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Levels of STEM Integration through Agriculture, Food, and Natural Resources

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Abstract

The purpose of this action research study was to develop a rubric that identified levels of integrated science, technology, engineering, and mathematics (STEM) lessons through agriculture, food, and natural resources (AFNR) lessons that were developed and implemented in afterschool programs by preservice informal educators. The research study expanded on the knowledge base by identifying three levels and six features of integrated STEM through the context of AFNR. Using the rubric, we analyzed 10 mini-units, consisting of 27 lesson plans, of STEM integrated AFNR lesson plans that were developed by preservice informal educators. There were three major findings. First, teaching AFNR content and skills was the main focus of integrated STEM lesson plans. Second, the lesson plans attempted to use real-world problems to connect students' learning to use content knowledge and skills to solve the problem, yet failed to connect other disciplines. Finally, students who had previous teaching experiences in non-formal and informal settings achieved the highest scores, but students who were in formal teacher preparation programs had the lowest scores in terms of developing integrated STEM through AFNR lesson plans.

Keywords: STEM integration; interdisciplinary learning; nonformal teaching methods

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Introduction

Interest in research around integrated science, technology, engineering, and mathematics (STEM) curriculum and instruction has been rapidly growing because of: (1) the demand for STEM-related jobs, especially in agriculture, food, and natural resources (USDA, 2015), (2) the *Next Generation Science Standards* (NGSS, 2013) encouraged teachers to use integrated learning in science education, and (3) increased funding to support interdisciplinary research and education on STEM teaching and learning through formal and informal education (Gonzalez & Kuenzi, 2012). Integrating STEM through AFNR is not a new idea for educators. School-based agricultural education (SBAE) was predominately science-focused 30 years prior to the passage of the Smith-Hughes Act in 1917 (McKim, Lambert, Velez, & Balschweid, 2017). The presence of science in SBAE was taught because some teachers chose to keep it a focus in the vocational agriculture curriculum (NRC, 1988). In 1963, the Vocational Education Act broadened the focus of the vocational agriculture curriculum to focus on integration in career and technical education and include additional occupational areas (NRC, 1988) with science connections such as horticulture, forestry and natural resources, food processing, agricultural technology and mechanization (Phipps,

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Osborne, Dyer & Ball, 2008). These occupational areas have evolved to be known as career pathways that represent the agriculture, food and natural resources career cluster, including agribusiness systems; animal systems; environmental service systems; food products and processing systems; natural resources systems; plant systems; and power, structural and technical systems (The Center to Advance CTE, 2017).

Nearly 30 years ago, the Committee on Agricultural Education in Secondary Schools (NRC, 1988) recommended the focus of Agricultural Education be changed and agricultural topics and concepts be incorporated into the existing K-12 curriculum. These recommendations resulted into two initiatives that are germane to topic of integrated learning in agricultural education. *Agriscience education* was the precursor to what has been discussed as agricultural STEM learning, and *agricultural literacy* was a contextualized approach to multidisciplinary learning (Spielmaker & Leising, 2013). Researchers have studied both integrated approaches in AFNR. For example, high school agriculture teachers claimed that it is natural to integrate STEM in agriculture, and they have done so in their lectures and activities almost every day (Stubbs & Myers, 2015), yet McKim and his colleagues questioned how effective agriculture teachers are in teaching science knowledge and stated, "SBAE as a whole is not meeting the vision to connect science and society" (McKim et al., 2017, p. 105). Moreover, the results among elementary teachers are mixed. Some elementary teachers saw the value and relevance of using AFNR as context in their instructional materials (Knobloch, 2008; Knobloch, Ball & Allen, 2007); however, some elementary teachers neither saw that agricultural topics supported their STEM education objectives nor aligned with the academic standards (Graves, Hughes, & Balgopal, 2016).

Although learning about AFNR provides a context for integrated learning, it can be especially challenging for teachers. The current educational system puts up barriers for cross-disciplinary collaboration, and creates a challenge that agricultural teachers lack science knowledge to integrate science into their classes (Baker, Bunch, & Kelsey, 2015). Likewise, STEM teachers are not trained to use agricultural contexts in their classrooms (Graves, Hughes, & Balgopal, 2016). Despite of having positive perceptions about integrated curriculum, some educators have not used integrated curriculum in their teaching (Lehman, 1994), nor they have enough knowledge to create one (Mason, 1996). Overall, integrated STEM through AFNR is an ambiguous concept and there are few standards to follow or be used to assess the level of integration, if educators are interested in teaching integrated STEM through AFNR.

Current literature that supports STEM integration focuses on integrating engineering with science, technology, and mathematics. For example, the frameworks for the NGSS (2013) clearly articulate the role for engineering and technology in science education moving the conversation from the broad recommendations of national documents toward action. Integrative STEM education appears to use engineering design-based approaches that intentionally integrated science and/or mathematics content to solve real-world design problems (Bryan, Moore, Johnson, & Roehrig, 2016; NRC 2014). Although many researchers and educators agree that engineering acts as an integrator to bridge science and mathematics in integrated STEM curriculum and instruction, one of the biggest challenges is that few general guidelines or no framework exist for teachers to follow regarding STEM integrated curriculum and instruction design. For example, in terms of integrating STEM through AFNR, no guidelines or framework exist on how, and to what degree, STEM content areas might be integrated with AFNR. Research on integrating STEM through AFNR has not kept pace with the educational reform. There is a clear need for a tool or rubric that provides guidance for researchers and educators to design and evaluate integrated STEM lessons.

The purpose of this study was to develop a rubric that would provide preservice informal educators feedback on integrated STEM lessons through AFNR. The study was guided by two research questions: (1) What were levels and supporting descriptions of integrated STEM education through AFNR? (2) What were the levels of STEM integration of 27 lessons representing 10 sample mini-units that were developed for afterschool programs?

Literature Review and Conceptual Framework

Agriculture, food and natural resources is an educational career cluster that represents a broad and comprehensive field that has been historically known as agriculture, broadly defined (NRC, 1988; The Center to Advance CTE, 2017). AFNR was purposefully included with STEM integration for several reasons. First, AFNR are "intertwined with other disciplines in the natural and social sciences" (National Research Council, 2009, p. 4). Second, AFNR provides contexts (Roberts & Ball, 2009) to integrating various STEM disciplines (Stubbs & Myers, 2016) by helping students see concrete applications of abstract science and mathematics concepts (Smith, Rayfield, & McKim, 2015). Third, AFNR helps facilitate learning experiences by engaging students to solve complex grand challenges, such as food security, bioenergy, sustainability, and climate change, and helping students see the interrelatedness of single disciplines (Barnosky, Ehrlich, & Hadly, 2016; Warburton, 2003). Finally, AFNR facilitates transdisciplinary learning and systems thinking (Francis et al., 2011; Schneider & Rist, 2014; Scott, Kurian & Wescoat, 2015).

Developing a precise definition of integrated STEM education has been a challenge (NRC, 2014). Many educators consider STEM integration as use of the four disciplines in their teaching, but they were not clear on how to execute the implementation (Breiner, Harkness, Johnson, & Koehler, 2012). They focused their integrated STEM curriculum and instruction on improving students' science and mathematics learning with little integration of technology or engineering (Bybee, 2010; Wang, Moore, Roehrig, & Park, 2011). Smith and Karr-Kidwell (2000) pointed out integrated STEM is "a holistic approach that links the disciplines so the learning becomes connected, focused, meaningful, and relevant to learners" (p. 22). In order to make STEM integration meaningful to learners, integrated STEM approaches need to combine some or all of the four disciplines and use real-world problems that relate to learners' everyday lives, and learners need to be given opportunities to solve the problems (Bybee, 2010; Moore, et al., 2014; NRC, 2014). Regardless of the various definitions of STEM integration, engaging learners in complex and interdisciplinary real-world challenges has been a common theme. Agricultural grand challenges that humans face today are complex and interdisciplinary real-world problems (NRC, 2009), and these challenges provide context to integrating some or all of the STEM disciplines (Stubbs & Myers, 2016). Therefore, AFNR challenges could potentially fulfill the definition of STEM integration from current literature to help educators facilitate STEM integrated learning experiences by engaging learners to use some or all of the four disciplines to solve complex interdisciplinary real-life problems.

Although teachers believe curriculum integration helps students to connect school learning with their personal lives and future work (Hargreaves & Moore, 2000; Mason, 1996; Schlechty, 1990), it raises a number of practical questions, such as what does *integration* really mean? Does *integration* need to present in each lesson plan or in a large unit? Recognizing the need for a model of integrated STEM education, National Academy of Engineering (NAE) and the Board on Science Education of the National Research Council (NRC) convened a committee to identify and characterize current approaches to integrate the STEM disciplines (NRC, 2014). The committee constructed a framework to help characterize and clarify selected STEM programs. The framework provided a broad guideline and lacked detailed criteria for educators to follow. For example, in the framework, one of the goals of integrated STEM education is to increase students' ability to make connections among STEM disciplines. The framework suggested that the instructional materials need to help students recognize the connections, and combine practices from two or more STEM discipline to solve a problem (NRC, 2014). Yet, no more descriptions were provided in terms of the scope of combining two or more STEM disciplines.

Many educators and scholars believe that STEM integration means teaching science and mathematics by integrating engineering and technology into the regular curriculum (Ramaley, 2007). The NGSS (2013) performance expectation offered a tight integration of eight science and engineering practices, which recommends students be required to make deeper connections between science and engineering. Echoing the performance expectation that NGSS has defined, Bryan and her colleagues (2016) identified five characteristics of a quality integrated STEM educational experience: (1) the content and practices of science and/or mathematics serves as an anchor discipline and defines some of the primary learning goals; (2) engineering design and practices of engineering serve as an integrator by providing a context and/or an intentional component of the content to be learned; (3) the engineering design output (i.e., process or product) requires the scientific and mathematical concepts to be included in the design justification; (4) the development of 21st century skills is emphasized; and, (5) the context of instruction requires solving a real-world problem or task through teamwork and communication. Bryan and her colleagues stated that quality of STEM integration depends of three key ideas. First, teachers need to meaningfully integrate STEM contents by providing coherence between the instructional activities and learning outcomes. Second, real-world design problems act as the integrator that meaningfully bridges students' learning and applying other disciplines, such as science and mathematics. Finally, pulling from what students have learned and their prior experiences, teachers help students think outside the box, and use their judgment and critical thinking to make decisions when they solve design problems.

Vasquez and her colleagues (2013) modified Drake and Burns' (2004) definition of STEM integration, and developed three approaches to design integrated STEM curriculum units. The three approaches are multidisciplinary, interdisciplinary, and transdisciplinary. Vasquez and her colleagues used seven categories to identify the differences among the three approaches to integrated STEM. These categories are organizing center, development of the content, role of the disciplines, role of teacher, learning goals, degree of integration, and assessment. For example, in the learning goal category, *multidisciplinary* focuses on "discipline-specific concepts, and skills." *Interdisciplinary* centralizes "concepts and skills that bridge between the disciplines." As for *transdisciplinary*, concepts and skills are used to "bridge between the disciplines, real-world contexts, and students' interests and concerns" (p. 74). Overall, multidisciplinary is the lowest level and transdisciplinary is the highest level of STEM integration. Some recognizable differences between the lowest level (i.e., multidisciplinary) and the highest level (i.e., transdisciplinary) of STEM integration are described as three levels. First, the lowest level of STEM integration clearly maintains the identities of S, T, E, or M and STEM content and skills are taught independently. The highest level of STEM integration, on the other hand, breaks or blurs the disciplinary boundaries of STEM using a real-life problem/project. Second, the lowest level of STEM integration is more teacher-centered, which teachers take the lead instruction and decide the content and skills that should be learned. As for the highest level STEM integration, it is more student-centered, which teachers act as facilitators to facilitate students' learning across disciplines, and students are invited to fully or partially determine the content and skills to be learned, and/or the direction of the design project. Finally, in terms of learning goals, the lowest level of STEM integration focuses on discipline-specific concepts and skills, and the highest level of STEM integration focuses on concepts and skills that bridge between the disciplines within real-world contexts. Although the continuum of STEM approaches to curriculum integration from Vasquez and her colleagues provided some guidelines to guide educators to develop integrated STEM curriculum, when we tried to use the framework to analyze the level of our students' integrated STEM through AFNR mini-units, we encountered some critical challenges. For example, one of the criteria that Vasquez and her colleagues used to separate the lowest and the highest level of STEM integration is by checking if the curriculum includes the real-life context and challenges. As we stated earlier, agricultural challenges are real-life challenges. Therefore, based on this criteria, all the integrated STEM through AFNR mini-units that the preservice informal educators developed fall into the highest level of STEM integration. This framework lacked detailed features that could be used to evaluate the level of integrated STEM through AFNR curriculum units. Therefore, we modified Vasquez, Sneider and Comer's work (2013) to construct a new rubric that could be used to guide and evaluate the level of STEM integration through AFNR.

Research Methods

Action research was chosen as the research method for this study because it is designed to bridge the gap between research and practice (Smoekh, 1995). Two instructors co-taught a three-credit, semester-long graduate-level course and engaged in critical reflection and peer-debriefing throughout the two semesters they taught the course. The instructors framed this innovative course as interdisciplinary learning (Ivanitskaya, Clark, Montgomery, & Primeau, 2002) for the development of integrated STEM through AFNR lessons. Students' comments and questions raised during the course prompted the instructors to dig deeper to understand the features, levels and evidences of teaching integrated STEM through AFNR. Throughout these debriefings, the instructors realized they were engaged in thinking in action because action research is an engaging tool for practitioners to use to study problems scientifically to evaluate, improve and steer decision-making and practices (Corey, 1953). As such, the two instructors studied how to better inform their teaching strategies based on carrying out self-reflective inquiry (Carr & Kemmis, 1986), such as students' comments and interpretations of the content, STEM integration, classroom activities, and lesson plan and teaching assignments. The course was taught twice in a two-year period and the instructors engaged in critical reflection during and after the course was taught (Kraft, 2002). The two instructors had different yet complementary teacher education training and professional teaching experiences. One instructor had a doctorate degree in science education with an emphasis on integrated STEM education and teacher professional development. The other instructor had a doctorate degree in agricultural education and had previously taught a teaching methods course with an emphasis on learner-centered teaching strategies.

Although the disciplinary training and teaching experiences of the two instructors were different, their interests and theoretical perspectives were complementary in developing an integrated STEM teaching methods course. The two professors were informed by a pragmatist perspective (Johnson & Onwuegbuzie, 2004) and engaged in praxis by conducting reflective research (Alvesson & Sköldberg, 2017) of their practice and with perservice informal educators. In doing so, the instructors recursively assessed the relationship that exists between "knowledge" and "the way of doing knowledge" in the context of the course (Calas & Smircich, 1992). In the first year, the instructors developed and framed the course, which was supported by lessons, examples, classroom activities and course assignments. In the second year, the instructors refined lessons and classroom activities to help students more clearly understand the features of integrated STEM learning. The instructors reflected on students' reflections and lessons, which pushed their thinking to more effectively communicate the features, evidences, and levels of integrated STEM learning. It became evident that the students had different interpretations of integrated STEM learning, which pushed the instructors to more deeply understand the students' interpretations and realized the students interpreted levels of integration as a checklist evaluation rather than thinking more holistically about the integrated learning experience. As such, the two professors clarified the features of integrated STEM based on what the current literature stated regarding integrated STEM.

The students, who are interested in becoming informal/non-formal educators and learning how to teach STEM through AFNR, in Purdue University College of Agriculture were research participants. Students developed STEM integrated lesson plans through AFNR and they implemented the lesson plans with upper elementary students in afterschool programs. Different examples of STEM integration were shared in the course to generate discussion of the different characteristics of STEM integration through AFNR instruction. Students were instructed that no existing integrated model is the best model to teach STEM through AFNR, and they had freedom to develop their own STEM integrated lesson plans.

A total of 15 students enrolled the course in two years and had a variety of previous teacher preparation and teaching experiences. Overall, three students were in formal teacher preparation programs, six students had taught at non-formal and informal settings before, and six students had limited to no teaching experience. Students were given the choice to developing their lesson plans as individuals or as teams of two educators. Five students created individual lesson plans, and 10 students paired up to co-develop their lesson plans. Each student, regardless if they worked individually or as a team, was asked to create the equivalent of 90 minutes of instruction known as a mini-unit (i.e., one 90-minute lesson plan or two 45-minute lesson plans). Students taught at least one integrated STEM lesson to elementary students in an afterschool program.

A total 10 mini-units consisting of 27 lesson plans were used as data sources. Two mini-units were single 90-minutes lesson plans (Happy Cows, Happy House, and Operation Separation). Three mini-units consisted of two (Buzz on Bees) and four (Science with Stella the Great and Bruno Uptown Funk Boss, and Healthy Food, Healthy Life) lessons that were 60 minutes in length. Five mini-units consisted of two (Agriculture and Food, and Exploring Your Natural World), three (The Great Forest Controversy), and four (Food and Water System, and Where'd You Get That?! By-products of Animals in Agricultural Settings) lessons that were 50 minutes in length. In total, there were two lessons (90 minutes in length), 10 lessons (60 minutes in length), and 15 lessons (50 minutes in length).

Data analysis focused on identifying the levels and evidences of STEM integration for each criteria of the integrated STEM through AFNR rubric, which resulted in an overall mean of the level of STEM integration for each of the 27 lesson plans. The constant comparative method selective coding (Strauss & Corbin, 1990) was used to identify Levels 1, 2 or 3 of each feature. All 27 lessons were reviewed independently by the two researchers. Ratings (i.e., Levels 1, 2 or 3) were identify for each feature at the lesson plan level. Means and standard deviations were computed at the lesson plan level and also at the mini-unit level for mini-units that had two to four lessons. After central concepts were generated from the selective coding, based on the central concepts, the language of description of each feature were identified. To ensure the trustworthiness of the qualitative analysis, interrater peer debriefing was conducted. Two authors of the study independently coded all of the lessons using the rubric. Each author rated each lesson using the six features and entered the ratings into an Excel® spreadsheet, which also served as an audit trail. Upon independent review of the two raters, intraclass correlation coefficient was computed to determine inter-rater reliability, which was high at 0.96. Regarding disagreements, the two raters engaged in peer debriefing until consensus was reached for discrepancies of codes, concepts, and description of each feature.

Results

Regarding Research Question 1, four features emerged from the current literature: (1) Goal of STEM integration; (2) STEM concepts, content knowledge, and skills; (3) learning outcome of STEM integration; and, 4) role of teachers. First, *goal of STEM integration* is one of the features that was described from a descriptive framework (NRC, 2014) and the framework of three approaches to design integrated STEM curriculum units (Vasquez, Sneider, & Comer, 2013). The literature defined the goal of STEM integration as "instructional materials need to help students recognize the connections, and combine practices from two or more STEM discipline to solve a problem" (NRC, 2014, p. 37), and "concepts and skills that bridge between the disciplines, real-world contexts, and students' interests and concerns" (Vasquez, Sneider, & Comer, 2013, p. 74). Although the goal of STEM integration is important, in order to apply this feature to lesson plan level, the two instructors discussed and decided to use the language of *Role of Integration in Learning Objectives*. Learning objectives play an important role in providing focus of lessons and helping to define the learning outcomes (Gagne, Wager, Golas & Keller, 2005). Combined the key points from the current literature, the definition of *the role of integration in learning objectives* is "learning objectives apply STEM knowledge to solve problems."

Second, *STEM concepts, content knowledge, and skills* focused on the role of knowledge. The definitions of STEM integration from current literature that described STEM concepts, content knowledge, and skills were "apply knowledge of mathematics, science, and engineering, an ability to design and conduct experiments, as well as to analyze and interpret data..." (Sanders, 2009, p. 4), "engage in practices to build, deepen, and apply their knowledge of core ideas and crosscutting concepts" (NGSS, 2013, front page of the website), and "the practices of engineering and engineering design provide real-world, problem-solving contexts for learning and applying science and mathematics, as well as meaningfully bring in other disciplines" (Bryan, et al., 2016, p. 25). The definitions of STEM concepts, content knowledge and skills are interwoven with many aspects in most definitions. After several discussions, the two instructors found that these definitions could be divided into two subcategories, which were presence and usage. In order to apply this feature to lesson plan level, the two instructor changed the feature to *Role of STEM Concepts, Content Knowledge, and Skills—Presence and Usage*. Synthesized the definitions from the current literature, the definition of the *presence* is "core disciplinary STEM concepts and skills are considered as prior knowledge, and are naturally and meaningfully used/applied to solve problems or multiple STEM disciplines are difficult to distinguish as separate disciplines because they closely interdependent." As for *usage*, we defined it as "use of STEM content knowledge is used to analyze and interpret the problem. Content knowledge is integrated, synthesized or transformed into some kind of tools or solutions that can be transferred beyond the knowledge used to solve the problem."

Third, *learning outcome of STEM integration* in the descriptive framework (NRC, 2014) particularly emphasized the learning outcome of STEM integration. The framework suggested measurable outcomes in integrated STEM education could be individual STEM literacy and STEM identity. The framework pointed out "individual aspects of STEM literacy, for example, understanding of specific science or mathematics concept or awareness of how the STEM disciplines help shape our world, are measurable outcome" (NRC, 2014, p. 39), and "efforts to study outcomes related to STEM identity have focused on single subject rather than the broader concept of STEM" (NRC, 2014, p. 40). To apply this feature to lesson plan level, the two instructors changed the feature to *Role of Learning Outcomes.* As such, the two key points, STEM literacy and identity, from the descriptive framework (NRC, 2014) were combined into a working definition. The *role of the learning outcomes* was defined as "learning outcomes focus on interdisciplinary concepts and skills that are woven throughout when solving problems."

Fourth, *role of teachers* of Vasquez and her colleagues' (2013) framework pointed out the importance of teachers' role in integrated STEM education. Vasquez and her colleagues (2013) defined the role of instruction in transdisciplinary (the highest level) as "set goals, facilitate student learning across disciplines, and invite students to help shape the learning experience" (p. 74). Other literature also emphasized the importance of teachers' role in integrated STEM education. These definitions were "[providing] a real-world problem or task centers on an authentic issue or meaningful challenge" (Bryan et al., 2016, p. 25), and "pedagogies for the instruction of the mathematics and/or science content need to be student-centered pedagogies" (Moore et al., 2014, p. 43). The language of this feature could be directly used to evaluate lesson plan level. Therefore, the two instructors did not change the language of this feature, but added the type of the instruction. By combining the key points from the current literature, the *Role of Instructors, and Type of Instruction* was defined as "the instructor is a facilitator and provides enough directions/guidelines to engage students to solve a problem. Students determined the direction of the task that needs to complete."

After reviewing and unpacking current literature, authors, also as the instructors, identified two additional features: (5) *Role of the AFNR content knowledge* and (6) *Role of students' thinking* that we considered are particularly important to integrating STEM through AFNR. As authors stated in the previous section, AFNR challenges are real-life challenges. Currently, literature has not provided enough information for authors to differentiate the level of real-life challenges in STEM integration. Therefore, the two new features, the *Role of AFNR Content Knowledge* and the *Role of Students' Thinking*, helped the two instructors identify the presence and the purpose of using AFNR real-life challenges. The two instructors defined the highest level of the *role of AFNR content knowledge* as "AFNR serves as an integrator of STEM learning by focusing on a real-world problem that blends disciplines," and the *role of students' thinking* as "thinking is predominantly outside of the box with few to no boundaries that limit thinking. Students demonstrate systems thinking, critical thinking, creative thinking, and/or complex problem-solving."

The two instructors classified the six features of the highest level of the integrated STEM through AFNR rubric from current literature and instructors' expertise. However, when instructors communicated the highest level of STEM integration to students, students demonstrated that they had different interpretation of the six features. The integrated STEM through AFNR lesson plans that students developed showed variations in each feature. Based on the feedback from students, the two instructors used the framework of three approaches to design integrated STEM curriculum units (Vasquez, Sneider, & Comer, 2013) as a guideline to develop the three levels of the integrated STEM through AFNR rubric. The first, second, and third levels are Exploring, Developing, and Advancing STEM Integration through AFNR. All 27 lessons were coded using the rubric to validate the language and interpretation of the descriptive evidences of each level for each of the six features. In summary, Table 1 shows the six features and the description of each level of the six features of integrated STEM through AFNR rubric.

Table 1

Rubric of Levels of Integration and Features

Levels of Integration	Exploring STEM Integration	Developing STEM Integration	Advancing STEM Integration
Role of Integration in Learning Objectives	Learning objectives create awareness of STEM connections	Learning objectives develop STEM learning content/skills	Learning objectives apply STEM knowledge to solve problems
Role of the STEM Concepts, Content Knowledge, and Skills · Presence · Usage	Core disciplinary STEM concepts and skills are mentioned to point out the connections in different disciplines or one of the STEM disciplines is predominantly present. No strong evidence of using STEM content knowledge to solve problems. It is activity-driven. For example, the activity focuses on practicing engineering design process or problem solving, but no explicitly stated STEM content knowledge is needed to solve the problem.	Core disciplinary STEM concepts and skills are taught and/or practiced to bridge different disciplines or multiple STEM disciplines are distinctly present. Use of STEM content knowledge are explicitly taught to solve the problem. Content knowledge is fixed, students do not go beyond the knowledge as it exists in its disciplines.	Core disciplinary STEM concepts and skills are considered as prior knowledge, and are naturally and meaningfully used/applied to solve problems or multiple STEM disciplines are difficult to distinguish as separate disciplines because they closely interdependent. Use of STEM content knowledge is used to analyze and interpret the problem. Content knowledge is integrated, synthesized or transformed into some kind of tools or solutions that can be transferred beyond the knowledge used to solve the problem.
Role of Learning Outcomes	Learning outcomes merely focus on one discipline (one concept, and/or one skill).	Learning outcomes mainly focus on one discipline (one concept, and/or skill), but other disciplines are used to support the understanding of the core learning outcomes.	Learning outcomes focus on interdisciplinary concepts and skills that are woven throughout when solving problems.

Table 1

Rubric of Levels of Integration and Features

Levels of Integration	Exploring STEM Integration	Developing STEM Integration	Advancing STEM Integration
Role of the Instructor and Type of Instruction	The instructor merely gives directions or guidelines. Students follow "cook book" type of instruction to complete the task.	The instructor mainly gives directions or guidelines, but students have some freedom to determine the direction to complete the task in a controlled environment.	The instructor is a facilitator and provides enough directions/guidelines to engage students to solve a problem. Students determined the direction of the task that needs to complete.
Role of AFNR Content Knowledge	AFNR content is the primary focus of lesson.	AFNR provides a context for STEM learning or experiential learning process.	AFNR serves as an integrator of STEM learning by focusing on a real-world problem that blends disciplines.
Role of Students' Thinking	Thinking merely stays inside of the box (the discipline, or the concepts/skills that need to be learned), but may see outside of the box upon completion of the problem-solving process.	Thinking is mainly inside of the box, but occasionally steps out the box to draw connections from other disciplines to solve the problem.	Thinking is predominantly outside of the box with few to no boundaries that limit thinking. Students demonstrate systems thinking, critical thinking, creative thinking, and/or complex problem-solving.

As we pointed out, the highest level of STEM integration through AFNR rubric was developed based on the current literature and the instructors' expertise and praxis. In this section, we provided evidences for the first and second levels of STEM integration through AFNR from the students' lesson plans.

Role of Integration in Learning Objectives. Some students' integrated STEM through AFNR lesson plans focused their learning objectives on promoting awareness of STEM connection (Level 1). For example, in the lesson plans of *Where'd You Get That?! By-products of Animals in Agricultural Settings*, the overarching learning objective was "student understanding and knowledge through STEM-related activities by raising awareness of where by-products originate...." On the other hand, some of the learning objectives focused on developing STEM learning content and skills (Level 2). For example, in the lesson plans of the *Buzz on Bees*, the overarching learning objective was "students learn and apply key concepts and ideas about bee habitat and importance as it relates to agriculture and food production process."

Role of STEM Concepts, Content Knowledge, and Skills—Presence. In the presence of STEM concepts, content knowledge, and skills, some integrated STEM through AFNR lesson plans predominantly focused on one discipline (Level 1). For example, the second lesson plan of *Where'd You Get That?! By-products of Animals in Agricultural Settings* was about by-products of sheep. The lesson plan was designed for the preservice informal educators first reviewed 5 minutes of what students had learned from the previous lesson. Then, the preservice informal educators taught 10 minutes about how people sheared sheep to get wool, and how to spin wool into yarn. Then, the preservice informal educators spent 25 minutes to have students shave shaving cream off of a balloon using a craft stick. The balloon coated with shaving cream represented a sheep. Then, the preservice informal educators spent the last 5 minutes reviewing/asking students about the purpose of shearing a sheep, and usage of wool. On the other hand, some lesson plans focused on using STEM concepts and skills that were taught to bridge different disciplines (Level 2). For example, the second lesson plan of *The Great Forest Controversy*, the preservice informal educator first spent 5 minutes reviewing what students had learned in lesson one. Then, students did an activity about 40 minutes to explore how clear-cutting a forest affected different animals. Students studied animals' life history traits and decided how these traits influenced its habitat preference (biology content). Then, students used a forest map to decide how the animal responded to the effects of clear-cutting on their habitat. During the last 5 minutes, the preservice informal educator helped students to reflect on what they learned.

Role of STEM Concepts, Content Knowledge, and Skills—Usage. In the usage of STEM concepts, content knowledge, and skills, some integrated STEM through AFNR lesson plans were activity-driven, or in some cases, predominantly focused on introducing and practicing engineering design process without any content (Level 1). For example, in the fourth lesson of *Food and Water System*, the preservice informal educators discussed the difference between point and nonpoint source of water pollution. However, students did not need to use the knowledge that they have learned to complete the activity, which was asking students to design a technology from assorted craft supplies, such as straws, craft sticks, rubber bands, and pipe cleaners, which were used to catch (clean) sediments in and floating objects on the water. On the other hand, some lessons that reflected the use of STEM content knowledge were explicitly taught to solve the problem, but students did not go beyond the knowledge as it exists in its disciplines (Level 2). For example, in lesson two of the *Science with Stella the Great and Bruno Uptown Funk Boss*, students first learned the six essential nutrients required for a healthy canine diet. Then, students mimicked the engineering design process to design their dog food recipes. Students analyzed and read the actual dog food labels as they were conducting their research before they designed their recipes. Students needed to include the six essential nutrients in their dog food recipes by thinking about what ingredients that they wanted to use. Finally, students tested their dog food recipes by presenting their recipes to people who have dogs to see if they would buy the dog food that they designed.

Role of Learning Outcomes. Some integrated STEM through AFNR lesson plans focused the learning outcomes as one discipline/concept/skill (Level 1). For example, the learning outcome for the *Operation Separation* lesson plans was if students could recall and use the 5-steps engineering design process to select correct tools to separate salt and pepper. On the other hand, some of the lesson plans focused the learning outcomes on using different disciplines to support the understanding of the core learning outcomes (Level 2). For example, the learning outcome for the *Happy Cows, Happy House* lesson plans was to use engineering design to evaluate if the cattle husbandry that students designed included all the essential components for cows to survive.

Role of Instructor and Type of Instruction. Some preservice informal educators focused their teaching by asking students to follow their instruction step by step (Level 1). In this type of teaching, the preservice informal educators gave detailed guidelines for students to follow to complete the activities. For example, when preservice informal educators taught the *Where'd You Get That?! By-products of Animals in Agricultural Settings* lesson plans, students followed detailed step-by-step instructions. Students first put the wool into a bowl. Then, students chose what color to dye the wool. After that, students created clothing using the paper clothes as guides, and so on. For some lesson plans, the preservice informal educators gave more freedom for students to determine the direction to complete the task (Level 2). For example, in the lesson four of the *Science with Stella the Great and Bruno Uptown Funk Boss*, students needed to design and build an agility course for a dog. The preservice informal educators explained the materials that were provided to the students. Then, the preservice informal educators had students draw an agility course that they would like to build. After that, students used the materials that the preservice informal educators provided to build the course.

Role of AFNR Content Knowledge. Some integrated STEM through AFNR lesson plans used AFNR content as the primary focus of lesson (Level 1). The first lesson plan of *Agriculture & Food* was an example. In the lesson plan, agriculture was the only focus. On the other hand, some lesson plans used AFNR to provide context for STEM learning (Level 2). For example, both *The Great Forest Controversy* and *Exploring Your Natural World* used forestry to teach biological concept of animal traits.

Role of Students' Thinking. In some of the integrated STEM through AFNR lesson plans, students learned and practiced certain concepts and skills (Level 1). The lesson plans did not require students to think critically to solve a problem. For example, the lesson plans from *Where'd You Get That?! By-products of Animals in Agricultural Settings* did not ask students to think critically to make their final products. Students followed a step-by-step process and created almost identical final products. On the other hand, some lessons demonstrated that students would think mainly inside of the box, but occasionally stepped out the box to draw connections from other disciplines to solve the problem. For example, *Science with Stella the Great and Bruno Uptown Funk Boss*, students needed to apply what they had learned about six essential nutrients, heredity and traits of different dogs, and the importance of dog health and fitness to design an agility course. In this mini-unit, students needed to use the knowledge that they learned and maybe draw some knowledge from their personal experiences to design the agility course.

For Research Question 2, 27 integrated lessons representing 10 mini-units were reviewed and categorized into levels of STEM integration for each feature using the rubric (see Table 2). For the *Role of Integration in Learning Objectives*, eight lessons (30%) were identified as Level 1, 16 lessons (59%) were identified as Level 2, and three lessons (11%) were identified as Level 3. For the *Presence of the Role of the STEM Concepts, Content Knowledge, and Skill,* 15 lessons (56%) were identified as Level 1, nine lessons (33%) were identified as Level 2, and three lessons (11%) were identified as Level 3. For the for *Usage of the Role of the STEM Concepts, Content Knowledge, and Skill,* 10 lessons (37%) were identified as Level 1, 16 lessons (59%) were identified as Level 2, and one lesson (4%) was identified as Level 3. For the *Role of the Learning Outcomes*, 16 lessons (56%) were identified as Level 1, 10 lessons (41%) were identified as Level 2, and one lesson (4%) was identified as Level 3. For the *Role of the Instructor and Type of the Instruction*, 11 lessons (37%) were identified as Level 1, 15 lessons (59%) were identified as Level 2, and one lesson (4%) was identified as Level 3. For the *Role of the AFNR Content Knowledge,* 15 lessons (52%) were identified as Level 1, 11 lessons (44%) were identified as Level 2, and one lesson (4%) was identified as Level 3. For the *Role of the Students' Thinking,* 17 lessons (59%) were identified as Level 1, nine lessons (37%) were identified as Level 2, and one lesson (4%) was identified as Level 3.

Table 2

Levels of STEM Integration for Lessons and Mini-Units

Mini-Unit	Lesson No.	Lesson Mean (SD)	Unit Mean (SD)
Happy Cow, Happy House	1	2.0 (.00)	2.0 (.00)
The Buzz on Bee	1	1.3 (.45)	1.4 (.47)
The Buzz on Bee	2	1.6 (.49)	
Operation Separation	1	1.4 (.49)	1.4 (.49)
The Great Forest	1	2.0 (.00)	2.3 (.00)
The Great Forest	2	2.0 (.00)	
The Great Forest	3	3.0 (.00)	
By-product Animals	1	1.3 (.47)	1.1 (.12)
By-product Animals	2	1.0 (.00)	
By-product Animals	3	1.0 (.00)	
By-product Animals	4	1.0 (.00)	
Exploring Natural World	1	2.0 (.00)	2.0 (.00)
Exploring Natural World	2	2.0 (.00)	
Food & Water Cycle	1	1.3 (.47)	1.1 (.21)
Food & Water Cycle	2	1.2 (.37)	
Food & Water Cycle	3	1.0 (.00)	
Food & Water Cycle	4	1.0 (.00)	
Agriculture & Food	1	1.0 (.00)	1.5 (.00)
Agriculture & Food	2	2.0 (.00)	
Health Food & Life	1	1.3 (.45)	1.6 (.48)
Health Food & Life	2	1.4 (.49)	
Health Food & Life	3	1.5 (.50)	
Health Food & Life	4	2.3 (.47)	

Table 2 (continued)

Levels of STEM Integration for Lessons and Mini-Units

Mini-Unit	Lesson No.	Lesson Mean (SD)	Unit Mean (SD)
Science with Stella	1	1.3 (.45)	
Science with Stella	2	1.9 (.35)	1.8 (.29)
Science with Stella	3	2.0 (.00)	
Science with Stella	4	2.1 (.35)	
Grand Means	27 lessons	1.6 (.20)	1.6 (.20)

Note. Level 1 = Exploring, Level 2 = Developing, Level 3 = Advancing

Overall, lessons were developed to help students *explore* and *develop* STEM integration through AFNR. The overall mean of the 10 sample mini-units represented by 27 lesson plans was 1.6 (*SD* = .20; Table 2). We noticed a difference in levels of integration based students' previous experiences with formal and nonformal/informal teaching experiences. Integrated lesson plans developed by preservice educators with previous teaching experiences in non-formal and informal settings were at a higher level of integration (*M* = 1.65) compared to their peers had previous teaching experiences in formal education setting (*M* = 1.18). Students who had no previous teaching experiences developed integrated STEM lessons at a level similar to their peers who had nonformal or informal teaching experiences (*M* = 1.58).

Mini-units that had more than two lesson plans provided scaffolding to help students learn STEM knowledge in the first lessons and then apply STEM knowledge and skills to solve a problem in the later lessons. As such, the first lesson plan always had the lowest score, but the last lesson plan had the highest score. These mini-units were *Agriculture & Food*; *Buzz on Bees*; *Exploring Your Natural World*; *Healthy Food, Healthy Life*; S*cience with Stella the Great and Bruno Uptown Funk Boss*; and, *The Great Forest Controversy* (see Table 2). Only one mini-unit's last lesson plan, *The Great Forest Controversy: Animals Stuck between Media, Science, and Management*, reached Level 3 in each feature of integrated STEM through AFNR rubric.

Conclusions & Implications

The research study further expanded the knowledge base by expanding a framework to identify levels and features of integrated STEM using AFNR as a context in four ways. First, three levels were identified to provide more accessible language understand there is a continuum of integrating STEM through AFNR. For example, preservice informal educators developed lessons that helped their students explore (Level 1), develop (Level 2), or advance (Level 3) integrated STEM learning through AFNR. Although Vasquez and her colleagues (2013) developed three approaches, multidisciplinary, interdisciplinary and transdisciplinary learning, to design integrated STEM curriculum units, preservice informal educators found the languages were ambiguous and unclear when they attempted to use the approaches to plan their lessons to represent the different levels of integration. This findings support that teachers may not have the knowledge to effectively teach STEM (Baker, Bunch, & Kelsey, 2015) or clarity in how to teach STEM integratively (Breiner, Harkness, Johnson, & Koehler, 2012). As such, the rubric can be used by teacher educators to help dissect the structure of integrated STEM lesson plans and unpack students' conceptions of integrated STEM. Moreover, the rubric can be used to evaluate more specific features and evidences of integrated STEM learning across the three levels.

Second, preservice informal educators developed lessons that reached Level 2 for three features, *Role of Integration in Learning Objectives*; *STEM Concepts, Content Knowledge, and Skills—Usage;* and *Role of Instructor and Type of Instruction*, but their lessons reflected Level 1 integration regarding the other four features, *STEM Concepts, Content Knowledge, and Skills—Presence; Role of Learning Outcomes; Role of AFNR Content Knowledge*; and *Role of Students' Thinking*. This indicates the preservice informal educators' integrated STEM through AFNR lesson plans focused on teaching STEM content and skills, and wanting students to directly use the content and skills that are taught to solve the problem. The lesson plans did not go beyond teaching and using AFNR content and skills. These Level 1 lessons could potentially move to Level 2 with some modifications and more focus on role of how STEM and AFNR content worked together in solving the real-world problem by helping students think outside of boxes. Teacher educators may use the rubric to more accurately evaluate integrated STEM lesson plans and hopefully have more meaningful conversations and reflections about integrated STEM learning experiences, especially regarding the presence of STEM concepts, content knowledge and skills, role of learning outcomes, role of AFNR content knowledge, and role of students' thinking.

Third, preservice informal educators' integrated STEM through AFNR lesson plans attempted to achieve the goal, to some degree, of using real-world problems to connect students' learning and use the content knowledge and skills to solve the problem (Bryan et al., 2016; NRC 2014). This conclusion supports current literature that real-world problems are used to support integrated STEM learning (Bryan et al., 2016), but the authenticity, complexity, and structure of the real-world problem can lead to different approaches of integrated STEM learning. For example, we used two lesson plans from *The Great Forest Controversy* and *Science with Stella the Great and Bruno Uptown Funk Boss* as examples to provide suggestions on how to connect not only AFNR content and skills but also to other disciplines. Among the 27 lesson plans, only one lesson plan, *The Great Forest Controversy: Animals Stuck Between Media, Science, and Management*, reached Level 3 in all features. The lesson plan was the last lesson plan in a mini-unit. The lesson plan engaged students to evaluate and analyze the actual data about clear-cutting that were collected by a group of researchers. Students needed to apply the knowledge that they learned from the previous lesson plans (lesson one and lesson two) to propose and justify appropriate management techniques, and explain the process that they used to develop an appropriate management plan in a boardroom activity. As for the *Science with Stella the Great and Bruno Uptown Funk Boss: Ag Fitness Dog Gym*, although the lesson plan reaches Level 3 of the *Role of integration in learning objectives*, the rest of features were at Level 2. The lesson plan also was the last lesson plan in a mini-unit, and it had an intention to connect students to use what they learned to solve a problem. The lesson plan was structured by having the students design an agility course for the dogs to run through, and the students have to use what they have taught in prior lessons (lesson one to lesson three) to design the agility course. Compared the two mini-units, *The Great Forest Controversy* asked students to evaluate and analyze the actual data that were collected from scientists to critically think the real-world challenge. Students needed to use content knowledge and skills from other disciplinary, such as math and science, to solve the problem. However, the real-world challenge in the *Science with Stella the Great and Bruno Uptown Funk Boss* either explicitly helped students connect other disciplinary content and skills, or went beyond to use their imagination when they tried to design the agility course for the dogs. To us, one is a real-world problem, but the other one is a problem that tried to mimic real-world problem. The design problem that *The Great Forest Controversy* used meaningfully integrated agriculture, science and math, but the design problem that *Science with Stella the Great and Bruno Uptown Funk Boss* used seemed lack of that effort. The rubric may help teachers focus, frame, and scaffold real-world problems to help their students apply STEM concepts, content knowledge, and skills in meaningful ways so students can see how STEM was applied to solve the AFNR-related problem integratively (Breiner, Harkness, Johnson, & Koehler, 2012).

Finally, preservice informal educators who had previous teaching experience in nonformal or informal education achieved higher scores of integrated STEM through AFNR lessons than those who had formal teacher education training and previous teaching experience in formal classrooms. One assumption was because the integrated STEM through AFNR lesson plans that the preservice informal educators developed were for afterschool programs. Therefore, individuals who had teaching experiences in non-formal educational settings were advantaged to develop the lesson plans for afterschool programs. Another assumption is because formal teacher education training is more structured and focused on specific content standards. Individuals who received formal teacher education training more likely encountered challenges to consolidate the information that they learned in the course about integrated STEM through AFNR because it was different than the previous lesson planning instruction they learning in a formal teacher preparation program. Teacher educators should acknowledge the philosophical assumptions and differences in instructional practices of integrated STEM learning than what preservice educators may have been previously taught in formal teacher education courses.

Although teaching of science and math by using engineering design practices is most commonly discussed in the literature (Bryan et al., 2016; Moore et al., 2014; NGSS, 2013; NRC 2014; Wang, Moore, Roehrig, & Park, 2011), STEM integration in the agricultural education literature has received limited attention (e.g., Stubbs & Myers, 2016). However, AFNR certainly aligned with existing features of integrated STEM, and AFNR educators and communities undoubtedly have potential to prepare people to solve complex interdisciplinary problems (Andenoro, Baker, Stedman, & Weeks, 2016), which is one of the major goals of STEM integration regardless if it has been discussed in the science or engineering education (Bryan et al., 2016; Moore et al., 2014; NGSS, 2013; NRC 2014). Through a review of STEM integration framework, and unpacking of the integrated STEM through AFNR lesson plans that were developed by preservice informal educators, the study addressed the gap of absent a tool/rubric that provides practical guidance for researchers and educators to design and evaluate integrated STEM through AFNR lessons. The three levels of the six features of integrated STEM through AFNR rubric served as a practical and effective tool for the instructors to evaluate integrated STEM through AFNR lesson plans and to communicate and articulate the criteria about the level of integrated STEM through AFNR lesson plans. By using the three level of the six features of integrated STEM through AFNR rubric to investigate the integrated STEM through AFNR lesson plans that the preservice informal educators developed, the two instructors had a better understanding about what integrated STEM through AFNR meant to preservice informal educators, and were able to point out specific features that the preservice informal educators can be improved in their lesson plan design.

Recommendations for Further Research

The rubric may provide practical guidance for researchers and educators to design and evaluate integrated STEM through AFNR lessons. Although Level 3 is the highest level of integration, the authors do not infer that all lesson plans in a mini-unit need to achieve Level 3 in all the six features to be the most effective integrated learning experience. In fact, we argue two key points. First, we question the extent an integrated STEM through AFNR mini-unit can have all the lesson plans that achieve Level 3 for all six features. Second, integrated STEM through AFNR lessons or mini-units could be different combinations of levels for each feature and still be effective. More research is need in this area to better unpack and understand effective integrated STEM learning experiences through AFNR, especially more work should focus on better understanding how to focus, frame and scaffold real-world problems that would facilitate effective integrated STEM learning experiences. Moreover, although potential biases were monitored, the potential biases of two instructors as researchers may have influenced the results. As such, we suggest more educational researchers use the rubric to determine its validity in multiple contexts, including other contextualized applications of STEM (e.g., medical, transportation), educational settings (i.e., formal & informal), and grade levels. Although the lessons were developed and tested with upper-level elementary students, the rubric should be tested for age-appropriateness across K-12 audiences. Further, the number of lesson plans is a limitation of the study. It is possible that the 27 lessons of integrated STEM through AFNR did not represent all the possibilities of examples of STEM integration through AFNR. Therefore, the rubric might be tailored to evaluate a certain type of integrated STEM through AFNR. More lesson plans need to be examined to ensure the rubric has external validity. The research study may have been limited by the approach and strategies used in the course. Therefore, the rubric should be studied in different courses and approaches, such as teaching preservice and in-service agriculture and/or STEM teachers to develop integrated STEM lessons. Finally, future research studies should triangulate data sources to include observations of integrated STEM lessons and student outcomes of lessons. This would further validate the utility and empirical evidence of teaching STEM through AFNR.

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