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Improving STEM Education Programs through the Development of STEM Education Standards

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At our institution, we offer two master's degrees for in-service teachers: A Master of Arts in Elementary Education with a Math/Science Emphasis and a Master of Science in Middle Grades STEM Education. These degrees are designed for practicing teachers in any STEM-related field. Our goal is to empower these teachers by enhancing their skills in all aspects of STEM education, including content and pedagogy. As we began a process of evaluating and revising these programs, we realized there was no single body of standards to guide the work of STEM educators such as ourselves, nor was there sufficient focus on educating STEM students in an urban, culturally diverse district. Drawing on existing resources, research, and discipline-specific standards, we developed and present here STEM Education Standards for teacher education programs and other educational groups that would benefit from them. In this paper, we describe the programs in-depth to provide background information. Next, we describe the process of creating the standards, the reasons for the standards we chose, and how we assess them. We also provide our final version of the standards. Finally, we share student reflection data regarding the effectiveness of the programs in which the STEM Education (STEM-E) Standards were piloted.

Keywords**:** STEM education programs, STEM standards, Middle grades, Preservice teachers

Across the globe, stakeholders are calling for a shift in focus from building students' knowledge in individual subjects such as mathematics and science, to a focus on integrating science, technology, engineering, and mathematics (STEM) content areas so that students' knowledge is broad, deep, and holistic (Kelley & Knowles, 2016; Vasquez, Sneider, & Comer, 2013). In contrast to other countries, there are not enough students in the United States (U.S.) pursuing STEM degrees in college and not enough people entering the STEM workforce (Carnevale, Smith, & Strohl, 2013; National Center for Education Statistics, 2012). Furthermore, when we consider those who do study and work in those fields, there are not enough women or people of color filling those roles (Cohn & Caumont, 2016; Jones et al., 2018). Some scholars (Jett, 2016; Joseph, Hailu, & Boston, 2017; Strutchens & Martin, 2013 have argued that the underrepresentation for these groups is rooted in access and equity. By 2020, 65% of all jobs will require STEM literacy skills (Carnevale et al., 2013), and there have been multiple calls for improving STEM education in the U.S. in grades K-12 (Handelsman & Smith, 2016; Jones et al., 2018; McClure et al., 2017; Moye, Dugger, & Starkweather, 2017). Despite this “global urgency” to improve achievement in science, technology, engineering, and mathematics for U.S. students, STEM teachers in the U.S. still struggle to understand and enact effective STEM education, particularly with diverse students (Kelly & Knowles, 2016). If STEM education is to improve - as the stakeholders in the global industry, the environment, and education insist that it must - so must the knowledge and skills of our STEM teachers. Our goal is to provide a series of standards to guide the education of STEM teachers across the globe including those in our own STEM education programs.

We ground our work in the research literature, specifically focusing on teacher education best practices (e.g. National Council for Accreditation of Teacher Education [NCATE], 2010) and Culturally Responsive Teaching (CRT) (Gay, 2000; Ladson-Billings,1995). We aim to better support diverse student populations that, historically, have been persistently marginalized and excluded from STEM fields. By supporting teachers to enact best teaching practices, we hope to increase the participation rate of all students, and specifically underrepresented groups, in STEM education and STEM careers. Furthermore, we draw on discipline-specific standards (e.g. National Council of Teachers of Mathematics [NCTM], 2012; Reimers, Farmer, & Klein-Gardner, 2015). The research and other standards informed our development of the STEM Standards for Teacher Education, which then influenced the activities, course expectations, assignments, mentoring model, and other experiences of the teachers enrolled in one of our master’s programs. We also analyzed relevant STEM pedagogy (Murphy & Mancini-Samuelson, 2012; Stohlmann, Moore, & Roehrig, 2012). In Figure 1, we present a framework for the design of and research around the proposed STEM Education (STEM-E) Standards for teacher education programs. Through this work, we hope to continue to conduct research, which will add to the literature base and thus may inform later iterations of the STEM-E standards. The research will guide each area of this work and will be used to consistently evaluate the students’ many deliverables.

Our work draws on previously developed discipline-specific standards for teacher education programs, including those presented by the National Science Teacher Association (NSTA, 2012), the National Council of Teachers of Mathematics, (NCTM, 2012), and the National Academy of Engineering (Reimers et al., 2015). We also draw on the theory that STEM education is something that should unite the disciplines in a deeply integrated way, as proposed by Vasquez et al. (2013):

> STEM education is an interdisciplinary approach to learning that removes the traditional barriers separating the four disciplines of science, technology, engineering, and mathematics and integrates them into real-world, rigorous, and relevant learning experiences for students. (p. 4)

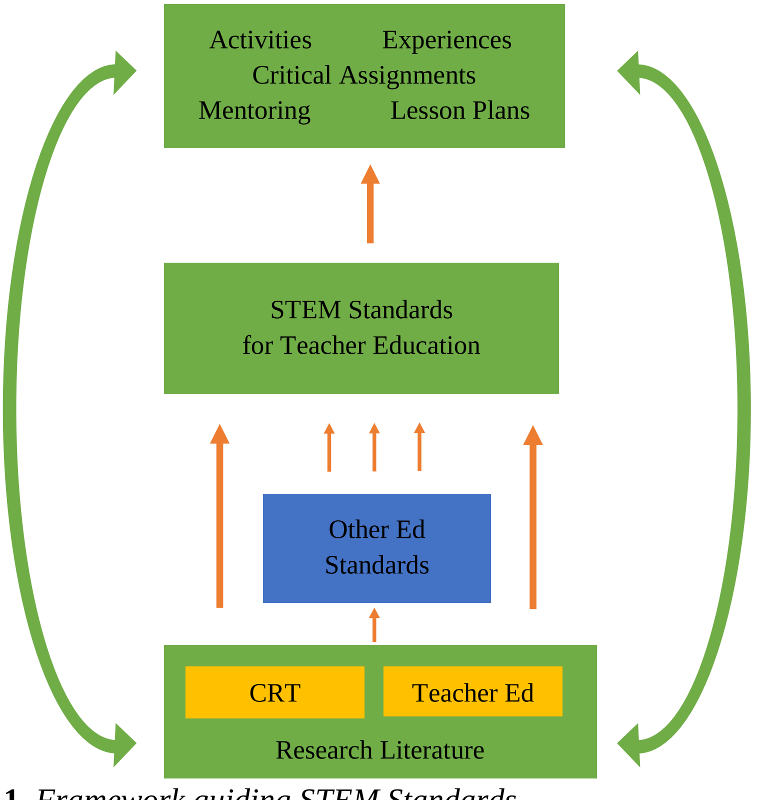

Figure 1. *Framework guiding STEM Standards.*

In this paper, we describe how a series of revisions to two STEM Education degrees led to the development of standards for those supporting the education of STEM teachers. We also recognize a need for these standards to be culturally-linguistically responsive (CLR), so as to meet the needs of all learners. We developed these standards to be utilized in teacher education programs, but they are also suitable for a broader audience including professional development leaders, STEM schools, and those practitioners seeking to become STEM-focused. Though these standards were developed locally, they can be applied beyond the state of Florida to include the rest of the U.S. and abroad as guiding STEM documents.

USFSP and Our STEM Programs

The University of South Florida St. Petersburg (USFSP) is part of the USF system and sits at the heart of downtown St. Petersburg, Florida. The surrounding school districts serve a wide variety of students, and many of our teachers work in urban schools with high numbers of students of color and English learners. The USFSP university system has nearly 5,000 students with roughly 4,500 of those being undergraduate students. The College of Education has the smallest student enrollment but offers more graduate options than the other colleges. Two of those graduate programs are central to the standards presented in this paper (they are described in more detail below). Unlike other STEM education programs, which typically allow their students to specialize in a specific discipline (e.g. math *or* science), our programs are unique in that they require teachers to take courses in all content areas and learn to integrate across the STEM disciplines.

The College of Education at USFSP recently spent nearly $1 million on our STEM Inq. Lab, which opened in October of 2018. The lab is equipped with Vex Robotics, Virtual and Augmented Reality equipment, Maker Spaces, 3D printers and, coming soon, a laser printer so that teachers can engage and learn how to use this equipment in their classrooms. These technologies have become a staple for our STEM education courses.

Currently, our institution offers two master's programs designed for in-service teachers[1]: an M.A. in Elementary Education with a specialization in Math and Science, and an M.S. in Middle Grades STEM Education. One program requirement for applicants is that they must be teaching in the classroom (public or private) or be instructional personnel like coaches and curriculum specialists. Although this program does offer some classes online or in a hybrid format, most classes meet weekly and require the teachers to attend in person. Thus, the teachers who are part of this program are local to the university, and they enter the program with varying strengths and in different stages in their careers. Some have the goal of enhancing their teaching while others are seeking to become leaders in their district.

Teachers typically take two years to complete the program. Because they are practicing teachers, all courses are either at night or online (possibly hybrid). The STEM degree for our Middle Grades program takes six semesters to complete while the Elementary program takes five semesters. The teachers take two courses each fall and spring semester and two courses in one summer semester. During the two years, elementary teachers have one summer off from the program because it has fewer course requirements than the Middle Grades program. The two courses per semester requirement ensure teachers meet the

[1] Here, we refer to our students as teachers. This is because they are working professionals, not undergraduates, and will help to avoid confusion when we refer to *their* students (to whom we will refer to as students).

time requirements for receiving financial aid. Each program is designed such that teachers can enter during any semester and graduate within two years.

Our goal in both of these programs is to increase teachers' pedagogical content knowledge (PCK) (Shulman, 1986), increase their knowledge of resources for use in their classrooms, and foster their ability to conduct action-based research (Dana, 2013). Our teachers typically do not wish to pursue a doctorate in education but some of them have or have expressed interest in going back for a terminal degree. Thus, we strive to find a balance between having a program with practical classroom-based applications and one that strengthens their ability to not only navigate the research but to also apply it.

Masters of Arts in elementary education with a math/science emphasis. This program is for practicing elementary school teachers. It is a 30-credit hour program requiring the ten courses listed in Table 1. The program has three core courses; one has a focus on child development and the other two have a focus on research. In the Foundations of Education Research course, the goal is to help teachers understand the fundamentals of research, while the Seminar in Curriculum Research prepares teachers to carry out a research study in their own classroom. These are the only classes in which the teachers may have classes with teachers from other programs.

The remaining seven courses are emphasis courses that are specific to this program; thus, only students in this master's program are enrolled in these courses. Six of the seven courses are specific to the elementary program. The Trends in Math/Science Assessment is the only course that teachers in both programs take. This course is very specific to the teacher and their classroom. This requires a lot of one-on-one interactions and meetings unlike other courses; thus, we are able to enroll both programs into this course without sacrificing grade-level content.

The three mathematics courses and two science courses are designed to increase content knowledge while also enhancing pedagogical skills. In the remaining course, Current Trends in STEM, teachers receive their certification as CodeX teachers and learn how to: code Vex Robots, integrate 3D printing into their teaching, and use Augmented and Virtual reality.

Master of Science in middle grades STEM education. Currently, this program serves teachers in grades 5 through 9, though we highly encourage grade 5 teachers to pursue the elementary master's program. This program is a 36-credit hour program requiring the twelve courses listed in Table 2. Just like the elementary program, two of the three core courses focus on research and conducting an action-research project in their own classroom. The third core course is a reading course that is designed to focus on the teachers' specific content areas.

Teachers in this program have two additional courses when compared to the elementary teachers. They take an additional science course, as well as a STEM Methods course that is specifically focused on how to integrate STEM content areas and create truly transdisciplinary lessons (Vasquez et al., 2013).

Table 1

Courses Offered in Masters of Arts: Elementary Education with Math & Science Emphasis

COURSE #	COURSE TITLE
	Core Courses
EDF 6481	Foundations of Education Research (online)
EDF 6120	Child Development (online)
EDG 6935	Seminar in Curriculum Research
	Emphasis Courses
SCE 6735	Trends in Science/Math Education for Elementary Teachers
EDG 6931	Current Trends in Math/Science Assessment
MAE 6315	Algebraic Thinking for Elementary Teachers
MAE 6334	Problem Solving for Elementary Teachers
MAE 6316	Geometry and Measurement for Elementary Teachers
SCE 6855	Teaching biology & Ocean Science in Elementary
SCE 6803	Physical Science for Elementary Teachers (Our goal is to make this a Physical and Earth Space Science)

The Need for STEM Standards

A short time after Dr. Hensberry began her employment at USFSP, Dr. Rosengrant – who had several years of experience at another university – was hired as the STEM Program Coordinator. As new faculty for the two STEM Ed programs, they wanted to make sure the programs were meeting the needs of all the enrolled teachers. They created and consulted with a STEM advisory panel comprised of current and former students, district personnel, and other faculty. In addition, they also consulted the literature to examine and revise the programs. These revisions were further fueled by their university's push to develop a Master Academic Plan for improving every degree offered at USFSP.

Drs. Rosengrant and Hensberry thus spent a great deal of time revising both the program and its courses. For example, they switched from offering each course every year to offering them every other year in a cohort model, which helped to increase enrollment in each course and avoid cross-listing the courses between elementary and middle grades (which was not successful for faculty or the teachers). This change allowed us to greatly reduce the number of adjunct faculty needed while at the same time creating more uniformity across the courses as they are now taught by full-time faculty with a strong understanding of the program mission and goals. During revision, we created the STEM Methods course listed in Table 2 to address requests from the STEM Advisory Panel. As Drs. Rosengrant and Hensberry restructured the courses, they ensured that the curriculum and assignments were coherent across the programs and that they utilized best practices.

Table 2
Courses Offered in Masters of Science: STEM Education

COURSE #	COURSE TITLE
	Core Courses
EDF 6481	Foundations of Education Research
RED 6544	Cognition, Comprehension, Content Area Reading
EDG 6935	Seminar in Curriculum Research
	Emphasis Courses
SCE 6836	Teaching Earth Space in Middle Grades
SCE 6876	Teaching Biology and Ocean Science in Middle Grades
SCE 6804	Physical Science for Middle-Grade Teachers
MAE 6329	Geometry and Measurement for Middle Grades
MAE 6650	Technology-Enhanced Numerical Analysis in the Middle Grades
MAE 6654	Teaching Technology-Enhanced Algebra in the Middle Grades
SCE 6738	Trends in STEM for Middle-Grade Teachers
EDG 6931	Current Trends in Math/Science Assessment
SMT 6315	STEM Methods for Middle and Secondary Grades

For example, in Dr. Hensberry's mathematics content courses, she models the use of the eight Effective Math Teaching Practices (NCTM, 2014), including using and connecting mathematical representations, facilitating meaningful discourse, and supporting the productive struggle. In Dr. Rosengrant's science content courses, he models the Investigative Science Learning Environment (Etkina & Van Heuvelen, 2007) in some parts while modeling the 5E cycle in others (Bybee et al., 2006). In addition to these pedagogical approaches, he spends a great deal of time focusing on how to teach multiple representations (Kohl, Rosengrant, & Finkelstein, 2007; Rosengrant, 2007; Singh & Rosengrant, 2001) and utilizing educational research in the classroom (Rosengrant, 2010). Finally, he emphasizes best practices for students utilizing the Next Generation Science Standards and 3-dimensional teaching (Bybee, 2014). One key component reflected in the courses they teach is that it is not just content and pedagogy that matter but the nature of science and how to assess aspects of it (Etkina et al., 2006). Furthermore, they incorporate technology like virtual and augmented reality (Rosengrant, Patel, & Guo, 2019) and engineering concepts and research-based practices into all their courses (Berry et al., 2010; Hensberry, Whitacre, Findley, Schellinger, & Burr, 2018; Whitacre, Hensberry, Schellinger, & Findley, 2018).

With full-time faculty now teaching the courses and then aligning the courses, we came to an important question: "To what are we aligning our courses?". At the same time, our college received recommendations from the Southern Association of Colleges and Schools Commission on Colleges

(SACSCOC), the regional body for the accreditation of degree-granting higher education institutions in the Southern states, which governs USFSP. Although the STEM Ed programs are for practicing teachers and only certification programs are required to align to standards, they recommended that we do the same. We needed to have additional data that showed we were meeting those standards. These data come in the form of critical assignments that teachers must pass and are directly linked to the chosen standard(s). This recommendation only reinforced the questions we were already asking ourselves: "To what are we aligning our courses and program?" and "What standards can we use to guide our development of critical assignments?".

We began to investigate what standards for teacher education would be relevant for our programs. There has already been a great deal of quality work in specific STEM areas (e.g. science education), but our focus is on STEM as an integrated whole rather than the individual disciplines. We noticed areas of overlap in general themes of some of the standards that we needed to include (e.g. strong content knowledge is crucial), but other areas do not allow for overlap (e.g. PCK in math is different from PCK in physics). We wanted to draw from one body of work rather than to pull from various sources and sets of standards, but we could not find one already in existence. Thus, the first two authors decided to create our own standards, which involved tweaking and rearranging work that had already been completed but framing it in a way so as to focus on STEM Ed as a whole rather than as disparate silos. We describe those resources in the next section.

Resources Utilized

We began our research utilizing the existing standards in each of the STEM areas. One problem we ran into was that the standards were developed for use either with K-12 students or with preservice teachers in certification programs, but our programs are for in-service teachers. Our program is not for certification and each of our teachers is certified in at least one subject area, but a practicing science teacher may be a novice teacher when it comes to mathematics, technology, or engineering. Thus, with small changes, we were still able to use and intertwine many of these standards. We therefore referenced several different sets of standards, books, and resources to provide a complete set of STEM education standards for teachers. We utilized the standards we could find for each of the STEM disciplines: Science (NSTA, 2012), Technology (International Society for Technology in Education (ISTE) Standards for Educators (2016)), Engineering (National Academy of Engineering Standards for K-12 Engineering Education; Reimers et al., 2015), and Mathematics (NCTM, 2012), as well as Common Core (2010). We also researched how teachers are using documents like the Next Generation Science Standards ([NGSS], 2013) and how it influences their students. We wanted to make sure that these standards align with standards like NGSS.

Because the existing standards focused on teachers requiring certification and were discipline-specific, we also utilized resources for practicing teachers. We referenced the National Board for Professional Teaching Standards (1986), as we wanted to support the development of teacher leaders. Finally, because no STEM standards for instruction were available, we utilized an informative book that highlights key components of STEM instruction (Vasquez et al., 2013).

Developing the Standards

We started the process by focusing first on the science and math standards. Our first determination was that we needed separate standards for grades K-5 and 6-12. Though many of the practices are applicable to both groups, there are enough differences that there needed to be two sets of STEM Ed standards. These served as the foundation and the bulk of our STEM Ed standards. Table 3 shows the alignment between the resources we utilized and how they align with the standards we created. In some instances, the standards are almost directly replicated but others involved some modifications. Most of the standards contain a set of sub-standards (see Appendix A for Elementary (K-5) and Appendix B for Secondary (6-12)).

Certain themes from NSTA and NCTM were similar and were therefore combined and adopted because all of our teachers take courses in both mathematics and science. Certain other themes, however, like safety (NSTA, 2012), were intentionally left as an individual unit as they had no matching counterparts from NCTM. Most standards were edited and slightly revised to keep the main content the same but to make them relevant for in-service teachers (i.e. some standards were written for preservice teachers and therefore needed rewording). Table 3 shows the alignment of the standards we created (1st column on the left) with the resources available.

The engineering and technology standards we utilized were more challenging to incorporate. One of the hurdles we needed to overcome was finding a balance of what is logistically possible in the two years and what are the key pieces of information our teachers need when leaving the program. Thus, for technology, we blended some of the ISTE (2016) standards together into one in our category. For engineering, we focused on Engineering by Design methodologies (Brophy, Klein, Portsmore, & Rogers, 2008) and focused on categories specific to how that can be implemented across the curriculum because we currently do not have any engineering education-specific programs/courses.

These standards reinforced the fact that we were drawing from teacher certification standards for an in-service teacher program. Engineering and technology standards may not be addressed in science or math preparation programs, and likewise, elementary education programs may not go into the necessary depth for science and math standards. However, there is a difference between the standards needed for certification programs and those needed for teachers who are practicing in the field. This is when we turned to the National Board Certification Standards and focused specifically on those standards focusing on helping teachers enhance their practice and their profession in and out of the classroom.

The next components that we needed to complete our standards were those that bring STEM together as a whole. What we had compiled already addressed all of the components and was interrelated across the disciplines; however, we felt that we needed one more standard that focused on STEM as a whole. We turned to resources that focused on how to teach integrated lessons (which we utilize in our courses) and made some of those best practices into a standard.

Table 3
Alignment of our Standards with Resources Utilized

Standard	NSTA	NCTM	Board	ISTE	NAES	Vasquez
1	x	X				
2	x	X				
3	x	X				
4	x	X				
5	x					
6	x	x				
7	x	x				
8			x			
9				x		
10						
11*					x	
12*						x

**Note that Standards 11 and 12 are specific to Secondary STEM Education.*

At this stage in development, we reexamined our program and all of the individual courses, including what had been created in the standards thus far, and found one missing piece: educational research. Though the standards already contained information about utilizing best practices in research, our program (and what most master's programs typically do) is have their students conduct an action research project. As this is a major component in our program, we felt the need to develop a standard related to this. Though we do not expect our teachers to become experts in conducting research, we do expect them to be able to conduct each step of the research process: (a) asking a question, (b) reading the literature, (c) designing the study with clear objectives, (d) conducting the study, and (e) disseminating the results of the research.

The final step in this process was garnering outside feedback on the standards. We presented this work at an international STEM conference (Rosengrant, Gibson-Dee, Hensberry, & Vernon-Jackson, 2018). We designed our presentation to focus on new ideas with the intent to garner feedback from stakeholders across the country. These standards were very well received and attendees provided suggestions for revisions or additions. We used this feedback and further modified the standards. The STEM Education Standards presented in this paper are those that include incorporated feedback.

The Standards

The complete list of standards is found in the Appendix link (www.educationforatoz.com/images/2019_1-8_JME_Dec--Appendix.pdf); however, it is important to briefly discuss the major categories and the justification for each. The first standard focuses on content knowledge. If an educator is not knowledgeable about their topic, they cannot be very effective. Related to knowledge is pedagogy (Standard 2). We are careful to emphasize PCK and not just pedagogy because learning how to teach your discipline effectively is superior to simply know the pedagogy because PCK includes those pedagogical skills as well as subject-specific strategies.

The third standard is Secondary Education Learning Environments. It is important that any STEM educator create a culture in the classroom that supports all individuals in STEM. Related to that is our next standard of Practices. This fourth standard truly embodies the integrative nature of STEM in that teachers need to learn how to view these integrations across disciplines as seamless and fluid.

Safety is the next standard. Science is more than just knowledge of everything around us; it is the processes of how we obtain that knowledge. In this process, there can be potential dangers that teachers must know how to minimize. Concern for students and their well-being should include both their physical and intellectual wellness. The sixth standard is referred to as the Impact on Student Learning. It is important that our teachers be able to analyze their students' work and use that information to modify their teaching when applicable so that they can provide challenging yet appropriate activities for their students. An aspect of this ability is understanding that they too are life-long learners, which is a focus of our seventh standard, Professional Knowledge and Skills. Not only is it important for educators to continue learning even after they have completed our program, it is important for them to continue seeking out resources and to share what they have learned with others.

Though the eighth standard could be applied under standard 7, we felt it was important enough to be its own: Systematic and Reflective Thinking. Being a life-long learner only works if you take the time to critically analyze and think about what it is that you are doing and how are you doing it. Educators should consistently question themselves; for example, "Is this the best way to help my students learn this particular phenomenon?" Sometimes the best way to help your students is through the use of technology, which is our next standard. Every year, there are new technologies that can benefit educators; thus, it is imperative that educators become comfortable with and embrace the technology accessible to them in the classroom.

One of the best ways to accomplish these standards is through understanding the work of other educators, and this idea is central to our tenth standard: Educational Research. It is important for teachers to able to understand and navigate academia to find ways to improve their teaching, regardless of whether they plan to pursue a doctoral degree later in their career.

The last two standards complete the missing link in STEM as well as how to integrate it together as a whole. The eleventh standard is Engineering as a Context for Teaching and Learning. The engineering by design process is a critical mindset for all students to learn. This process is easily integrated into other STEM fields, which relates to our final standard of Integrated STEM Education in Action. Seeing the relationships and being able to teach interdisciplinary content is necessary for an educator that focuses on STEM as a whole as opposed to the content being in silos.

Assessing the Standards

Our approach as a college is that assessment should be holistic, authentic, performance-based, and tied to standards. We thus make use of "Critical Assignments", which are assignments specifically tied to standards and are required for graduation regardless of what grade is earned in the particular course in which they are assigned. In the past, we did not have these types of assignments in our two specific graduate programs, but with the development of these standards, we are now implementing critical assignments throughout the curriculum. A critical assignment is one in which the student must obtain a passing grade or else they automatically fail the course. Typically, each course will have one critical assignment. These assignments are uploaded to a repository where we can keep a permanent record of the assignments, all of which are aligned directly to specific standards. For example, teachers will need to create engineering by design lesson that they can potentially use within their future classrooms (Standard 11). Another example would be requiring teachers to complete a critical assignment in which they would need to develop an augmented reality app that enhances their teaching or a flipped classroom video (Standard 9). In addition to passing a science safety certification course, they also have to describe how they promote safety both in general and in specific labs they teach (Standard 5). Nearly all of the courses have assignments related to implementing activities in the classroom (Standard 3). Some of our standards are assessed not by individual assignments but rather courses as a whole. For example, for content knowledge and content pedagogy (Standards 1 & 2), teachers must get a score of a B- or better in their content courses.

There are now two other major projects that teachers who enter the program must complete. First is an action-based research project in the Seminar course in which the teachers design, conduct, and present their own research project from within their own classroom. They use that data to analyze how their strategies affect student learning. This project addresses Standards 6 and 10. The last project that all teachers must complete is a portfolio. The portfolio includes a self-reflection on how they were as practitioners when they started the program to where they are now nearly 2 years later as they finish the program. One of the other requirements for this project is that the teachers develop a STEM-themed unit that encompasses all aspects of STEM into one coherent project that addresses Standards 4, 8, and 12. Future versions of our portfolio will include a career projection in which teachers will be asked how they will continue to grow and share this knowledge with others (Standard 7).

Researching Program Effectiveness

When conducting a preliminary analysis of the effectiveness of this program, we analyzed the reflection pieces of our elementary education portfolio submissions for four semesters. Teachers in our Middle Grades STEM program were not initially required to complete a portfolio and reflection, but it is a requirement now. We analyzed the portfolios submitted from the following semesters: Spring 2018, Summer 2018, Fall 2018, and Spring 2019. These portfolios are a culminating project and are not submitted as part of a particular class. Rather, portfolios are a last-semester project teachers complete outside of course requirements. After multiple faculty assess the portfolios using a scoring rubric, teachers are given the opportunity to make any modifications if they did not satisfy the rubric requirements.

In the portfolios, the teachers are required to reflect on how the program influenced their teaching, both by providing specific classroom examples and by applying their broad philosophy as an educator. Teachers are required to provide specific examples to support their reflections, but are not graded on the quality of their teaching per se nor on any personal opinions. We chose the four most recent semesters in this program because these teachers are those who went through the program. These teachers had courses in which the content was influenced by both the initial development of these standards as well as by the program modifications made based upon the collaborative efforts with our advisory board. There were nine portfolios submitted by teachers during this time.

When we analyzed the responses of the teachers in the programs, all of them indicated they benefitted from the program and wrote about how their practices improved. For example, one teacher said:

> To begin with, I did not know the difference between teaching science in an inquiry-based manner compared to teaching science in general. I found out that inquiry-based science allows students to work through the scientific method in an investigative way. I assumed that students might not enjoy inquiry-based science. I also assumed that inquiry-based science may be too difficult for students in primary grades. I was incorrect about both assumptions; students thrive while learning in an inquiry-based fashion. True inquiry-based science leads to high levels of student engagement and excitement.

Another teacher reflected that:

> Before this program, I believed that mathematics and science learning always required a paper product and a gradual release model in which students had a chance to practice exactly what was learned. Throughout this program, I've learned that this is not true and that teachers can get a great deal of information by watching how students use critical thinking skills more than what they write down on the paper.

In our time at our institution, we have not observed teachers speak negatively about the program in their portfolios. It is worth noting that the teachers know they can speak freely in their portfolios because opinions are not graded. As this is a preliminary study, we plan to conduct a larger assessment of the program and to provide more targeted questions to all of our alumni. Our goal is that we would also be able to gauge the program effectiveness over time.

Discussion

As education is becoming increasingly less "siloed", the need for standards that expand beyond one discipline is also becoming more necessary. The popularity of STEM schools is increasing across the country, and although our created standards were initially designed to focus on these particular programs, they are applicable to a broader audience as well. For instance, these standards could be used by schools that lack a STEM designation, such as charter or specially designated public schools, as benchmarks to help determine how well they are integrating STEM as a whole as opposed to individual components of STEM curriculum.

Our team has completed several revisions of these standards based on documents that have been carefully scrutinized. However, they are also living documents in that they will be revisited and revised when necessary as they and our programs evolve over time. Any feedback or discussions are welcome to be sent to Dr. Rosengrant, who is the first and corresponding author for this manuscript.

Our goal for this work is to give others standards to serve as benchmarks in one concise location when referencing STEM education. We purposely designed the standards to be broad yet specific in the nuances of STEM integration. The time has come for a distinct set of standards in STEM education that address not only all aspects in STEM but also how to implement and make use of STEM curriculum and instruction such that STEM becomes obtainable for all.

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