overview of the resources, materials, and activities included in the curriculum. The sustainable bioenergy curriculum was compiled from Oklahoma Ag in the Classroom (n.d.) curriculum, National 4-H Council (2016) activities, and from modules developed by the Department of Plant and Soil Sciences at Oklahoma State University. Specifically, the curriculum consisted of five lessons including bioenergy history and biodiesel, bioplastics, plant growth readings, ethanol and fermentation, and oil extraction. Each of the lessons included the delivery of critical concepts through readings and biofuels content shared through a PowerPoint presentation, followed by a relevant laboratory experiment. To further facilitate the learning experience for SBAE students, five corresponding laboratory activities were developed, including biodiesel, bioplastic, soybean, Arabidopsis germination, ethanol, and oil extraction from vegetable matter. Each laboratory experience was embedded with STEM-based connections and conveyed the use and importance of the scientific method.

After completing the sustainable bioenergy curriculum training and the five bioenergy laboratories (i.e., bioenergy and biodiesel, bioplastics, plant growth, ethanol and fermentation, and oil extraction) on campus, pre-service teachers were asked to deliver the sustainable bioenergy curriculum to SBAE students during their 15-week student teaching internship. To further support the curriculum, pre-service teachers were provided a complete sustainable bioenergy laboratory kit to use including all components of the curriculum: a chemistry glassware set, petri dishes, rubber gloves, PH meter, spring scale, pipettes, digital scale, caliper, timer, tape measure, filtration system, filter paper, tea candles, string, bromothymol blue, yeast, pens, centrifuge tubes, tape, thermometer, goggles, laboratory coats, matches, hot plate/stirrer, hand operated vacuum pump, grow system, coffee grinder glycerin, balloons, corn starch, vegetable oil, canola oil, growing containers, planters, soil brick, methanol, ethanol, separatory funnel, fertilizer, potassium hydroxide, and nine seed varieties. A ready-made lesson plan and video tutorial accompanied each lesson and laboratory exercise included in the kit. The lessons aligned with STEM based careers in agriculture to serve as an opportunity for career exploration. In addition to teaching the curriculum, pre-service teachers were asked to collect pre- and post-test data from their students. In return for teaching the sustainable bioenergy curriculum and providing their pre- and post-test data, pre-service teachers were allowed to keep the sustainable bioenergy laboratory kit for their future use as in-service teachers. In total, the biofuels kits were valued at $1,200 each and were purchased through a grant-funded project through USDA NIFA.

A criterion-referenced examination was developed to measure bioenergy content knowledge. The examination consisted of 25 multiple-choice questions to measure the knowledge of students on bioenergy history, biodiesel, bioplastics, plant growth, ethanol and fermentation, and oil extraction. The requirements of Wiersma and Jurs (1990) were followed to ensure reliability of the examination. In addition to the criterion-referenced questions, the STEM semantics instrument (Knezek & Christensen, 2008) was included to assess students' perceptions of each of the four disciplines represented by STEM and a STEM-based career.

A semantic differential scale (Osgood et al., 1957) was selected to better understand the participants' interest in STEM and STEM based careers. Specifically, five pairs of polar adjectives were asked for each STEM component (i.e., five questions for science, five for math, five for engineering, five for technology, and five for a career in STEM). The polar adjectives included fascinating and mundane, appealing and unappealing, exciting and unexciting, means nothing and means a lot, and boring and interesting. Each of the items was ranked on a seven-point semantics scale ranging from one to seven for each polar adjective pair (Osgood et al., 1957), as the labels are essential for item comprehension (Garland, 1990). The ordering of the adjective pairs were randomized to limit straight line responses (Privitera, 2020). Results for each STEM semantic scale were evaluated separately instead of establishing an overall STEM component score, helping to further understand the intricacies of student's perceptions of STEM in agriculture.

The research team has over 40 years combined experience in SBAE and SBAE teacher preparation. In addition, two members of the team have expertise in instrument development. A pilot test was administered with 35 pre-service teachers enrolled in the agricultural education program at Oklahoma State University during the Spring of 2019 (Eck et al., 2020a; Eck & Robinson, 2020). Between the research team and the pilot test, the instrument was deemed valid, as the criterion-referenced items used in the exam served as a predictive measure of current knowledge prior to content delivery, followed by the post-test demonstrating knowledge gain (Privitera, 2020). The STEM semantics scale was previously validated through the work of Knezek and Christensen (2008) and then implemented within this study. The pilot group not only participated in the sustainable bioenergy content delivery but also completed the pre- and post-test, ultimately providing feedback on face and content validity (Privitera, 2020) of the instrument.

Eight pre-service SBAE teachers from Oklahoma State University administered the sustainable bioenergy pre-test to a total of 142 secondary SBAE students. Of those initial 142 students, 42% (n = 60) completed the entire unit of instruction, including the post-test. Four pre-service SBAE teachers from Oklahoma State University instructed a total of 60 students across four distinct secondary programs. After informal qualitative questioning by the research team, it was identified that four of the initial eight pre-service SBAE teachers from Oklahoma State University failed to complete the unit of instruction due largely to COVID-19 interruptions in the school district attendance of in-person instruction, causing students to not be able to participate in hands-on laboratory activities. Therefore, only the data from the 60 secondary SBAE students who completed both the pre- and post-test data were included in the analysis. Data were analyzed using SPSS Version 26 and included descriptive and inferential statistics. The majority of participants were male (55.0%), non-Hispanic/Latino (85.0%), and ranged in age from 14 to 18 years old. Additionally, over 51% were first year agricultural education and FFA members and equally represented both rural (41.7%) and suburban (45.0%) communities. Table 1 outlines the complete list of personal characteristic data (i.e., gender, age, ethnicity, race, year in FFA, and school classification) for SBAE students participating in the study.

Table 1
*SBAE Student Participant Characteristic Data (*n *= 60)*

Demographic	*f*	%
Gender		
Male	33	55.0
Female	26	43.3
Other	0	0.0
Prefer to not respond	1	1.7
Age		
14	4	6.7
15	24	40.0
16	20	33.3
17	9	15.0
18	2	3.3
Prefer to not respond	1	1.7
Ethnicity		
Hispanic/Latino	6	10.0
Non-Hispanic/Latino	51	85.0
Prefer to not respond	3	5.0
Race		
Indigenous American	6	10.0
Black or African American	2	3.3
White	37	61.7
Two or more races	12	20.0
Other	0	0.0
Prefer to not respond	3	5.0
Year in FFA		
First	31	51.7
Second	11	18.3
Third	12	20.0
Fourth	5	8.3
Prefer to not respond	1	1.7
School Classification		
Rural	25	41.7
Suburban	27	45.0
Urban	5	8.3
Unknown	3	5.0

It was assumed all students in each SBAE classroom completed the electronic pre-test prior to any and all curricula being delivered. Having students complete the pre-test at varying intervals could allow for potential differences in scores should questions be shared with other individuals. Secondly, it was assumed all students completed the post-test individually and after the final lesson had ended. Without having direct access to observe students completing the post-test, it can only be assumed students followed instructions to complete the online post-test individually. Similarly, it is assumed all students completed the post-test under the same conditions as each other. Conditions that were assumed to have been constant for all secondary students included: no notes allowed during the test, all students completed the test individually, and no additional outside sources of information were provided nor accessed during the commencement of the post-test. Although all eight pre-service teachers received the same training throughout the teacher preparation program and in the delivery of the sustainable bioenergy curriculum, students, classroom resources, and teaching styles varied from one school and individual to the next which may have impacted the study's findings.

Findings

Research Objective 1: Determine the Change in Content Knowledge Prior to and After the Delivery of the Sustainable Bioenergy Curriculum. The pre-test resulted in a mean score of 12.94 (*SD* = 3.16), which equated to 52%. Scores on the pre-test ranged from a low of 1 correct answer to a high of 21 correct answers. After students completed the pre-test, a five-day sustainable bioenergy unit of instruction was delivered by the student teachers. After completion of the unit, a post-test was administered to measure students' growth. The post-test included the same 25 criterion-referenced questions related to content from the unit of instruction. The question and answer choices were reordered prior to distribution to account for test effect. Students completed the post-test with a mean score of 20.45 (*SD* = 4.72), which equated to 81%. The post-test scores ranged from a low of 7 to a perfect score of 25.

Table 2

Pre- and Post-Test Scores for the Sustainable Bioenergy Criterion Referenced Exam

Test	*Mean*	*SD*
Pre-Test	12.94	3.16
Post-Test	20.45	4.72

Note. All items were equally weighted (1-point each), with a total of 25 points (25-items).

To further understand the change in content knowledge based on the sustainable bioenergy curriculum, a one-way analysis of variance (ANOVA) was implemented to compare the pre- and post-test scores. Prior to the ANOVA, the data was evaluated for assumptions, Levene's test for homogeneity of variance was not statistically significant ($p > .05$) and the data were normally distributed. The results of the ANOVA indicated a statistically significant difference $F(1, 58) = 159.88$, $p < .01$ in scores after the five-week unit was taught (see Table 3).

Table 3
Comparative Analysis of Student Performance by Group Means as Measured by the Sustainable Bioenergy Criterion Referenced Exam

	SS	*df*	*MS*	*F*	*p*
Between Groups	2190.80	1	2190.80	159.88	.00
Within Groups	2740.59	58	13.70		
Total	4931.39	59			

Research Objective 2: Identify the Career Interest in STEM Prior to and After the Delivery of the Sustainable Bioenergy Curriculum. To determine STEM career interest, a 25-item STEM semantic differential scale (Knezek & Christensen, 2008) was used. The scale implemented a 7-point semantic scale, as outlined in Table 4. The mean scores for each of the five-item stems (i.e., science, math, engineering, technology, and a career in STEM) are provided in Table 4 for both the pre-test and post-test, along with the corresponding semantic ranges. It should be noted that the semantic scale ranges were randomized for each item stem; therefore, it is important to consider the meaning of a 1 or a 7 on the scale (see Table 4).

Table 4
*SBAE Student STEM Semantic Ratings (*n *= 60)*

Item Stem	Semantic Scale	Pre-Test	Post-Test
Science is . . .	Fascinating (1) to Mundane (7)	3.68	3.12
	Appealing (1) to Unappealing (7)	3.86	3.09
	Exciting (1) to Unexciting (7)	4.07	3.22
	Means Nothing (1) to Means a Lot (7)	4.09	3.86
	Boring (1) to Interesting (7)	3.53	3.60
Math is . . .	Boring (1) to Interesting (7)	3.08	3.06
	Appealing (1) to Unappealing (7)	4.14	4.20
	Fascinating (1) to Mundane (7)	4.36	3.76
	Exciting (1) to Unexciting (7)	4.54	3.69
	Means Nothing (1) to Means a Lot (7)	3.85	3.57
Engineering is . . .	Appealing (1) to Unappealing (7)	3.47	2.86
	Fascinating (1) to Mundane (7)	3.47	2.96
	Means Nothing (1) to Means a Lot (7)	4.86	4.41
	Exciting (1) to Unexciting (7)	3.83	3.10
	Boring (1) to Interesting (7)	4.41	4.18
Technology is . . .	Appealing (1) to Unappealing (7)	3.05	3.28
	Means Nothing (1) to Means a Lot (7)	4.37	4.13
	Boring (1) to Interesting (7)	4.47	4.21
	Exciting (1) to Unexciting (7)	3.42	3.14
	Fascinating (1) to Mundane (7)	3.54	3.16
A Career in STEM is . . .	Irrelevant (1) to Relevant (7)	3.87	4.04
	Boring (1) to Interesting (7)	4.23	4.22
	Exciting (1) to Unexciting (7)	3.61	3.12
	Fascinating (1) to Mundane (7)	3.69	3.23
	Appealing (1) to Unappealing (7)	3.83	3.37

Note. Sematic differential scale ranged from 1 to 7 across the five pairs of polar adjectives.

Conclusions, Implications, and Recommendations

Overarchingly, this study resulted in a statistically significant increase in students' STEM knowledge as a result of teaching the content and laboratory experiences in the sustainable bioenergy curriculum kit F (1, 58) = 159.88, $p < .01$. Mean scores increased three letter grades and almost 30 percentage points from 12.94, or an F letter grade (52%), on the pre-test to 20.45, or a B letter grade (81%), as a result of the student teaching lessons from the sustainable bioenergy unit. Perhaps additional curriculum with a STEM focus on inquiry-based teaching practices and hands-on delivery of instruction needs to be developed specifically for SBAE teachers to teach after receiving in-service training. Doing so would align with other researchers (Eck et al., 2021b; Ferand et al., 2020; Kelley & Knowles, 2016; Roberts et al., 2020) who have clamored for the need to further emphasize and integrate STEM in SBAE. It would also emphasize the relationship between teachers' STEM knowledge and their willingness to integrate STEM curricula (Kelley & Knowles, 2016; Margot & Kettler, 2019).

Considering the semantic range included a seven-point scale, the majority of pre- and post-test mean scores fell in the middle of the range, with pre-test scores ranging from 3.05 to 4.86 and post-test scores ranging from 2.86 to 4.41. It is important to consider the semantic scale stems for each item, as four of the five semantic scale mean scores for science look to indicate a decrease between the pre- and post-test, although, four of the five actually resulted in a gain due to the random ordering of the items (see Table 4). Ultimately, students found science to be more fascinating, appealing, exciting, and meaningful after participation in the sustainable bioenergy curriculum. Similarly, math became more fascinating, exciting, and meaningful, although it became less interesting and more unappealing after the curriculum was taught. Engineering was found to be more appealing, fascinating, and exciting at the end of the bioenergy unit. Although technology was found to be more exciting and fascinating after the unit of instruction, it became less meaningful, less interesting, and more unappealing. A career in STEM became more relevant, exciting, fascinating, and appealing to students, while the interest remained almost constant. Considering the individual items within each STEM semantic component, helps the researchers further understand the intricacies of participants instead of reporting an overall semantic score in the middle of the range.

Although a change in content knowledge was documented, SBAE student interest in STEM settled in the middle of the 7-point semantic scale. Although minimal differences existed in student interest in STEM as a result of the experience (see Table 2), many of the areas did result in some level of growth. The greatest changes in the semantic differential scale were in students' appreciation for science and their interest in STEM-based careers after participating in the sustainable bioenergy unit of instruction. Even though the changes were minimal, perhaps the delivery of additional STEM-based units of instruction would further increase the appreciation for STEM and interest in STEM careers. With the documented need of additional STEM-related training for SBAE teachers (Stubbs & Myers, 2016), emphasis should seek to further develop instructional planning methods and effective teaching strategies to aid in student engagement and learning in SBAE teacher preparation programs. Doing so aligns with the findings of Whisenhunt et al. (2021). Further research on the instructional delivery method preferred by the secondary students may also uncover evidence of additional needed revisions to the current curriculum base.

Considering the development of the participants' individual human capital, it can be concluded that the situated STEM learning (i.e., sustainable bioenergy unit of instruction) depicted in Figure 1, was a success based on SBAE student test scores on the criterion-referenced exam. Ultimately, our program developed careers specific human capital (Becker, 1964) within the student teachers, who were in turn charged with developing human capital (Schultz, 1971) in their secondary students. Could it be that integrating the training specific to the sustainable bioenergy unit of instruction prior to the student teaching experience better positioned the pre-service teachers to effectively integrate STEM due to the recency effect? Regardless, the cohort type approach served as a community of practice to integrate the STEM components within an agricultural unit of instruction (Kelley & Knowles, 2016).

Further, the human capital of the SBAE students can be viewed through their achievement (Zimmerman, 1999), as indicated by their increased test scores, and their change in perception, level of interest, or choice of activities (Smith, 2010), as it relates to STEM. Ultimately, the human capital development focused on generating STEM interest and on potential future employability (Becker, 1964), as the findings demonstrate an increased STEM interest. Therefore, continuing this type of purposeful STEM integration within SBAE could help address the nationwide STEM workforce demands identified in previous research (Haynes et al., 2021; Swafford 2018). To further this development, a need to lengthen the curriculum beyond a 5-day lesson exists.

Unfortunately, math, engineering, and technology are still areas that SBAE teachers need to address further within their curriculum, as those STEM components tended to show less impact using the semantic differential scales. Similarly, Wang and Knobloch (2020) found current STEM integration within SBAE to focus primarily on the science within agricultural education. Although the sustainable bioenergy curriculum aimed to incorporate all components of STEM, science served as the primary connection. Perhaps future curriculum development and delivery could provide additional emphasis in these discipline areas. Conceivably the integration of a STEM through AFNR rubric (Wang & Knobloch, 2018) in an SBAE teacher preparation program could further enhance the development and preparedness of preservice teachers to make purposeful STEM connections.

Considering this study and others, SBAE teacher preparation programs and professional development opportunities need to focus on the complete STEM model and not solely on science. Future research needs to explore the preparedness of SBAE teachers to develop, teach, and evaluate their impact across all four components of STEM (i.e., science, technology, engineering, and math). In addition, an analysis of state and national SBAE standards could help determine the expectation and rigor of SBAE courses in different career pathways on a state-by-state basis, ultimately considering the state specific needs. Understanding SBAE teacher preparedness and self-efficacy, along with the expectation and rigor in each state, will allow SBAE teacher preparation faculty the opportunity to tailor the development of in-service and preservice teachers to increase STEM integration.

Future research should further evaluate the change in self-efficacy of both the pre-service teacher and the SBAE students participating in a STEM enhanced curriculum. Perhaps this research could be replicated using CASE curriculum as a potential model for STEM integration. As the number of participants within this study was limited, future delivery of the sustainable bioenergy curriculum should aim to reach a larger sample, replicating the study to better understand how to best develop purposeful STEM integration in SBAE programs.

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