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Research Article

Preservice educators' interpretations and pedagogical benefits of a STEM integration through agriculture, food and natural resources rubric

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In the K-12 settings, teachers are encouraged to teach STEM subjects using a more integrated approach, and not be treated as stand-alone disciplines. STEM integration represents a way to think about curriculum change. It is a concept of how to restructure what is taught and what students learn. The nature of STEM disciplines no doubt creates certain challenges for STEM teachers. Despite researchers having made extensive progress in understanding of STEM integrative approaches, there are considerable barriers that relate to revolution of curriculum, assessment, and teaching practices in the K-12 STEM education system. For example, tools for assessing integrated STEM instruction have been developed, yet there has been limited implementation or adoption of teacher assessment for integrated STEM instruction. The purpose of this action research study was to understand how the preservice educators interpreted the language in the integrated STEM through AFNR rubric that was developed in 2018 (Wang & Knobloch, 2018). Four themes emerged when examining how preservice educators interpreted and applied the rubric for integrated STEM education: (1) Prejudgments based on prior knowledge and experiences, or course expectations informed interpretation of levels of STEM integration; (2) limited to no teaching experience resulted in novice interpretation of the integrated STEM lessons; (3) level one (Exploring) was a clean cut, but gray areas existed in interpreting levels two (Developing) and three (Advancing); and, (4) the rubric was a tool that helped preservice educators reflect on the purpose of teaching certain content/concepts. Preservice educators also gave recommendations to improve the rubric. Additionally, they recommended more scaffolding, examples, expert modeling, group discussion, and experiences when learning to use the rubric.

Keywords: STEM integration; Action research; Interdisciplinary learning; Lesson plan assessment

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1. Introduction

Over the past decade, science, technology, engineering, and mathematics (STEM) education has experienced a substantial surge in reformation (National Academy of Engineering [NAE] & National Research Council [NRC], 2009, 2014). In K-12 settings, teachers are encouraged to teach

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STEM subjects using a more integrated approach, rather than as stand-alone disciplines. STEM integration attempts to break down traditional subject-specific instruction and segmented curriculum to focus on the importance of interdisciplinary approaches through an emphasis on real-world situations and problem-solving techniques within social, cultural, economic, and environmental contexts (Bryan et al., 2016; Bybee, 2010; NRC, 2012). Some compelling arguments that drive STEM integrative approaches include simulating real-world STEM issues and constructing authentic learner-centered, problem-solving learning environments, equipping students with STEM knowledge and 21st century skills, and preparing students to become STEM-literate citizen and ready for joining STEM workforce (Moore et al., 2020; Moore, et al., 2014; NAE & NRC, 2014; National Science & Technology Council 2018). Despite researchers having made extensive progress in understanding of STEM integrative approaches, there are considerable barriers that relate to revolution of curriculum, assessment, and teaching practices in the K-12 STEM education system (Herschbach, 2011). One of the biggest challenges is the lack of a unified definition and implementation model (Moore et al., 2020; Scherer, et al., 2019). Professional societies and researchers continue to wrestle with what constitutes STEM integration. The divergence of agreements includes the number of disciplines (e.g., two to four of the disciplines), implementation strategies (e.g., a single class, unit, or lesson), levels of integration (e.g., content or context integration), and role of individual disciplines (e.g., core content or process) (Moore et al., 2020).

In K-12 settings, STEM integration represents a way to think about curriculum change. It is a concept of how to restructure what is taught and what students learn (Herschbach, 2011). The nature of STEM disciplines no doubt creates certain challenges for STEM teachers. For instance, science and mathematics are considered as foundational and formal knowledge and are aligned with standardized tests and discipline-based structure and rules, as such it could be argued that science and mathematics are focused on preparing high school students for college. In contrast, technology, engineering, and agriculture, are recognized as career and technical education (CTE) career clusters and thus considered to be practical subjects that apply science and mathematics concepts. It could be argued that CTE teachers focus on preparing high school students for careers and the workforce (Wang & Knobloch, in press). Teachers, who teach different STEM subjects, conceptualize STEM integration distinctively and are unclear on how to navigate challenges to transition to STEM integration (Wang et al., 2020).

We started our journey to teach preservice educators how to integrate STEM subjects using agriculture, food, and natural resources (AFNR) as a CTE context in 2016. We were open and flexible in our approach and provided different examples of how to blend multiple disciplines in multidisciplinary and interdisciplinary ways. Preservice educators reflected on their conceptualizations of integrated STEM and wrote rationales to explain and justify the approach and strategies to blend different subject matters. We used the term preservice educators because they could teach in non-formal educational settings, whereas, preservice teachers are commonly aligned with formal education. From our understanding of integrated STEM, the integrated STEM lessons that the preservice educators developed were not really STEM integrated lessons when we started teaching the course. Most examples were activity-based and multidisciplinary in nature, and some were primarily single discipline-based lessons that showed potential connections to science and math. When we asked students to explain why they thought their lessons were integrated lessons, they over-estimated the levels of disciplinary blending. As instructors, we spent three years (from 2016 to 2018) reflecting on the initial teaching experience and delineated criteria, levels, and evidence of integration. This resulted in a rubric (Appendix A) that we developed to help students better understand integrated STEM in developing their lessons (Wang & Knobloch, 2018). We used the rubric to evaluate previous preservice educators' lesson plans so students, who took course in 2020 and 2021, could apply and evaluate levels of STEM integration. This provided us feedback on how preservice educators were using the rubric. Although the rubric provided preservice educators more clarity, we could see that preservice educators wrestled with the interpretation of the language of STEM integration and what they interpreted as STEM integration in the lesson plans. Although rubrics have been used in different content domains (e.g., writing; business) and contexts (e.g., K-12 & higher education) for the purpose of evaluating assignments (Panadero & Jonsson, 2013), we were also interested in knowing how the preservice educators benefited from using the rubric as a pedagogical tool.

1.1. Purpose and Research Questions

The purpose of this action research study was to understand how the preservice educators interpreted the language in the integrated STEM through the AFNR rubric (Wang & Knobloch, 2018) and the benefits from using the rubric as a pedagogical tool. The following research questions guided the study:

1. How did preservice educators interpret and apply the rubric for integrated STEM through AFNR education?
2. How did preservice educators benefit from using the rubric and what recommendations did the preservice educators share to improve the rubric?

2. Literature Review and Conceptual Framework

2.1. Preservice Educator Training in Integrated STEM

How we structure teacher education frames preservice educators' teaching philosophy, beliefs, and ways of teaching. Domain-specific teacher education (e.g., teacher licensure programs) prepares educators to conceptualize STEM knowledge as isolated concepts in education, and changes are needed regarding integrated STEM education (Corp, et al., 2020; Schwartz & Gess-Newsome, 2008). Without experiencing STEM integrative approaches at the preservice stage, interpretation of integrated STEM education is often left to the district, and educators do not have clear understandings of integrated STEM education when they begin their careers (Guzey et al., 2020; O'Brien et al., 2014). Streamlining the experience between preservice educators and practicing professionals is needed to transfer integrated STEM instructions from novelty intervention to academic centerpiece (Gardner, 2017).

Preservice educators should be taught integrated STEM education more explicitly (Guzey et al., 2020). In preparing educators to understand and teach integrated STEM, early exposure to STEM integration and interdisciplinary collaboration is necessary (Shernoff et al., 2017). Calling for transformation of teacher education by focusing on STEM integrated approaches and interdisciplinary collaboration, some programs have added integrated STEM teaching methods into their curriculum either as a core or elective course. At the elementary level, Radloff and Guzey (2017) studied elementary teachers' conceptions of integrated STEM through video-based interventions in a 15-week teaching method course. The course engaged preservice educators in viewing, analyzing, and reflecting five 15-minute integrated STEM teaching video clips. At the end of the course, the preservice educators were asked to create five lesson plans to implement during their student teaching. Radloff and Guzey found that after the course, students' conceptions of STEM integration aligned more with the six central components of every integrated STEM unit, which are: (1) relevant and engaging contexts, (2) engineering design challenges, (3) elements of failure and redesign, (4) standards-based math and/or science aims within real-world problems, (5) student-centered teaching approaches, and (6) an emphasis on teamwork and communication abilities (Moore et al., 2015). Bartels et al. (2019) collaborated with 13 elementary education preservice educators to design instruction that involves the integration of mathematics and science. To model STEM lessons, Bartels et al. shared various STEM lessons as examples in the course. Similar to Radloff and Guzey (2017), at the end of course, the preservice educators planned and delivered a STEM lesson to elementary students as their final exam. The result showed that the majority of the preservice educators developed their integrated STEM lessons to include engineering design components, such as creating a plan, searching on the Internet for ideas, designing or building something, and then testing it and collecting data. There are similarities and differences between the two courses (Bartels et al., 2019; Radloff & Guzey, 2017), and preservice educators' lessons showed that they developed various conceptual understanding about STEM integration.

As for secondary education, Ryu et al., (2018) developed an integrated STEM teaching method course to teach secondary preservice educators in the STEM disciplines. The course collaborated with in-service educators (e.g., technology and mathematics) to provide field experience for the preservice educators. Students, who took the course, worked with the in-service educators to develop and teach an integrated STEM mini-unit (3-5 lessons). The course was taught using an interdisciplinary approach. Students learned general integrated STEM knowledge, such as reform-oriented discipline-general pedagogical approaches and reflected on discipline-specific instructional approaches. At the end of the course, the preservice educators used different approaches to develop their integrated STEM lesson plans. They drew upon resources and ideas from their own experience, classroom observations, and the Internet. Additionally, to-be-learned contents were almost always placed at the beginning of the mini-unit and engineering design tasks were almost always at the end.

In summary, Corp and her colleagues (2020) conducted a large-scale literature review and concluded only a few studies describe limited results on students' ability to create integrated STEM lessons. Evidence shows that preservice educators overestimated their abilities to develop higher levels of STEM integration lessons (e.g., transdisciplinary), and they commonly encountered barriers to align their learning with integrated STEM teaching strategies (Guzey et al., 2020; Wang & Knobloch, 2020). Although adding an integrated STEM teaching methods course in the curriculum exhibited promising results for increasing preservice educators' confidence about planning integrated STEM lessons, the limited examples that we provided in this section also demonstrated the integrated STEM lessons that preservice educators developed had various qualities.

2.2. Assessments of Integrated STEM Approaches

Assessment tools should be developed that holistically and accurately assess student outcomes of integrated STEM education to make improvements to integrated STEM instruction (Guzey et al., 2020). Assessment tools are needed to assess integrated STEM instruction and learning in other disciplines, including CTE contexts. Specifically, clearer definitions and pedagogical alignment of integrated STEM are needed in agricultural education (Scherer et al., 2019; Stubbs & Myers, 2016). Stubbs and Myers (2016) recommended teacher educators teach preservice educators to have accurate definitions and conceptions of STEM integration in agricultural education. Moreover, preservice educators shared how their lack of pedagogical knowledge and experiences (i.e., novice understanding of lesson planning, STEM content, and STEM integration) played a role in how they critiqued and developed their integrated STEM lessons (Rice & Kitchel, 2018).

Tools for assessing integrated STEM instruction have been developed (Walker et al., 2018), yet there has been limited implementation or adoption of teacher assessment for integrated STEM instruction. Rubrics that assess students' performances need to account for the extent students were able to demonstrate evidence of integrated STEM learning (Douglas et al, 2020). Accessible language plays an important role in helping students understand and use rubrics for their learning and development (Andrade, 2001). Moreover, rubrics can be interpreted in multiple ways. Some are general and some are more task specific. The level of specificity of rubrics may be the most important characteristic of rubrics. For example, general rubrics can be used to help students learn and also to evaluate their performance, whereas task specific rubrics are more oriented toward evaluating performance (Bookhart, 2018). Further, substantive criteria help students focus on the quality of their work compared to trivial or surface-level criteria (e.g., quantity of effort; Bookhart, 2018).

Panadero and Jonsson (2013) reviewed 21 studies, and synthesized the pedagogical benefits of rubrics, which included increased transparency (Andrade & Du, 2005; Reynolds-Keefer, 2010), reduced anxiety (Kuhl, 2000; Wolters, 2003), facilitated the feedback process (Andrade & Du, 2005; Schamber & Mahoney, 2006), improved students' self-efficacy (Panadero et al, 2012), or supported student self-regulation (Andrade & Du, 2005; Panadero, 2011). Although research studies support positive outcomes, more research on rubrics is needed to explore how students actually use rubrics (Panadero & Jonsson, 2013) and the performance-level descriptions (Bookhart, 2018). Moreover, researchers should study how rubrics help students monitor their work, make self-assessment judgments (Bookhart, 2018), and be used to effectively help students develop and apply targeted skills and outcomes (Andrade, 2001).

2.3. Conceptual Framework: The Integrated STEM through AFNR Rubric

Although there are various definitions, we defined integrated STEM education as "intentionally and purposively blending multiple disciplines (i.e., academic and vocational) to help students meaningfully learn and apply academic content through real-world problems framed in designed complex systems and grounded in career and technical contexts that facilitate multidisciplinary, interdisciplinary, or transdisciplinary learning for the development of life-long and workforce development connections and skills" (Wang & Knobloch, in-press).

Through reviewing, analyzing, and unpacking literature, the authors (also as the course instructors) developed the integrated STEM through AFNR rubric (Wang & Knobloch, 2018). The rubric consists of seven criteria: (1) role of integration in learning objectives; (2) role of the STEM concepts, content knowledge, and skills - presence; (3) role of the STEM concepts, content knowledge, and skills - usage; (4) role of learning outcomes; (5) role of the instructor and type of instruction; (6) role of AFNR content knowledge; and (7) role of students' thinking. Adapted from Vasquez et al.'s (2013) framework, the rubric has three levels: Exploring, Developing, and Advancing. For example, in the role of integration in learning objective, Level 1 (Exploring) is creating awareness of STEM connections as the exploring. Level 2 (Developing) is developing STEM learning content/skills and Level 3 (Advancing) is applying STEM knowledge to solve problems. The seven criteria are explained across the three levels in Appendix A.

3. Research Methods

3.1. Action Research

Action research was chosen as the research method for this study to examine, reflect, and improve the integrated STEM through AFNR rubric. Action research involves "a process of systematic reflection, enquiry and action carried out by individuals about their own professional practice" (Frost, 2002, p. 25). Action researchers aim to understand, to evaluate and ultimately to apply research to improve educational practice (Bassey, 1998; Smoekh, 1995). The authors co-taught integrated STEM through the AFNR teaching method course. The two instructors had different, yet complementary, teacher education training and professional teaching experiences. One instructor has a doctorate degree in science education with an emphasis on integrated STEM education and teacher professional development. The other instructor has a doctorate degree in agricultural education (CTE) and had previously taught a teaching methods course with an emphasis on learner-centered teaching strategies. The two instructors 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 students through AFNR teaching method course. The instructors framed this innovative course as interdisciplinary learning (Ivanitskaya et al., 2002) for the development of integrated STEM through AFNR mini-units (3-5 lessons). The instructors engaged in 30 hours of critical reflection during and after the course was taught (Kraft, 2002) each year for two years (2020 and 2021).

Based on our conceptual and reflection-in-practice knowledge and three years of teaching experience, the rubric was published (Wang & Knobloch, 2018) and we were able to use it to establish baseline knowledge and experiences of the preservice educators. Although the authors studied preservice educators' lessons and levels of STEM integration (2018) and preservice educators' beliefs regarding development of their lessons (2020), the authors did not conduct any previous research on the rubric that is used as an instructional tool, such as how students actually used the rubric and how the rubric helped students monitor their work. As action researchers, we were interested in learning how preservice educators interpreted the rubric and how they benefited from the rubric as a pedagogical tool. Based on their interpretations and experiences, we were interested in knowing if the preservice educators perceive any aspect of the rubric could be changed or how it could be used more effectively in helping the preservice educators better understand STEM integration through AFNR.

3.2. Integrated STEM through AFNR Teaching Method Course and the Instruction

The integrated STEM through AFNR teaching methods course was a three-credit, semester-long graduate-level course. The course is one of the selective courses for acquiring a STEM certificate. The course consists of 3-hour weekly sessions for 15 weeks. The course particularly serves students who are interested in becoming educators for both formal and non-formal settings and wanting to learn how to teach STEM through AFNR. Although the course is a teaching methods course, instead of teaching specific methods, the instructors focus on different approaches to integration. 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 based on their perceptions of integrated STEM through AFNR.

The course content included introduction to STEM and AFNR and the nature of S, T/E, M as single disciplines (weeks 1-4), examples of integrated STEM through AFNR (weeks 5-6), developing integrated STEM through AFNR mini units and assessment tools (weeks 7-10), micro and field teaching (weeks 11-13), and reflecting on implementation and presenting final mini-units (weeks 14-15). After the integrated STEM through AFNR rubric was developed and published in 2018, the rubric was used in week six (2020), and week nine (2021) to serve as a tool that helped students critique integrated STEM through AFNR mini-units. In 2020, the rubric was used after introducing the nature of S, T/E, M and examples of integrated STEM through AFNR lessons. Two integrated STEM through AFNR mini-units, Byproducts and the Great Forest (Table 1) were used as examples for students to critique in the class. After first implementing the rubric in 2020, the instructors engaged in extensive self-reflections and discovered that it was too soon to introduce the rubric in week six. In 2021, the instructors moved the critiquing mini-units to week nine, which students had experienced multiple examples of integrated STEM through AFNR approaches, and they were at the later stage of developing their own mini-units. The same two mini-units (Table 1) were also used in 2021.

3.3. Participants

Five graduate students (4 MS, 1 PhD) participated in the study. Three were men and two were women. Three participants took the integrated STEM through AFNR course in 2021, and two participants took the course in 2020. Although the participants reported that they had no or limited teaching experience and knowledge about STEM integration prior to taking the course, they should have a certain understanding of based principles and strategies of integrated STEM through AFNR prior to using the rubric and critiquing the mini-units. The participants' undergraduate majors include animal science, forestry and natural resources, agricultural economics, and horticulture (Table 2).

3.4. Ratings of Levels of STEM Integration in the Rubric

During the class, preservice educators evaluated the two mini-unit examples, Byproducts and the Great Forest, using the integrated STEM through AFNR rubric. The course instructors also rated the two mini-unit examples using the rubric. Tables 3 and 4 summarize the preservice educators' ratings and instructors' ratings of the lessons and mini-units. Through this class exercise, the

Table 1
Examples of Integrated STEM through AFNR Mini-units

Mini-Unit	No. of Lessons	Overall Learning Objectives	Brief Description
Byproducts	4	1. Develop an animal by-product using the engineering design process, while keeping proper documentation. 2. Construct a mock production process to represent of a by-product from start to finish on a large scale. 3. Connect by-products within respective species.	This unit begins with basic recognition of everyday products and will be broken down into four lessons that will focus those directly related to swine, cattle, bees and sheep. For each individual lesson, students will go through the process to make a specific by-product. For example, lesson 3 incorporate bees and the by-products associated with them, including beeswax which can be found in crayons. The students simulate the process and create their own lip balm.
The Great Forest	3	1. Investigate the impact of a clearcut in southern Indiana on the whole bird population and abundance of individual species 2. Explore how a species' life history traits influence its habitat preference 3. Practice using data and knowledge about a natural system to propose appropriate management techniques using the engineering design process	The unit begins with students critically investigate how both the total bird population and different forest animals individually respond to a clearcut timber harvest. Students discuss the importance of forests, the necessity of forest products (wood, paper, etc.), and watching an anti-logging video. The unit then transitions into several activities using real data from researchers in southern Indiana to explore the effects of clearcuts on both the total number of bird species and individual animals' abundance. Finally, students participate in a mock boardroom activity and use the engineering design process to decide as a class the best management plan for a southern Indiana forest.

Table 2
Participants Demographic Information

Name (Pseudonym)	Mindy	Yuki	JP	Denny	Scott
Gender	F	F	M	M	M
Degree	MS	MS	MS	MS	PhD
Undergraduate Major	Animal Science	Animal Science	Horticulture	Forestry and Natural Resources	Agricultural Economics
Years	2021	2021	2021	2020	2020
Teaching Experience	TA animal science	None	None	Lab assistant in a college	4-H guest instructor

**Note:* TA = Teaching Assistant

instructors observed that preservice educators rated the lessons and mini-units higher than they rated the lessons. This class exercise prompted the instructors to pursue this action research study to better understand the preservice educators' interpretations of using the rubric.

Table 3
The Rating of the Byproducts Mini-unit

Mini Unit	*Byproducts (Instructors)*					*Byproducts (Students)*				
(Lessons)/Unit	L1	L2	L3	L4	**U**	L1	L2	L3	L4	**U**
Learning Objectives	2	1	1	1	**1.25**	1.75	1.5	1.75	1.5	**1.60**
STEM Connections (Presence)	1	1	1	1	**1.00**	1.25	1.25	1.75	1.75	**1.50**
STEM Connections (Usage)	1	1	1	1	**1.00**	1.25	1.25	1.75	1.75	**1.50**
Learning Outcomes	1	1	1	1	**1.00**	1.4	1.6	2	2	**1.75**
Instruction	2	1	1	1	**1.25**	1.88	1.75	1.75	1.25	**1.66**
AFNR Content	2	1	1	1	**1.25**	1.75	1.75	1.75	1.75	**1.75**
Student Thinking	1	1	1	1	**1.00**	1.5	1.25	1.5	1.25	**1.36**
Overall Mean	1.43	1.00	1.00	1.00	**1.11**	1.54	1.48	1.75	1.61	**1.59**

**Note*: L1 = Lesson 1, L2 = Lesson 2, L3 = Lesson 3, L4 = Lesson 4, U = Unit

Table 4
The Rating of the Great Forest Mini-unit

Mini Unit	*The Great Forest (Instructors)*				*The Great Forest (Students)*			
(Lessons)/Unit	L1	L2	L3	**U**	L1	L2	L3	**U**
Learning Objectives	2	2	3	**2.30**	3	2.75	2.75	**2.83**
STEM Connections (Presence)	2	2	3	**2.30**	2.25	2	2	**2.08**
STEM Connections (Usage)	2	2	3	**2.30**	2.25	2	2	**2.08**
Learning Outcomes	2	2	3	**2.30**	2.75	2	2.5	**2.42**
Instruction	2	2	3	**2.30**	2.5	2.75	3	**2.75**
AFNR Content	1	2	3	**2.00**	2.5	2.25	2.25	**2.33**
Student Thinking	2	2	3	**2.30**	2.25	2.25	2.75	**2.42**
Overall Mean	1.86	2	3	**2.26**	2.50	2.29	2.46	**2.42**

**Note:* L1 = Lesson 1, L2 = Lesson 2, L3 = Lesson 3, U = Unit

The ratings were assigned through the progression of the rubric: (1) Exploring, (2) Developing, and (3) Advancing. To ensure inter-coder reliability, the course instructors coded the two mini-units separately and then met to compare and discuss any differences in ratings. After two rounds of testing in this manner, the two instructors reached agreement. In 2020 and 2021, before coming to the class, the preservice educators read the integrated STEM through AFNR mini-unit examples (Byproducts and/or The Great Forest) and worked as teams to collaboratively rate each lesson in the class. They shared what they have learned about the mini-units and discussed the levels of integration for each category at both the lessons and overall mini-units. The length of the activity was about 1 hour and 20 minutes. Means were computed for the preservice educators' ratings of the lessons and units. Overall, the preservice educators' ratings were higher than the instructors' ratings at the lesson and unit level for both mini-units (Table 3 and 4).

3.5. Data Collection

Preservice educators completed course assignments, which were data sources for the study. Data sources included final mini-units that the participants developed through the course, reflection, and a post-course interview.

Preservice educators developed a final mini-unit, which each mini-unit had three to five lessons, as one of their course assignments. Each lesson that participants developed was between 45 to 60 minutes, and needed to meet the standard requirements, such as Indiana State Standards, Next Generation Science Standards, Common Core, and/or the AFNR Career Cluster Content

Standards. Table 5 shows a brief description of the mini-units that participants developed at the end of the course.

Table 5
Descriptions of the Mini-units that Were Developed by the Participants

Mini-Unit and Instructors	*Brief Description*	*No. of lesson*
Meet your meat (Mindy & Yuki)	Students (6-12 grades) will gain understanding and knowledge through STEM-related activities by informing them what the aspects of meat quality are and how they can marinate their meat for better flavor and palatability.	5
Design a homemade hydroponic (JP)	Students (3-5 grades) will learn how to grow lettuce using Hydroponics farming system, whereby the mini unit focuses on the students' understanding of what plants need to grow and factors to consider when designing a hydroponics system to meet those needs.	3
Wood: The ultimate building materials (Denny)	Students (6-9 grades) will learn about the buoyancy, density, specific gravity, and strength of different wood species, then they will design and make quarter scale chairs.	3
Homegrown gardening and soil science (Scott)	Students (3-5) will employ engineering design and modeling to learn about the life science principles involved in creating a sustainable plant growing system in the form of a terrarium	5

Reflections also were one of the course assignments. Participants submitted five reflections throughout the course. Reflections were 700 to 1,000 words. The five reflections asked students to reflect on topics of definition of STEM, lesson planning, meaningful STEM integration and teaching pedagogies, using integrated STEM through AFNR rubric, and course recommendations. We used the reflection topics of meaningful STEM integration and teaching pedagogies, and using integrated STEM through AFNR rubrics as one of the research data.

The semi-structured post-course interview was conducted after the participants completed the course. The length of the interviews was between 50 to 60 minutes. The interview questions focused on how the participants interpreted rubrics, if the rubric helped the participants have a clearer understanding of integrated STEM education, what recommendations the participants had to make the rubric easier to use, and how did the critique of existing integrated STEM through AFNR mini-units help the participants to develop their integrated STEM mini-units. The purpose of conducting the post-course interview gave the participants opportunities to provide more details to elaborate and explain their post-teaching reflection.

3.6. Data Analysis

Through a deductive approach, thematic analysis was used to analyze the reflection and semi-structured interviews. Thematic analysis identifies and analyses patterns of meaning to elucidate the specific nature of a given group's conceptualization of the phenomenon under study (Braun & Clarke, 2006). Three existing concepts (i.e., interpretation of the rubric, course instruction, and recommendations) were used to structure coding and theme development (Table 6). For the first-round coding, the two researchers individually coded the data. After the first-round coding, the two researchers shared and debriefed the coding to establish consistency in identifying codes that relate to the existing concepts. The researchers used *in vivo* (Saldaña, 2016) coding to conduct the first cycle coding. *In vivo* coding is "literal coding" (Saldaña, 2016, p. 105) to try to capture the actual language that was used by research participants without losing the true meaning. For example, both JP and Mindy mentioned in their interview that the integrated STEM concept was new to them. The coding for the statements was "New." The second-round of the coding was primarily done by the lead researcher. The purpose of the second-round of the coding was to synthesize the coding and generate common themes based on the three existing concepts. After the themes were generated, the second researcher independently reviewed the quotes and language that were used to describe the themes to ensure clarity, neutrality, and consistency.

4. Findings

4.1. Research Question One

Three themes emerged when examining how preservice educators interpreted and applied the rubric for integrated STEM education: (1) Prejudgments based on prior knowledge and experiences, or course expectations informed interpretation of levels of STEM integration; (2) limited to no teaching experience resulted in novice interpretation of the integrated STEM lessons; and (3) level one (Exploring) was clear cut, but gray areas existed in interpreting levels two (Developing) and three (Advancing).

4.1.1. Theme 1: Prejudgments based on prior knowledge and experiences, or course expectations informed interpretation of levels of STEM integration

Preservice educators' prior knowledge and experiences in the content areas played a role in their perceptions of the rubric. Their previous experiences could result in bias in how they interpreted the rubric. Mindy and Yuki rated Byproduct unit higher than the Great Forest because of their animal science background. For example, Mindy said, "I'm still going to understand it [Byproducts], because I have a deeper understanding of byproducts. But as for wood...I wouldn't be able to tell if it's STEM integrated, because I don't have a good understanding of wood." Yuki also had a similar comment, she said, "I guess at a time, to admit total bias, that's the lesson plan [Byproducts] I liked the most...The content-wise I related to it the most, and I found it the most interesting."

Besides preservice educators' prior knowledge and experiences in the content areas, how they defined STEM integration also influenced their interpretation of the rubric. At the time of using the rubric in the class, JP thought STEM integration was "putting together those four disciplines in the learning process (Reflection)." When he used the rubric, he first tried to decide how many disciplines that he could find in the lessons. He recalled, "We first looked at the STEM disciplines. We find science, we're understanding the effect of bird population." Denny also pointed out that "I thought integrated STEM just meant if you have some formulas and you talked about science, and that's integrating it. I didn't realize, going into the class, that there were different levels." Yuki believed a quality integrated STEM through AFNR lesson meant that everything (i.e., all content areas) needed to be integrated. Yuki recalled, "So now, I don't think all the lessons in one unit will have the same levels of integration, but at the time [in the class], I guess it all has to be at least two or three [levels]." Yuki also misinterpreted the instructors' expectations of the course. She thought that her unit had to achieve either developing or advancing STEM integration to perform well in the course. Otherwise, she would flunk the course. Due to this preconceived opinion, Yuki interpreted the example units, both Byproducts and the Great Forest, that the instructors used in the course were good examples that must have achieved either developing or advancing STEM integration.

4.1.2. Theme 2: Limited to no teaching experience resulted in novice interpretation of the integrated STEM lessons

Two sub-concepts were related to the second theme. First, all the preservice educators indicated that integrated STEM through AFNR was something new to them. Although they understood the language in the rubric, they had a difficult time deciding the levels of STEM integration through AFNR due to the fact that they had no or limited experience of STEM integration through AFNR. To preservice educators, STEM integration through AFNR was a relative concept, and they needed something as a comparison. For example, Scott pointed out that STEM integration through AFNR was new to him. Therefore, he had difficulties deciding the levels of STEM integration through AFNR. He stated, "When it's brand new to us, especially if we don't have as much experience going through those [integrated STEM lessons], then it is going to be much harder because maybe we're just caught up in sections that a curriculum has." Denny said, "I've not read a lot of lesson plans. I have a small pool of experience in lesson plans. So maybe I was a little more impressed with the lesson plans, not the content in them." Yuki was puzzled about what she was doing in the class. She recalled, "I didn't really know what I'm looking at. I also didn't really know what to expect, type of a thing...the whole concept was very new to me." Mindy echoed what Yuki said, "I guess it comes back to that general understanding of the rubric, or not really knowing examples of what exploring STEM is, or developing STEM is, or advancing STEM is." JP had encountered comparable challenges. He summarized his thoughts and stated, "I would say it takes time as a student who is learning something new...to explore, to understand and to use it [the rubric]."

Second, the preservice educators were developing their own understanding of STEM integration through AFNR while they were taking the course. The purpose of the course was encouraging the preservice educators to form their own understanding of integrated STEM through AFNR. There was no one unified definition of integrated STEM through AFNR used in the course. Cognitively, it was a hurdle for the preservice educators to juggle between gaining and comprehending knowledge of STEM integration through AFNR. They acknowledged that they understood the wording of the rubric, but it was more challenging for them to use the rubric to analyze and evaluate the example units. Mindy said, "So I think it all boils down to your understanding of STEM, and then the rubric, and the different types of STEM integration. And then also, how clear is the lesson plan in general?" Scott reflected, "We're trying to teach ourselves what components are there...I don't know if it was necessarily the wording, but just trying to critique [lessons] as a novice curriculum developer was probably difficult for me." JP described the hoop that he needed to jump between developing and comprehending the concept of STEM integration through AFNR by saying, "We had not yet understood it [STEM integration through AFNR] in the context of this rubric. It had been hard to adjust [our mind] right away." Then, JP concluded, "I would say...understanding it [STEM integration through AFNR] and applying it in the real world... like evaluated lessons... was a different task. So, putting those two together wasn't something that clicked right away."

4.1.3. Theme 3: Level one (Exploring) was clear cut, but gray areas existed in interpreting levels two (Developing) and three (Advancing)

Almost all preservice educators agreed that they could identify if an integrated STEM through AFNR lesson was at level one (Exploring), but it was not easy for them to decide between levels two and three, Developing and Advancing. In other words, they could compare what was not STEM integration (Level 1) to what could be STEM integration (Levels 2 and 3). Yet, they had a more difficult time interpreting the differences between Levels 2 and 3. For example, Denny stated, "I think the Exploring is more black and white... I think the difference between the Developing and the Advancing can be a little bit gray." Scott also said, "It was relatively new to think about STEM in that way [integration]...I think it's a little bit easier to see when things are one [Exploring] versus a two [Developing] or a three [Advancing]." Mindy echoed, "...[Developing] versus Exploring, I would see the [Exploring] learning objectives be a little bit more in general. And then if it's like Advancing STEM, I guess I don't really have a big knowledge of advanced STEM integration." When using the rubric, the preservice educators were able to see the higher levels of STEM integration were moving beyond learning content to solve real-world problems by applying content from various disciplines. They also acknowledged if a lesson emphasized critical thinking or deep thinking, then it was at the higher levels of STEM integration. For example, JP described how he evaluated the Great Forest unit, he said, "So without a clear understanding of this [rubric], we took it on the Level 1 as understanding content. Whereas now students were being exposed to real-world applications. So, I thought it was at the highest level." Yuki recalled how she rated the two example units by saying, "It [Byproduct] was much of a cookbook, do this, do that...not so much critical thinking. At least for the [Great] Forest one, you're presenting knowledge and you're giving an idea to the concept basically like solving the problem." Denny reflected on his rating process, he said, "The Exploring can just show some numbers and some science concepts. The Developing, I guess… is more you might have to find the formulas and find the data. And, the Advancing is more...I don't know...applying STEM concepts."

4.2. Research Question Two

All the preservice educators stated that the rubric helped them develop their mini-units. Some of them indicated that they used the rubric as a checklist to evaluate their own integrated STEM through AFNR lessons. For example, Yuki said, "Like you have a guideline for your entire unit...You check these boxes basically saying this box met this level of integration and this box met this level of integration." Mindy recalled when she developed her integrated STEM through AFNR unit, she used the rubric to guide the writing process. Mindy shared she understood what a good and bad lesson plan looks like and the rubric helped her to evaluate the quality of her lessons. She stated, "Okay, what is the lesson plan supposed to look like? If we see the criteria has been met, then we can focus on the STEM [content] that's coming to the surface." The rubric also acted as a tool that helped the preservice educators reflect on their purpose of having specific activities and teaching certain content/concepts. They asked themselves the question, "What is the purpose and why do I have this activity in my lesson?" This made them think more critically in developing rationales for building integration into their lessons. For example, Scott said, "How it [the rubric] really made us think even more critically on what we were putting together [as a unit]…We asked ourselves, 'would that be STEM integration or just a fun activity?'" Denny also pointed out, "I think it [my unit] turned out to be a fine unit, because of this [rubric]... We're doing more than just teaching the kids facts. We wanted to have them learn something and apply it to a real-life situation." After used the rubric, JP reflected on the process of developing his own unit and said, "I knew that it [my unit] was not enough. Then, I took time to reflect on it and tried to tie it to these [higher] levels. That's why I thought about what hydroponics does? Why do we even need it?"

The preservice educators' mini-units were aligned with their interviews. They considered STEM integration as a developmental or building process. As Yuki wrote in her reflection and said in the interview that "the rubric itself is a progression." All the preservice educators' mini-units started with learning STEM content, such as photosynthesis, pH, density and buoyancy, or ecosystem. They all included a design activity/project as the culminating activity at the end of the mini-units. Some of the design activities/projects had explicitly used engineering design processes, such as the Wood: The ultimate building materials (Denny) and Design a homemade hydroponic (JP). Others, such as Meet your meat (Mindy & Yuki) and Homemade gardening and soil science (Scott), placed more emphasis on inquiry-based learning without explicitly discussing engineering design processes. All the mini-units that the preservice educators developed used either project-based or inquiry-based instructions and moved away from the cookbook type of instruction. The rubric helped preservice educators think about which teaching methods they should use to support STEM integration and ways to make their lessons more learner-centered.

Although all the preservice educators agreed that the rubric helped make their own integrated STEM through AFNR mini-units better, they also gave recommendations to improve the rubric. With the exception of the category of the Role of Learning Objectives, without seeing more examples, all the preservice educators had various challenges deciding the levels of STEM integration through AFNR in the Role of STEM Usage, Present, Outcomes, AFNR, and Student Thinking. As Scott pointed out, "We were not really provided with examples, but came into the class and then did this activity with your peers...so without seeing more examples, it was hard to judge the levels. The most difficult were STEM Usage and Present." Mindy felt like instructors just thrown the rubric at them and asked them to do activity in the class. She said, "It would be better if we were provided examples. Like the usage of STEM...My understanding was, oh yeah, if you had a little bit of math, I might think, yeah, they're using STEM." In Denny's reflection, a similar comment was found. He wrote, "I feel like I could use one more example to help solidify my understanding." Denny also stated in his interview, "I like having examples..., and then the teacher explains why these are the answers, then I guess that would click in my mind." Yuki particularly pointed out that she was confused about the role of AFNR and students' thinking. In her reflection she wrote, "I wish the explanation between these two categories for the Role of AFNR Content Knowledge and the Role of Students' thinking would be a little clearer. I'm confused about the meaning of 'inside' and 'outside' the box." In her interview, Yuki echoed her reflection and asked for more examples by saying, "If an example could go with it [inside and outside of box] when you're explaining the rubrics like 'this is mainly inside the box, and this is a scenario where it's predominantly outside of the box.'"

The preservice educators also commented on what the course instructors should do in the class to help them use the rubric by providing more examples. Denny wished for a teacher-centered approach where the course instructors would directly provide the rating for all the categories and levels. In his reflection Denny wrote, "I was having some trouble understanding the difference. I was looking at that wrong. I wished the instructors told me this is how I should look at it." Others preferred a learner-centered approach where the course instructors provided more examples, but also give them freedom to develop their own understanding of integrated STEM through AFNR. For example, Although JP thought it would be great if instructors could provide more examples, he also believed instructors should give students flexibility to come up with their own ideas. He said, "Giving an example and helping them [preservice educators]…That's one option. We [preservice educators] might come up with another way. But the main idea is to help students reflect how the three levels are evaluated in different ways." Scott had a similar suggestion as JP. He opposed instructors to spoon feed students answers but to help students compare the different levels. He stated, "It might be helpful to have more examples of lesson plans that are definitely a two [Developing] versus those that are definitely a three [Advancing] and then be able to look at those together."

As for modifying the rubric, all the preservice educators agreed that the rubric aligns with their definition of STEM integration through AFNR. Besides a rating unit column, the rubric categories are comprehensive, and no components were missing in the rubric. When asked how to modify the rubric, Yuki pointed out, "So I think if there was, I don't want to say another rubric, but just another tier, say like 'you had evaluated the unit.'" Although preservice educators did not think there were missing categories in the rubric, they suggested a half-point rating option between the levels of Exploring and Developing, and the levels Developing and Advancing. Yuki said, "When I feel I don't know what to do with it, I'm going to rate it 0.5…If you gave the knowledge and then you asked them [students] to use it, then I would probably do a 0.5." Scott also mentioned the half-point column idea. He said, "People were trying to maneuver because they just weren't sure. If it's not a full three, I think it's because there could be a little bit more integration in there. It might be a 2.5, in my opinion." Scott and Mindy suggested leaving the half point column blank, so the preservice educators could write their reasons why they give a half point. They suggested that by doing so, the course instructors could understand how preservice educators were clear or not clear regarding their interpretations of the levels of integration in the rubric.

5. Conclusions and Implications

There were two conclusions for the study, which were based on the two research questions. We will present each conclusion and discuss implications for each.

5.1. Preservice Educators' Interpretations Can be Supported Pedagogically

The first conclusion, based on the first research question, is that preservice educators' understanding and interpretations of integrated STEM lessons were informed by their existing knowledge of the content, how familiar they were with the content, and previous teaching and learning experiences with the content. Preservice educators felt more comfortable using the rubric to critique integrated STEM lessons when they were familiar with the content; familiarity with the content of a lesson played in important role. This parallels the findings of Rice and Kitchel (2018) who reported that if beginning agriculture teachers do not feel comfortable with the content, they used coping strategies such as ignoring content they were unfamiliar with and focusing on familiar content. Although the integrated STEM lessons did not have difficult content because they were written for elementary, middle or high school students, preservice educators shared they did not feel comfortable critiquing lessons if the content was unfamiliar. As such, it is important that teacher educators select example lessons that represent a broader range of content so preservice educators with diverse content backgrounds can identify with lessons in which they are familiar. Also, it may be beneficial if the lesson was taught and demonstrated by the teacher educators (or video recordings of the lesson) so preservice educators might feel more comfortable in using the rubric to critique the lesson.

Next, the rubric provided pedagogical language and structure for preservice educators to engage in the process of developing their understanding of STEM integration and lesson plans. The process of developing preservice educators' understanding of integrated STEM lessons through AFNR was challenging and preservice educators recommended more scaffolding, examples, expert modeling, group discussion, and experiences when learning to use the rubric. Knowing how the preservice educators interpreted the rubric and used it to evaluate lessons helped the instructors understand how to provide specific pedagogical supports to develop integrated STEM lessons. This aligned with Eck and his colleagues (2021) recommendation that preservice educators in agricultural education would benefit from examples and modeling of well-designed agricultural STEM lesson plans. Preservice educators shared they were novices and did not have the previous knowledge and experience in teaching and learning to develop and critique lesson plans, or integrated STEM lessons. They acknowledged they rated the lessons higher because they had limited understanding of integrated STEM compared to their instructors who were experts. However, the rubric helped facilitate a process and guided conversations to evaluate existing STEM lessons and provided preservice educators feedback on the lessons they developed.

Preservice educators unanimously shared they wanted to see examples of different levels of STEM integration for each criterion, and they wanted opportunities and more time to develop their skills in developing competency to use the rubric. The instructors modeled learner-centered teaching with an open inquiry approach--they shared there was no single way to develop integrated STEM lessons and the preservice educators should creatively develop their integrated STEM lessons. Preservice educators commented on the open inquiry approach and shared it was challenging and frustrating not being told a formula to develop integrated STEM lessons. The complexity of evaluating and developing integrated STEM lessons using the rubric required students to engage in complex problem-solving and reasoning, which can create excessive cognitive load (Van Merriënboer & Sweller, 2005), especially for learners who are new to the task of critiquing and developing integrated STEM lessons. Constructivist learning theories support the premise to engage learners with a challenge or difficulty (e.g., desirable difficulties, productive failure, pure discovery-based learning). There is a delicate balance in helping learners navigate the cognitive dissonance and epistemic emotion, which is based on: (1) personal factors such as prior knowledge, self-efficacy, and self-regulation; (2) sequence, structure, and design of the learning task; and (3) the type and timeliness of feedback, guidance and support the learners receive throughout the authentic task (Lodge et al., 2018). It is important for experts to make their knowledge explicit by thinking out loud or placing their comments in text format on the example lessons and rubric. Furthermore, preservice educators should see examples that are carefully chosen to demonstrate different integration approaches and encourage creativity and adaptability in how lessons build on each other for content integration. Teacher educators should also help develop preservice educators learn the process and skills of self-regulation, which is an important skill for teachers to be able to monitor their own thinking as they develop and grow (Uzuntiryaki-

Kondakci et al., 2017). Preservice educators should also be encouraged to consider (and possibly revise) their conceptualization and definition of integrated STEM as they develop lessons, get feedback, and reflect on their experiences.

Furthermore, the desire to earn a good grade and ambiguity of knowing how to develop integrated STEM lessons played into the preservice educators' frustrations and challenges in developing integrated STEM lessons. Additionally, preservice educators shared they comprehended the rubric when they read the article that explained it. However, they were not as clear when they used the rubric to analyze and evaluate existing lessons, and when they created their own integrated STEM lessons. This aligns with Bloom's revised taxonomy of higher-order thinking (Krathwohl, 2002), and it can be difficult to use teaching methods that encourage students to think, perform and develop cognitive needs (Gul et al., 2020). We found this to be the case in our study as the rubric engaged preservice educators in higher-order thinking, yet they shared additional teaching strategies that would have helped them perform better and address their cognitive needs. Expert executive guidance is necessary to help learners manage cognitive load when elaborating on their knowledge (i.e., explaining their rationales of critiquing or creating integrated STEM lessons; Kalyuga, 2009). Authentic learning tasks that engage students in solving complex problems can hamper learning because such tasks can impose excessive cognitive load (Van Merriënboer & Sweller, 2005).

Novice learners need structure and guidance when presented a complex authentic task (Van Merriënboer & Sweller, 2005). Instructional strategies to help manage cognitive load may include: (1) scaffolding by providing part-task sequencing practice that progresses to the whole and more complex versions of the whole task; (2) experts who model knowledge elaboration using examples through the scaffolding process; and (3) providing students with a process worksheet that describes the phases they should go through in solving the complex problem. The process worksheet should also provide tips that help students successfully complete each phase (Van Merriënboer & Sweller, 2005). Although the rubric provided preservice educators with a framework, which they found to be helpful in critiquing and developing integrated STEM lessons, a process worksheet that guides them through the steps and phases of how to use the rubric to evaluate the lessons would be beneficial in helping them manage cognitive load. As such, preservice educators need expert guidance and practice to develop competence (Eck et al., 2021) using the rubric, and more lesson examples should be provided through the guided process of using the rubric to demonstrate different levels of STEM integration for each criterion.

Level 1 was the easiest level for the preservice educators to grasp because it is the most familiar to single subject instruction. Preservice educators were able to see the differences between Levels 1 and 3 because they have the greatest contrast in seeing differences across the criteria. Preservice educators' understood the language in the rubric, but it was more difficult for them to see integration differences between Levels 1 and 2, and Levels 2 and 3. Level 2 should be introduced after preservice educators are familiar with the differences between Levels 1 and 3. Finally, although the preservice educators had limited to no previous experiences with lesson plans, they drew upon their existing knowledge and learning experiences in AFNR and STEM to develop their integrated STEM lessons. This was aligned with Ryu et al.'s (2018) finding that preservice educators used their prior experiences to develop integrated STEM lessons. Finally, because of the connection between critical and deep thinking and higher levels of integration, teacher educators should spend time teaching preservice educators about the development of critical and deep-thinking skills, and how this can be facilitated through integrated STEM lessons.

The first conclusion supports that personal factors played a role in how preservice educators critiqued and planned integrated STEM lessons. The preservice educators shared how their lack of pedagogical knowledge and experiences (i.e., novice understanding of lesson planning, STEM content, and STEM integration) played a role in how they critiqued and developed their integrated STEM lessons (Rice & Kitchel, 2018). Because preservice educators were not employed as in-service educators in the field or an organizational context, structural and cultural resources (Stubbs &

Myers, 2015) were not mentioned by the preservice educators as playing a role in how they developed their integrated STEM lessons. Preservice educators' reflections of the lessons provided insights regarding their goals and the choices they made to implement strategies to implement integrated pedagogy of STEM lessons (Sias et al., 2017).

5.2. Rubric as a Pedagogical Tool

The second conclusion has two parts, as did the second research question, on which this conclusion was based. First, the rubric was a pedagogical tool that helped preservice educators develop their understanding and confidence in developing integrated STEM lessons through AFNR. The rubric and this study contributed to developing pedagogical competence of future educators. The rubric provided instruction for preservice educators in several ways. First, preservice educators shared the rubric communicated expectations and delineated criteria for them to develop integrated STEM lessons. This supported the idea that the rubric increased transparency (Andrade & Du, 2005; Reynolds-Keefer, 2010) and had accessible language (Andrade, 2001) for students to understand and apply the rubric. Further, this conclusion supported that a clearer definition and implementation model for STEM integration (Moore et al., 2020; Scherer et al., 2019) in the context of AFNR (Stubbs & Myers, 2016) is more clearly understood among preservice educators, and integrated STEM education is being taught more explicitly (Guzey et al., 2020).

Second, the rubric provided students structure in seeing what integrated STEM education is and is not so they could focus on ways to increase the level of STEM integration. Further, the rubric helped preservice educators to see that lesson plan development is a building process and the key components should support each other, and additional lessons should build on previous lessons for higher integration. This supported Bookhart's (2018) finding that rubrics communicate criteria and descriptions of different levels of low to high performances for each criterion. Moreover, preservice educators unanimously interpreted integrated STEM through AFNR as having the following components: (1) applying STEM content to solve real-world problems; (2) making cross-disciplinary connections; and (3) using learner-centered teaching strategies to promote critical and deeper thinking (Asunda & Walker, 2018; Cheng & So, 2020; Moore et al., 2020; Mustafa et al., 2016; Thibaut et al., 2018; Walker et al., 2018). Also, design activities and project-based learning helped preservice educators reach higher levels of integration because they help learners use critical and deep-thinking skills to solve real-world problems. All the preservice educators progressed in developing lesson that were learner-centered by using inquiry-based learning or project-based learning. Integrated STEM education helped educators shift from being teacher-centered to being learner-centered (Du et al., 2019).

Third, the rubric helped preservice educators see the components of an integrated STEM lesson and helped them develop a rationale to justify the content, methods, activities, and assessments in the lesson. This supports prior research that rubrics should help develop self-efficacy (Panadero et al, 2012) and supported self-regulation (Panadero, 2011; Andrade & Du, 2005). Further, rubrics should help students monitor their work and make self-assessment judgments (Bookhart, 2018) to help them develop and apply targeted skills and outcomes (Andrade, 2001). The rubric helped preservice educators think about the purpose of a lesson, alignment of learning activities with learning outcomes, and why they would use the learning activities to fulfill the purpose of the lesson.

Fourth, the rubric was a tool to have instructional conversations between the instructors and the preservice educators and among the preservice educators as they considered developing their lessons. This also supported Panadero and Jonsson's (2013) finding that rubric facilitated the feedback process (Andrade & Du, 2005; Schamber & Mahoney, 2006) and Guzey et al.'s (2020) recommendation that collaborative approaches be used to unpack teachers' misconceptions of integrated STEM education to improve their understanding of integrated STEM education.

Finally, the second research question also focused on recommendations to improve the rubric. As such, the preservice educators agreed the rubric was not missing any criteria and it helped them develop their lessons. Yet, they recommended two changes be made to the original rubric. First, replace "outside the box thinking" with "thinking creatively in a new way or using a different perspective than what has been conventionally used." The original language was too ambiguous for preservice educators to interpret and was not specific enough to help them evaluate their performance (Bookhart, 2018). As such, language in the rubric was modified to help preservice educators focus on the quality of their lessons. Second, the preservice educators recommended adding 1.5 and 2.5 options to the rating choices, which would provide five choices: 1.0, 1.5, 2.0, 2.5, and 3.0 (Appendix B). Although five choices could create more ambiguity for preservice educators because they would have five rating options rather than three options, we see this as an opportunity for preservice educators to have more options to explain their reasoning and rationale. This aligns with Douglas et al.'s (2020) recommendation that rubrics need to measure the extent teachers were able to demonstrate evidence of integrated STEM learning.

6. Limitations and Recommendations

We acknowledge three limitations of this study. First, preservice educators' limited teaching experience and pedagogical content knowledge restricted their ability to comprehensively analyze and critique the lessons. Yet, the rubric served as a pedagogical tool to provide structure to reviewing, discussing and critiquing the lessons. The pedagogical benefits identified by the preservice educators' provided insights on how to use rubrics more effectively as a pedagogical tool. Second, we acknowledge the themes identified in the literature review were supported by the findings relating to preservice educators' content knowledge limitations, restricting their ability to evaluate the example lessons. These results are limited based on the novice understandings of the participants, yet they provided experienced-based insights on how the instructors could adapt the use of the rubric to provide more scaffolding and guided discussions. Although these limitations are based on preservice educators' limited knowledge and experience, we conducted this action research study to better understand more effective pedagogy to advance preservice educators' knowledge, interpretations, and applications of integrated STEM education. Finally, we do not know if integrated STEM lessons taught at Level 3 will result in the highest student outcomes. The levels of STEM integration were conceptualized based on literature and reflective teacher education practice as being a more idealistic framework of integration. Yet, the rubric has not been tested empirically to know if K-12 students reach higher levels of STEM outcomes when engaged in lessons that are Levels 2 and 3.

Regarding future research, we recommend other instructors who have expertise in teaching STEM through AFNR use the rubric with their preservice educators. This could provide transferability and credibility in using the rubric in other courses and preservice education contexts. Furthermore, we recommend using the rubric with in-service teachers who have previous knowledge and experiences in teaching STEM through AFNR. The different levels of knowledge and experiences could provide insightful feedback regarding the credibility and usefulness of the rubric. Moreover, a follow-up study should be conducted to determine how preservice educators interpret the differences between Levels 2 and 3 immediately after they learned how to use the rubric so they can provide more specifics regarding their thinking and interpretation of the rubric. This may provide insights regarding the preservice educators' schema and how they navigated cognitive load when using the rubric. Next, the rubric can be modified and used for integrated STEM learning in STEM and STEM-related contexts. The rubric provides language and criteria for quality of integrated STEM lesson plans and should be adapted and used in other STEM-related contexts. Finally, researchers should study K-12 student outcomes of the different levels of STEM integration. This could also help determine the type of impacts integrated STEM lessons have on students' cognitive and careers development and how they make connections to their families, industry professionals, and communities.

In summary, this study contributed to the knowledge base in two ways. First, rubrics can be beneficial when used as a pedagogical tool to help make complex tasks and concepts more accessible to preservice educators. Specifically, preservice educators shared they benefited accessible language (e.g., learning outcomes were clear), substantive criteria (e.g., considering the purpose of the lesson), increased transparency (e.g., expectations and criteria), feedback (e.g., examples and learner-centered teaching), increased self-efficacy (e.g., progressing to Levels 2 and 3), and self-regulation (i.e., familiar content and pedagogical conversations). It is important to listen to how preservice educators interpret (or struggle to interpret) rubrics so teacher educators can modify the rubric, and more importantly, make pedagogical adjustments to help students gain greater usefulness and benefits of the rubric as a pedagogical tool.

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Appendix A. Rubric of Levels of Integration and Features (Version 1; Wang & Knobloch, 2018)

Levels of Integration	**Exploring STEM Integration**	**Developing STEM Integration**	**Advancing STEM Integration**
The 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	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.	Core disciplinary STEM concepts and skills are taught and/or practiced to bridge different disciplines or multiple STEM disciplines are distinctly present.	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.
· Usage	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.	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.	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.
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.

Appendix B. Rubric of Levels of STEM Integration through AFNR (Version 2)

Levels of Integration	**Exploring STEM Integration (Level 1)**	**Developing STEM Integration (Level 2)**	**Advancing STEM Integration (Level 3)**	**Rating 1, 1.5. 2, 2.5, 3**	**Comments**
The 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	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.	Core disciplinary STEM concepts and skills are taught and/or practiced to bridge different disciplines or multiple STEM disciplines are distinctly present.	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 are closely interdependent.		
Role of the STEM Concepts, Content Knowledge, and Skills · Usage	No to limited of STEM content knowledge is present 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.	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.	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 focus on one discipline (one concept, and/or one skill).	Learning outcomes 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.		
Role of the Instructor and Type of Instruction	The instructor gives directions or guidelines to complete the lesson. Students follow "cook book" type of instruction to complete the task.	The instructor 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 completed.		

Appendix B continued

Levels of Integration	Exploring STEM Integration (Level 1)	Developing STEM Integration (Level 2)	Advancing STEM Integration (Level 3)	Rating 1, 1.5. 2, 2.5, 3	Comments
Role of AFNR Content Knowledge	AFNR content is the focus of lesson.	AFNR provides a context for STEM learning or experiential learning.	AFNR serves as an integrator of STEM learning by focusing on a real-world problem that blends disciplines.		
Role of Students' Thinking	Thinking is conventional for the discipline, or for the concepts/skills that need to be learned.	Thinking is conventional for the discipline, or for the concepts/skills that need to be learned, and helps students to make connections from other disciplines to solve the problem.	Thinking creatively in a new way or using a different perspective than what has been conventionally used. Students demonstrate systems thinking, critical thinking, creative thinking, and/or complex problem-solving.		