An Investigation of Special Education Preservice Teachers' Perspectives and Practices of STEAM Education

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Abstract

Science, Technology, Engineering, Arts, and Mathematics (STEAM) education is an instructional approach whereby teachers intentionally construct design-based learning opportunities to help students learn and apply content knowledge across disciplines in real-life situations. The present study investigated how twenty preservice teachers in a university special education program perceived STEAM education and how they applied STEAM education in the K-12 classroom after a series of trainings and embedded experiences. Results indicate that continuous support in STEAM education is still needed to help preservice teachers move from positive perspectives toward STEAM education to effective practices in the K-12 classroom.

Keywords: special education, STEAM education, teacher education, K-12 classroom

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Introduction

The technological improvements, scientific discoveries and engineering solutions that continue to transform our society impress an urgent need for education to teach life skills for students to become productive citizens (Bybee, 2013; Spillane, 2014; Zollman, 2012). Beginning in the early 1980's, the Excellence Reform Movement ushered in a new era of renewed focus on the teaching and learning of science, technology, engineering and mathematics (STEM) content.

Despite widespread efforts to affect meaningful educational reform toward societal literacy through integrative STEM education, the results have been lackluster at best (Wells, 2008). As a result, many US citizens remain ill-equipped to make thoughtful decisions and to think critically and creatively about the use of technology as well as to employ a full range of cross-cutting skills and knowledge in daily life (Dugger, Meade, Delany & Nichols, 2003; National Academy of Engineering & National Research Council, 2002; National Research Council, 2013).

Recently, STEM educational mandates became more inclusive in scope by requiring evidence of educational growth for *all* students toward the production of a literate society (Bybee, 2013; Handelsman & Smith, 2016). Regardless of race, class, economic status, or dis/abilities, each and every student must have the opportunities to realize their academic and personal potential. However, STEM fields largely remain out of reach for women, minorities, and those with dis/abilities (Handelsman & Smith, 2016; Hwang & Taylor, 2016; Posner & Patoine, 2009). In order to address this inequity, and in keeping with identified gaps revealed by educational research, the U.S. government prioritized three areas for improvement: improving STEM teaching, improving access to rigorous STEM courses, and intentionally improving access to STEM learning for all students (Handelsman & Smith, 2016). When considering the above-referenced priorities, the centrality of the teacher is obvious. Preparation must include, but not be limited to deepening the teacher's content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK) (Shulman, 1986, 1987), and technological pedagogical content knowledge (TPCK) (Koehler & Mishra, 2008) with teachers engaging in communities of practice that support educational transformation (Darling-Hammond & McLaughlin, 2011; Shulman & Shulman, 2004).

Integrative STEAM education

It is important to note that both artists and engineers engage in the process of design in order to make meaning and develop understanding. Artistic design and engineering design are parallel processes in inquiry (Gess, 2015) and, for this reason, an integrative approach to STEM education may be expanded to integrative STEA(arts)M education (Bequette, & Bequette, 2012; Daugherty, 2013; Yakman, 2010). Recognizing that the addition of arts results in increased motivation, engagement, achievement within STEM disciplines (Becker & Park, 2011) and learning among STEAM disciplines (Henriksen, 2011; Henricksen & Mishra, 2013), lawmakers advanced H.Res. 51 to "develop a STEM to STEAM Council in order to facilitate a comprehensive approach to incorporate art and design into federal STEM programs" (H. Res. 51-113th Congress, 2013-2014).

Integrative STEAM education utilizes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEAM subject and one or more other school subjects (Sanders, 2009). This approach has been shown to "provide scaffolding for future learning, to aid in transfer of knowledge and skills, and to demonstrate to students the applicability of their learning in the real world" (Spillane, 2014, p. 1). By definition, the integrative approach encourages the intentional combination of the content and practice of STEAM disciplines and encourages further integration with other disciplines. "The term 'integratIVE' implies an ongoing, dynamic, learner-centered process of teaching and learning distinct from 'integratED', which connotes a static, completed, teacher-centered process" (Wells, 2013, p. 29). At the heart of this approach is the design process, which may be employed in the classroom to "connect hands-on with minds-on , where hands-on experiences are intentionally utilized to achieve minds-on learning outcomes" (Wells, 2016). Thus, the effective teacher will have command of STEAM content knowledge (CK) as well as STEAM pedagogical content knowledge (PCK) and STEAM technological pedagogical content knowledge (TPCK) that is founded in the ideation, creation and employment of authentic design tasks in order to engage all students. In other words, the focus on the process of learning becomes paramount in the classroom as students engage their minds in the activity of designing. All students may gain knowledge and understanding through participation in design and reflection of the process (Cross, 2001).

The design tasks of STEAM education are commonly situated around authentic, real-life situations and activities are tackled in groups, thereby capitalizing on the individual knowledge and experiences that each student brings with them to the class. Allowing students to demonstrate understanding through either engineering or artistic applications will increase motivation for students who have historically been unsuccessful in content-heavy disciplines that are traditionally associated with STEM (Posner & Patoine, 2009). Through working with preservice teachers in the field of special education, the present study investigated how twenty preservice teachers in a university special education program perceived STEAM education and how they applied STEAM education in the K-12 classroom. The research questions that guided the study are:

1. How do preservice teachers perceive STEAM education after intentional exposure to it through a STEAM workshop and/or a STEAM site visit?
2. How do preservice conduct STEAM lessons in the K-12 classroom after the intentional exposure to STEAM education?
3. How do preservice teachers perceive STEAM education after conducting STEAM lessons in the K-12 classroom?

Methods

Data Collection

The data were collected from twenty preservice teachers in a university teacher preparation program after obtaining Institutional Review Board approval. The university utilized a professional development school (PDS) model whereby students participated in eleven weeks in classes on campus and five weeks of field placement in K-12 partner schools each semester. Since the students are specializing in special education (SPED), their placement may be in any grade level (K-12). Among the participants, eleven participated in two consecutive semesters (Fall, 2016 and Spring, 2017), three participated only in Fall and six participated only in Spring. Participant demographic information may be found in Table 1.

Table 1
Participant demographic information

Pseudonym	Gender	Ethnicity	Employed in school as a para-educator	Semester Participation
Angie	Female	Caucasian	No	Fall and Spring
Barbara	Female	Caucasian	Yes	Fall and Spring
Bonnie	Female	Caucasian	No	Fall and Spring
Becky	Female	Caucasian	No	Fall and Spring
Cindy	Female	Caucasian	No	Fall and Spring
Charles	Male	Caucasian	Yes	Fall and Spring
Elizabeth	Female	Caucasian	No	Fall and Spring
Fiona	Female	Caucasian	Yes	Fall and Spring
George	Male	Caucasian	No	Fall and Spring
Katy	Female	Caucasian	Yes	Fall and Spring
Sally	Female	African American	Yes	Fall and Spring
Conner	Male	Caucasian	No	Fall Only
Leslie	Female	Caucasian	No	Fall Only
Mary	Female	Caucasian	No	Fall Only
Bella	Female	Caucasian	No	Spring Only
Lucy	Female	African American	No	Spring Only
Lisa	Female	Caucasian	No	Spring Only
Octavia	Female	Caucasian	No	Spring Only
Sarah	Female	Caucasian	No	Spring Only
Wally	Male	African American	Yes	Spring Only

Note. Among the twenty preservice teachers, four were male and the rest were female. Three were African American and the rest were Caucasian. Six students were employed as para-educators and the others were not employed in the school system. Eleven students participated in both Fall and Spring semesters, three students only participated in the Fall semester, and seven students only participated in the Spring semester.

Workshop. Early in Fall 2016, preservice teachers read three peer-reviewed, published articles (2013) about STEAM education, in order to increase their awareness of an integrative STEAM and to familiarize them with the idea that STEAM education can be an effective pedagogical approach for all students, including those with disabilities. In the middle of each semester, preservice teachers participated in a 3-hour integrative STEAM education training workshop. At the beginning of the workshop, students were asked to respond to two direct questions concerning their knowledge and understanding of STEAM educational approaches to teaching and learning. During the 3-hour workshop, preservice teachers learned about the advantages and challenges of implementing STEAM education as well as how to design STEAM lessons for K-12 learners. At the end of the workshop, participants were again asked to respond to the same questions used in the pre-workshop survey.

STEAM Site Visit. In order to deepen understandings, preservice teachers were given an opportunity to observe a leading model of a STEAM school in Savannah, GA, where they took a full school day to observe classes in session and talk with students, teachers and administrators. The activities during this site visit included welcome and introductions, a tour of applications, small group rotations in classrooms, Q&A with students, Q&A with 6th grade teachers, and a wrap-up session. Preservice teachers were asked to anonymously reflect in writing on the experiences of the day, giving special regard to their perceptions of the advantages and challenges of the approach.

Teaching Reflection Journals. After the workshop, field observation, and follow-up meetings, preservice teachers planned and taught at least one STEAM lesson during each PDS placement. Preservice teachers shared their experiences relative to incorporation and implementation of STEAM education in the classroom in order to participate in an open discussion about their experiences, as modeled in the workshop. Finally, preservice teachers reflected, in writing, on their practice and their peers' feedback. After submission, professors contributed feedback about each preservice teacher's lesson plans, teaching, and reflection paper. The reflection questions included but were not limited to:

- Barriers and needs to persist in using STEAM education?
- Benefits to STEAM education?
- Challenges of incorporating STEAM education?
- What are your perceptions with regard to STEAM education?
- Is the integrative STEAM approach appropriate for SPED teacher candidates?
- Describe your collaboration with your clinical teacher with regard to STEAM education.

Instrumentation and Data Analysis

To investigate preservice teachers' perspectives of using STEAM education, our instruments included feedback forms and reflection papers. For the feedback forms, we used open-ended questions to obtain all possible answers that participants found relevant to the STEAM workshop and the site visit. In the Fall, we asked the participants to share what they knew about STEAM education, in writing, before and after participating in the workshop. In the Spring, we again asked participants to share their impressions of the site visit and their thoughts about STEAM education.

Feedback on the workshop and the site visit as well as reflection papers were analyzed to reveal understanding about participants' perceptions. We used a qualitative content analysis method (Hsieh & Shannon, 2005) to code emerging themes derived from the raw data. We then synthesized and refined the themes based on the relevance of the information and generated a coding book.

To inform teacher educators as to the impacts of the workshop and/or site visit in changing teacher planning, STEAM lesson plans were evaluated for evidence of essential elements of STEAM education. Specifically, plans were evaluated for evidence of the use of a real-life "driving question" (Krajcik & Mamlock-Naaman, 2006) to guide the lesson, elements of the design process, co-listed multidisciplinary standards, and evidence of interdisciplinary applications. Presence or absence of the above elements were documented in order to give a quantitative representation of the result for each lesson plan. Although participants were not limited to use any particular lesson plan template, they all chose the template that they routinely use in their program for mock edTPA. Thus, the use of this template prompted the inclusion, at a minimum, of learning goals, measurable lesson objectives, planned supports, common core standards related IEP goals or IEP objectives, accommodations and modifications, communication skills, resources and materials, introduction, the body of the lesson, closure, and assessments in all lessons. To evaluate the alignment of lesson plans with STEAM education, we modified an instrument previously developed by Wells, Wells & Deck (2015). A summary of the instruments and data analyses in the present study is shown in Table 2.

Table 2
An overview of the research questions, instruments, and data analysis

Research Questions	Instruments	Data Analysis
1. How do preservice teachers perceive STEAM approach after intentional exposure to it through a STEAM workshop and/or a STEAM site visit?	Preservice teachers' written feedback: 1. Workshop (Code: Participant pseudonym). 2. Site visit (Anonymous feedback, Code: Participant A, B, ...Q).	Qualitative content analysis
2. How do preservice conduct STEAM lessons in the K-12 classroom after the intentional exposure to STEAM education?	Pre-service teachers' reflection papers (Code: Participant pseudonym)	Qualitative content analysis
3. How do preservice teachers' perceive STEAM education after planning conducting a STEAM lesson in the inclusive classroom?	Preservice teachers' reflection papers (Code: Participant pseudonym)	Qualitative content analysis

Results

1. How do preservice teachers perceive STEAM education after intentional exposure to it through a STEAM workshop and/or a STEAM site visit?

Pre-workshop: Before coming to the workshop, participants were asked to read three STEAM articles that were published in a top, peer-reviewed practitioner journal in special education – *Teaching Exceptional Journal*. It was our intent that participants would garner some basic knowledge of the general idea and goals of STEAM education before coming to the workshop. On the pre-workshop questionnaire, participants' answers focused on relating what STEAM education *is*, rather than what STEAM education *does*. The majority (7/12) participants described their understanding of STEAM education by simply spelling out the acronym of STEAM: Science, technology, engineering, arts, and mathematics. Three participants articulated that in a STEAM class, the teacher should "integrate STEAM disciplines into the lessons - combining them" (Bonnie). One participant interpreted the STEAM acronym as indicating that the teachers should be sure there is "time set aside for each class"(Mary). Another participant advocated for the use of each STEAM discipline "to help participants understand the world and develop critical thinking" (Katie). Finally, 100% of participants shared that they had never used STEAM in the classroom or been taught about STEAM education.

Post-Workshop: After the workshop, participants were again asked to articulate their thoughts about STEAM education. Their responses were much more varied but about half of the responses again articulated impressions of what STEAM education is and the other half focused on what STEAM education does. For example, participants described STEAM education as "a teaching approach" that is "responsive", "inclusive" and "relevant". Three participants decided that STEAM education was when "all STEAM disciplines are taught and tested together." Eight participants used "integrative" and five used "collaborative" when discussing STEAM education. Participants also described STEAM education for what it does in the context of the classroom: "fostering habits of mind", "moving participants forward" and "helping participants engage the world through critical thinking and analysis." Finally, three participants articulated that this teaching approach would improve educational access for all students with and without disabilities.

STEAM Site Visit: We grouped participants' anonymous feedback on the STEAM site visit into four categories: 1) the environment, 2) the school administrators, 3) the teachers, and 4) the participants (see Table 2). In terms of the environment, most participants described that the learning environment was respectful and positive. School administrators, teachers, and students were proud of what they were doing and they held each other accountable. For example, Participant K stated:

> *I enjoyed the pride and knowledge that students, teachers, and administrators showed for the school. I have never been in a middle school with so much respect and understanding for one another. The teachers have so much freedom within their classes, which shows to facilitate harder work from the teachers, harder work which translates to the students working harder.*

Participant Q concurred when he said:

> *The relationship between student-student, student-teacher, teacher-teacher, and teacher-administration is amazing. Everybody was humble and polite...The kids were very confident in their work as well as the teachers' confidence in the students. The school presented a relaxed environment, which was improved by the flexible seating and the lighting in the classrooms.*

Several participants discussed that this successful and harmonious teaching and learning environment could happen because of the level of the teamwork and communication as well as school climate. The STEAM school cultivated each school member's ownership and responsibility for his/her work. The autonomy and independence reduced the likelihood of problem behaviors in the classroom. In terms of the school administrators, participants were impressed by the principal's leadership, personal skills, and empowerment. He actually cared about the students' and the teachers' well-being and made teachers and students very comfortable and proud to be a part of this school. Participant H stated that "the principal is an amazing and awesome human being. The only person I have ever seen to love and respect his staff and students with the highest esteem." The classrooms had different but equally engaging styles of teaching. In terms of teachers, teachers were excited about what their students were doing. Teachers acted more like facilitators than leaders. They established a respectful and trustful relationship with their students. They guided students' to explore knowledge and to express their own thoughts confidently. For instance, Participant C said,

> *Academic engagement was off the charts. I didn't seen one student that was off task in any class that I went into. The confidence students exuded was remarkable. They were sure of themselves, knew who they were and what they liked, and could convey that. Students not only directed, but led instruction. In fact, I don't think I saw a teacher standing in front of the class with a PowerPoint at all. Depth of knowledge was amazing. To hear 7^{th} graders talk about the harmful effects of pesticides and animal feeding behavior in explicit, accurate terms was incredible.*

The great relationships existed not only between teachers and their students, but also teachers and teachers. Each teacher was approachable and supportive to each other to maximize students' learning. Teachers were willing to come to the school earlier and stay longer to help students catch up with tasks. In terms of students, due to the student-centered frame as well as good relationships among peers and teachers, students seemed excited to be at school and enjoyed coming to school every day. Moreover, students willing to work with teachers, share their ideas, and offer advice to teachers and the school. Participant E stated:

> *It was interesting to see how the students worked professionally with each other...One major note that touched me was when the students said that they actually liked coming to school. As a person who never really liked school, I want to ensure that students look forward to coming to school. It is very cool and interesting that students are working on real-life projects.*

Because students were encouraged to explore knowledge, find the meaning of their projects, and elaborate their thoughts, many students had developed remarkable confidence, respect and inclusivity, communication skills, and team efficiency. Participant G said, "The communication amongst students was a sight to see. They were always collaborating and never denouncing an idea that someone has come up with." Participant F also shared a similar thought: "I was very impressed when I discovered that in one class, students would design a robot and then send digital plans to be completed. The students' peer-to-peer and peer-to-adult skills were also extremely impressive." While the STEAM site had diverse learners from different cultural backgrounds, participants were hoping to see more students with special needs being involved in such a positive learning environment.

Overall, the STEAM site visit was mind-blowing to many participants who had received most of their education in the teacher-directed classroom. By visiting the site, STEAM education became more concrete and doable to them. The school promoted a dynamic student-centered education that focused on real-life situations for all students. Personal satisfaction across school administrators, teachers, and students were evident in the interviews, observations, and practices.

2. How do preservice teachers conduct STEAM lessons in the K-12 classroom after the intentional exposure to STEAM education?

Lesson planning. In the Fall, 40% of the participants discussed science and thirty five percent listed English-language arts (ELA) in their STEAM lesson plans. Among them, 30% explicitly listed science objectives and 20% listed ELA objectives when planning. Mathematics was discussed by 25% of Fall students but only 20% actually listed mathematics objectives. All other disciplines (technology, art, engineering, social studies) were discussed and explicitly listed by ten percent or fewer students. In the Spring, 35% of the participants listed science and the same percentage listed ELA and explicitly listed these objectives in their plans. More telling is the number of times that the subjects were actually co-listed in the same lesson plan, thus evidencing efforts toward integrative approaches. For the Fall semester, 36% of students discussed teaching using more than one standard across subject matters in their lessons and 79% explicitly aligned the standards to reflect that intention. In the Spring, the same percentage of students discussed teaching using more than one standard across subject matters in their lessons and 88% explicitly aligned the standards to reflect this intention. When planning in the Fall, 54% of students chose to include science in the STEAM plans and 36% chose to include math and/or ELA. In Spring, 44% of students chose to include science and 40% chose to include math and/or ELA. Finally, the data did not reveal a preference as to which subjects students most often placed together in plans.

Assessment. In the Fall, 92% of the participants planned to test only one subject, regardless of the standards listed. In the Spring, 56% of the participants planned to assess only one subject, but 44% attempted to test all subjects included in the standards. All Fall participants designed assessments to test knowledge level information. In the Spring, two participants planned on using a more integrative assessment that incorporated some design and higher-order thinking beyond knowledge level.

Science and ELA were most often represented, followed by math. Seven participants in the Fall versus two participants in the Spring used sub-questions to drive their instruction. Only two participants in the Fall used driving questions, and none of the participants in the Spring used driving questions. Participants who used science were more likely to list standards in their lesson plans, and that was true in both semesters. 13 out 15 in the Fall confined instruction to facts; 12 out 15 in the Spring were concerned with facts; higher-order thinking skills were absent from the lessons. We saw no evidence in promoting students' thinking or designing process.

3. How do preservice teachers' perceive STEAM education after conducting a STEAM lesson in the inclusive classroom?

Post lesson reflections focused on the benefits and challenges of STEAM education. Constant comparative analysis revealed eight emerging themes across two semesters with regard to benefits: authenticity, literacy, engagement, inclusivity, family/community, knowledge transfer, teacher collegiality/collaboration, and student empowerment/self-efficacy. Additionally, for the same period of time, five themes emerged as participants' perceptions of challenges for implementing STEAM education. Table 3 provides a list of themes and a brief explanation of each.

Table 3
Coding results

Level 2 Code	Level 1 Code	Description
Benefits	Authenticity	In order to express authentic experiences, preservice teachers referred to lessons that were relevant, hands-on, and experiential.
	Literacy	References to student development of skills such as problem solving and critical thinking.
	Engagement	Students' meaningful interactions with the learning or lesson.
	Inclusivity	Responses include language about all students being actively involved in the lesson/learning.
	Family/Community	Preservice teachers spoke about the explicit lesson connections to students' families and/or communities.
	Knowledge Transfer	Responses that discussed students' use of learned material in more than one context, either in or out of school.
	Teacher collegiality/collaboration	Preservice teachers made specific references to the need for and/or appreciation of explicit collaboration between in-practice and novice teacher as a necessary part of implementation of STEAM educational approaches.
	Student empowerment/self-efficacy	Explicit expressions of improved teaching confidence as a result of planning and/or implementing STEAM educational lessons.
Challenges	Content Knowledge (CK)	Preservice teachers spoke about their collaborating teacher's need for deeper understandings in content knowledge in order to effectively implement STEAM educational opportunities in the classroom.
	Pedagogical Content Knowledge (PCK)	References to participants teachers who had never heard of STEAM or STEAM education or who had not received training in integrative practices.
	Technological Pedagogical Content Knowledge (TPCK)	Preservice teachers referenced use of software to create reports or to play games. No mention of using technology to design or creating technological outputs such as, but not limited to, creation of apps

		or use of computer-aided-design tools (CAD).
	Support	Preservice teachers spoke about the need for support outside of the collaborating teacher and/or family such as (but not limited to): funding, school and district administration, and teaching time.

Benefits

Authenticity. After planning and teaching a lesson, participants overwhelmingly concluded that their efforts brought authenticity to classroom learning opportunities. Fall participants reported learning being given a "purpose" (Cindy) with explicit opportunities to apply learning in a "real world" or "real life" situation (Barbara). Participant Barbara went further to explain:

> *Science concepts, reading concepts, and math concepts were all integrated into one lesson. I feel as though this demonstrates real life for the children. On an everyday basis, we have to use all of these skills to solve problems … helps to wire their minds to use knowledge across the board to solve a problem. Instead of the traditional way, in which teachers try to segment the children's brain in not only solving math problems… Helps students to use all aspects of their knowledge to solve a problem instead of focusing on one single topic at one time.*

Other preservice teachers also asserted that in order for students to be able to "generalize what they are learning" engaging content through a STEAM approach gives a "way for students to see how lessons and skills learned in school can be used to answer many of life's big questions" (Mary). Spring participants referred more often to their observations at the STEAM school than their own lessons when referencing authenticity. For example, when referring to a discussion with a STEAM student, Mary said: "Students need to feel like they are valued and that what they are doing actually makes a difference or is relevant to real life".

Participants often paired the theme of authentic learning with the idea of necessary skills and abilities for each student to acquire through schooling. These preservice teachers highlighted their observations that through the application of important skills into the authentic context students tended to demonstrate skills that are associated with improving literacy such as, but not limited to, persistence, collaboration, communication, thinking critically and thinking analytically. For example, Cindy stated:

> *Students need to learn that failure is a good thing and that they can in fact benefit from it in life...students will most likely be working in groups…in lessons like this, students begin developing people skills, how to communicate well with others, work in a group efficiently, and collaborate within their group with making decisions or how to overcome obstacles...Students learn a lot about themselves as well and where they will benefit most within society.*

Literacy. One main goal of a STEAM educational approach is to promote a literate society. Students in both semesters identified learning outcomes that are associated with 21st century skills as potential results from engaging students in STEAM lessons. In the Fall, Cindy said:

> *Students need to learn that failure is a good thing and that they can in fact benefit from it. … Math is not something simply by itself, neither is science, technology, art, etc. STEAM teaches students to take advantage of what other subjects have to offer. In STEAM lessons, students will most likely be working in groups…allowing them to begin developing people skills, teaching them how to communicate well with others, work in a group efficiently, and collaborate within their group with making decisions or how to overcome obstacles…Students learn a lot about themselves as well and where they will benefit most within society.*

Elizabeth echoed the sentiments of her colleague, saying that "Children who have been introduced to STEAM education early in their education would score better ….dig deep and think critically." In the Spring, other students articulated similar sentiments. Wally said that STEAM lessons "promoted functional everyday living skills" and Sarah said that "students also learn how to manage their time wisely and how to work with others in a group". Lisa, in discussing STEAM education, went further:

> *STEAM lessons require students to read, think, analyze and apply what they have studied. Students that need to build on their social skills are also helped when the teacher follows and supports the characteristics of persistence, communication, creativity and collaboration that these types of lessons require.*

Engagement. In addition to STEAM type lessons being more authentic and supportive of student literacy, participants talked at length about the lessons being opportunities for students to be interested and engaged in the learning. Participants conveyed this sentiment by describing lessons that were "fun", "exciting", "interesting", "hands on" and "engaging." Fall participants reported their students "talking to me about what they smelled, saw and felt" (Becky), and "being more excited" than normal in class (Barbara). Another participant excitedly wrote that "The day after I implemented my lesson plan, a student approached me and asked a few questions in regards to pesticides" (Angie). One participant reported that his/her cooperating teacher said "she had never seen her class so engaged before" (Mary). Several participants concluded that in a STEAM school, students will develop motivation to come to school and will be more motivated to learn. Spring participants also specifically mentioned the potential of STEAM education to meaningfully engage students with disabilities. "Special education students need options in order to learn to the best of their ability and the STEAM approach gives the students multiple subjects to take from to be able to learn" (Mary).

Inclusivity. Many Fall participants articulated perceptions that an integrative approach to lessons can specifically improve education for all students. In a STEAM lesson, "students will most likely be working in groups versus individually" (Cindy) and George, after articulating the same sentiment, went on to say that "teaching with a STEAM approach allows teachers to fully promote the use of differentiation allowing the students to develop ways of learning that are more specific and beneficial for them individually." Conner agreed, saying that STEAM approaches can “give students multiple ways of learning the same information.”

Spring perceptions were similar to those from the Fall. Octavia recounted “When I did the STEAM activity, I noticed that all of the children, no matter the level of their cognitive and developmental delays, were able to enjoy and learn something from the activity.” Wally relayed similar perceptions when he concluded that a significant part of a STEAM approach to teaching allowed him to “differentiate teaching in a way that makes learning interesting for all those different kinds of personalities and disabilities teachers might encounter.” Finally, Angie articulated:

> *The STEAM approach gives me the ability to differentiate instruction by capitalizing on each student’s strong point … to incorporate in the lesson. For example, if a student struggles in science, but does well with hands on activities, the teacher should use this to an advantage and incorporate the arts into the science lesson.*

Family/Community. No participants made discernable references to Family and/or Community impacts or participation in the Fall semester. However, after visiting the STEAM school in the Spring, almost all participants mentioned this element in some way. Barbara (who participated in both Fall and Spring) said **“**One way to help STEAM move along is to incorporate the community and the family in this approach, come up with a program that could help bring more attention to a concept while also helping students learn and make the connection between school and home.” Sally, also a 2-semester participant, in the Spring said “family and community engagement is very important. With the support of the community there are more opportunities for the school to receive more resources.” In the Fall, Cindy did not reference communities. However in the Spring, she noted that in STEAM lessons, “students are doing and learning huge things, things that communities want to support.”

Knowledge Transfer. In their reflections, Fall participants identified knowledge generalizability or knowledge transfer as theoretical results of STEAM lessons. Angie said she observed that “students were able to comprehend more knowledge using two content areas rather than one” and Conner similarly asserted:

> Implementing a lesson that works on both skills from multiple subjects can help the kids understand the concepts from both of the subjects. Lessons from multiple views can be a way to help the kids retain more of the information.

Mary concurred with her fellow participants. She stated:

> A STEAM approach can help students generalize what they are learning. The student is able to see that English does not just stay in English… use what you have learned in English to be able to successfully write an essay in science… or use equations that you have learned in math to be able to build a bridge. Students need to realize that subjects bleed into one another.

Spring participants also identified the possibility of transfer as an outcome, but some students also reported seeing the outcome in their field experience. Octavia said that she intentionally set up stations in her lesson where students took a math problem from one station and applied it in many other subject contexts in different stations. Most students opted to make themselves the center of the math problem that they took from station to station and she concluded that the activity "allowed the students to get creative while also generalize the learning goal and see how they can apply the standard to their everyday life." Barbara, in her Spring teaching, also saw that intentionally planning lessons with a "real- life perspective" and using students' "fascinations" to frame the lesson:

> *…students were able to connect the things that they are learning in the classroom to things that they see happening and going on within their own homes or environments. This makes learning more beneficial to them by showing them that it is useful to know the things that they are learning.*

Teacher Collegiality/Collaboration. Like the Fall semester, participants in the Spring semester also made clear references to the help and participation of their collaborating teacher while they planned and taught using a STEAM instructional approach. Five Fall participants specifically articulated the positive impact of the cooperating teacher's "reassurance" and "cooperation." For example, Angie said "my teacher reassured me that I should not worry about the lesson. She looked over my lesson plan and noticed my fear…she would ask and make suggestions about what she thought needed to be added to my lesson plan." Similarly, Sally recounted "my collaborating teacher was very helpful through this entire process. She gave me countless advice and helped me decide. She was willing to help me with anything I needed. Many participants indicated that participating in the STEAM approach stimulated professional dialogue with their collaborating teacher. Katie's narrative is a good example of this result: "I showed Mrs. R my plans. She showed me the lesson plan her school uses. Mrs. R was willing to help me with whatever I needed." Barbara's narrative linked dialogue and collegiality with resulting encouragement: "Communicating with my clinical teacher was important. She was excited and formatted her lesson plans to fit in my STEAM lesson. She was encouraging." Later in the same reflection, Beth noted, "You need to collaborate with other teachers from other disciplines to find out how best to connect the information and assist your students in learning."

In the Spring, the majority of participants spoke about the "helpfulness" of their cooperating teacher and how it was necessary for successful classroom implementation. "My collaborating teacher was very helpful through this entire process. Even though she did not have much experience with STEAM, she gave me advice and she was willing to help me with anything I needed" (Sally). Other students also spoke about the benefits of cooperating with teachers across the curriculum to promote successful outcomes. Elizabeth indicated that "working with the Gifted Education teacher can be a huge help as well for integrating STEAM into the curriculum." Fiona saw value for both her collaborating teacher and herself through the experience. She said:

> *Teachers can also benefit from a STEAM approach by being challenged to work with colleagues or professionals with a variety of expertise in order to create coherent and well-constructed STEAM lessons. I have been able to resolve issues*

> *by getting plenty of input from my observing teacher. I have been able to consult with people who have created STEM lessons for students with disabilities and tell them my concerns. Thankfully I have worked with a very encouraging team oriented teacher and she has been very positive about my use of STEAM approaches in the classroom.*

Moreover, some collaborating teachers had misconception that STEAM education works better for young children than older students. For instance, Katie said "The SPED teacher I worked with was helpful but she suggested I collaborate with the first grade teacher for STEAM education."

Student Empowerment/Self Efficacy. Participants from both semesters identified improved student empowerment and student confidence as a result of utilizing STEAM educational approaches in the classroom. Fall participants connected STEAM education with "student success in lessons" and student "enjoyment" leading to less hesitancy toward "attending college" (Angie). In addition, Connor connected STEAM education with "Students being able to talk about their interest and question they have" and Barbara saw a result of the STEAM approach as "giving students options." Elizabeth went further to connect interest with confidence:

> *Not everyone automatically sees themselves as a math person or a science person, but if students are able to combine their passions with a strong set of STEAM skills, they can do what they love. This approach can give students ability to have knowledge as well as the confidence to dream big and work hard. The sense of confidence and accomplishment that comes from completing a task through STEM will help any student leaps and bounds into their own futures.*

Spring participants' comments were similar to those of their Fall semester counterparts. Barbara said that while teaching a STEAM lesson, "it was interesting to see kids brainstorm." She further noted that the students behaved as if "they have a part in what they learn." The same sentiment of student centeredness came from Fiona "STEAM approach can be an exciting way to give students a voice in the planning process." Other students saw the STEAM approach as one that "allows for the students' strengths to be used and for their weaknesses to be developed. Students can show more of what they know because they are not being measured by one standard" (Sarah).

Challenges

Content Knowledge (CK). When talking about challenges, participants in both semesters discussed the need for improved content knowledge on the part of the teacher to be able to effectively deliver authentic, integrative education to all students. In the Fall, Katie succinctly stated "the main barrier is a lack of knowledge." Leslie told us that in order to be able to effectively plan and teach using a STEAM approach, "you have to research all the ideas and hands on activities." Spring participants expressed similar sentiments to their Fall counterparts. "A STEM lesson requires the teachers to have more in-depth knowledge of the subjects than they are normally expected to have, especially those who are going into the lower grades" (Lisa). Wally concurred when he stated "STEAM subjects are difficult to learn but also difficult to teach."

Pedagogical Content Knowledge (PCK). Participants recognized that they, along with their mentor teachers, need additional training and opportunities to practice planning for and implementing STEAM education in the classroom. George, a Fall participant, noted that in the school where he was placed, "there was a huge lack of consistency which, from what I saw, made it difficult for any of the teachers to further promote the use of STEAM in the school." Angie echoed this observation when she said "Many school systems are having a difficult time doing STEAM due to the lack of knowledge of STEAM…many schools are letting the students create science projects and calling it STEAM." Katie ran into a roadblock when trying to design and implement a STEAM lesson. She recounted "I let my collaborating teacher know I was supposed to add STEAM to my lesson plan. She said the school was not a STEAM school and therefore the inclusion classes don't add STEAM to the lesson plans." Leslie also saw a lack of understanding by in-practice professionals when she participated in her Fall field experience. She observed that the teachers "have not got the correct training on STEAM education or sat in a lecture of what STEAM lessons are or what they consist of." Bonnie also articulated the existence of poor teacher self-efficacy and a need to "be perfect on the first try" as a result of lack of pedagogical understanding about STEAM education. After their field experiences in the Spring, participants' reflections included many of the same sentiments as noted from their Fall counterparts. Angie (who was both a Fall and Spring participant) said "not many people that were there that were able to give me advice on developing a STEAM lesson plan. Learning experiences are for the both of us." In Katie's Spring placement, she reported that "Teachers say they have heard of STEAM or they have had training but don't use it." Several students advocated for additional teacher training in STEAM approaches. "Teacher preparation is not sufficient in the colleges of today. Nor have teachers been trained correctly. Teachers need to do research on STEAM approaches and how to incorporate STEAM lessons into their own class" (Sarah).

Technological Pedagogical Content Knowledge (TPCK). The "T" in STEAM stands for Technology and refers to engineering technologies and the technology education associated with this discipline (Kelley, 2010). In their lesson plans and reflections, however, all participants referred to their use and incorporation of instructional technologies like smart boards. Not one of them referred to engineering, technological, or artistic design as the root of the learning processes in their lessons. For example, Mary (a Fall participant) stated "We decided to implement technology into the lesson such as watching the movie trailer on the smart board or playing a game on the smart board." Octavia talked about "keeping students engaged and motivated using the kahoot game." Similarly, Charles thought that "modern technology, such as the Promethean board, made utilizing the technology component of STEAM very simple as all modern classrooms are implemented with one." He continued his discussion of technology by referencing the "class website" to "formulate an online document" thereby "using technology more fully."

Support. Study participants identified many areas needed to support STEAM teaching. Fall responses focused on the lack of ready-made curricular resources, a lack of time to effectively plan and implement integrative lessons, and a lack of funds to purchase supplies. Overwhelmingly, the majority of the comments spoke to time as the biggest barrier.

"Having the time to implement a STEAM lesson efficiently, not something to be rushed," was a specific concern of Cindy's. Faith thought that "adding more activities and new information to an already tight schedule proved to be the biggest challenge of all." Emily articulated similar sentiments:

> *The amount of time it takes when using a hands-on approach to teaching typically takes more time than simply lecturing students. As a future teacher in hopes of implementing STEAM, I will have to do hours upon hours of extensive planning and research.*

Finally, Leslie revealed "it does take more planning time out of your work day as well as your personal time. Teachers at my school wondered about the time that it would take out of their planning time." Spring participants, like their Fall peers, expressed concern about lack of money and other supplies and lack of time. Cindy, for example, spoke to each of the above-referenced issues:

> *Having the time to efficiently implement a STEAM lesson and being well-prepared for it are very crucial. It is a thoroughly thought out process. Not all schools have the money for things in a low income school, they may not have enough money to purchase the equipment and supplies.*

Elizabeth also referenced time and resources as issues:

> *The amount of time needed to plan a STEAM lesson, in my opinion, is more time than it takes to compose a regular lesson plan. Administration may not support the use of STEM in a special education setting and therefore not give the supplies or monetary support. Teachers are under a lot of pressure to fulfill other duties and the idea of developing entirely new lesson plans involving STEAM are low on the priority list.*

Fiona stated "a lot of teachers simply may not have sufficient time to create and collaborate with others about STEAM lessons." Katie concurred "the time it takes to prepare a STEAM lesson is longer than a non-STEAM lesson." Bonnie asserted that school structure must change to support a STEAM educational approach because "you need to collaborate with other teachers from other disciplines to find out how best to connect the information and assist your students in learning." Participants in the Spring semester articulated that a lack of parent/community involvement could also be a barrier. Many schools do not have the resources to provide proper STEM education. "One way to resolve the lack of resources is to ask parents to donate, as the community to donate, as the businesses to donate" (Sarah). Katie concluded, "I believe educators have to buy into STEAM per say and then they have to sell it to the families and communities".

Discussion and Conclusion

The present study involved a period of two consecutive semesters and about half of the participants took part in both Fall and Spring. At the outset of the research cycle, participants read current, peer-reviewed articles about STEAM education. It was interesting to note that before attending the first training session and despite their background reading, participants revealed deep misconceptions about STEAM education. They viewed STEAM as S.T.E.A.M. (individual disciplines) or different subject matters that one teacher should cover in a course. Participants did not express awareness of design as the core of learning nor of any cross-cutting skills that could result from this educational approach. Although the articles that participants had read prior to the training workshop provided explanations about what STEAM education is, they did not make consistent interpretations of the meaning of STEAM education. This phenomena does not stand alone. Despite increasing national funding and awareness, definitions and explanations about STEAM education continue to be lacking in continuity among authors, reviewers and practitioners National Science Board (2016). These pervasive inconsistencies in the educational literature and among STEAM professionals contribute to a lack of meaningful impact to student achievement in STEAM disciplines and subsequent student persistence in STEAM subjects (National Science Board, 2016).

After the workshop, most participants perceived specific advantages of STEAM education and articulated the belief that this approach would benefit all students, including students with special needs. It seems that the more the participants learned about STEAM education, the keener they were to implement STEAM in the classroom with all students. Participants began to discuss the importance of integrative learning across content areas, real-life problem solving skills, critical thinking, and teacher collaboration in their reflection papers. A STEAM site visit was conducted in the second semester before students taught their STEAM lessons in K-12 classrooms. After the school visit, participants wrote their reflection on this trip. All of them viewed STEAM approaches positively and were impressed by the learning environment arrangements, school administrators' support, teachers' collaboration, and students' confidence. Several participants mentioned that they wished to see more students with special needs being involved in such a positive learning environment, and to learn more about how to accommodate students with special needs in the STEAM classroom. The experience added valuable perspective to what these participants were learning in class.

In both semesters, despite articulating the need for integrative approaches to affect student development of 21st century skills, participants did not include most of these essential components in their lesson plans. Participants tended to lean on science and ELA as the dominant subjects for their STEAM lessons and no design focus or designing of artifacts to demonstrate understanding was utilized. Almost all participants in both semesters constructed lessons that were confined to student learning of facts. When given the choice, participants in the Fall more often chose science to include in their lessons and used science as the "go to" discipline in which to find context for application. In essence, the participants equated science with STEAM. By Spring, this preference was no longer visible. Participants were equally as likely to choose math or ELA as subjects to present in a STEAM lesson, but like their Fall counterparts, situated student outcomes in the learning of facts and not higher level skills or abilities. No participants made reference to the use of arts or engineering as contexts for applying knowledge or constructing understanding. Additionally, they did not demonstrate use of the same habits of mind that they were trying to teach and found valuable.

Moreover, the participants' practices in the classroom indicate that they did not have a conception of technological artifacts or engineering artifacts. They did not understand technology as engineering technologies. Rather, they identified technology as the tools in the classroom to help deliver instructions. Instructional technologies are important components of effective instruction - STEAM or otherwise. In our current technologically defined society, it is important that students be able to effectively utilize technological tools. From the perspective of STEAM education, however, having preservice teachers engaged in the design process toward the production of an engineering, technological or artistic artifact as a framework in which to construct and provide evidence for educational understandings is the hallmark of this approach. The participants' misunderstandings are consistent with what has been observed in other studies and points teacher-educators to an area for improvement.

Reflections also revealed that collaborating teachers are still in the beginning stages of the teaching continuum themselves, therefore not able to meaningfully support the novice teacher out of a directive mode and into a more facilitative role. Several participants pointed out that their collaborating teachers were also new to STEAM education, and thus they did not receive much instructional support on their STEAM lessons during fieldwork. Another important issue is the relationship between collaborating teachers and preservice teachers. When the participants had a better relationship with their collaborating teachers, they tended to feel more comfortable to use innovative teaching strategies. Through the requirement of implementing a series of STEAM lessons, participants were placed more in a position of equality and collaborating teachers and participants became co-inquirers in the classroom.

Interestingly, although response to intervention (RTI) and other approaches like differentiated instruction had been introduced to the participants throughout their program, none of them discussed the incorporation of evidence-based strategies to help deliver STEAM education more effectively. Some participants even had a misconception that by "doing STEAM" they were automatically facilitating differentiation. That is, they thought that when students have access to multiple subjects at the same time, this would automatically qualify as differentiated instruction. The goal of using differentiated instruction is to help students perform better on a lesson through utilizing a variety of strategies. Lilian Katz's quotation provides a good explanation for why teachers need differentiated instruction, which also distinguishes differentiated instruction from the STEAM approach: "When a teacher tries to teach something to the entire class at the same time, 'chances are, one-third of the kids already know it, one-third of the kids will get it, and the remaining third won't. So two-thirds of the children are wasting their time' (IRIS modules, 2017). In other words, when teachers are implementing STEAM education in their classrooms, they still need to find intentional ways to help those who are behind to catch up with their peers, regardless of teaching one single subject or multiple subjects, and to challenge those who are more advanced than their peers.

The present study leads to several important implications for STEAM education practitioners and providers. It is imperative that all stakeholders strive to reach consensus as to a working definition and research-based approaches that may be considered hallmarks of STEAM education. Confusion about the acronym and its applications, both in and out of the classroom is pervasive and may be inhibiting meaningful K-20 progress toward a STEAM literate society. Additionally, explicit training in integrative practices toward transdisciplinary approaches is a meaningful endeavor for all teachers. Preservice and inservice teachers are largely uninformed as to the methodologies that undergird this kind of education and would therefore benefit from explicit instruction and support as they learn how to implement integrative approaches in their classroom. Such training should include opportunities for collaboration across disciplines as well as among educators of all different experience levels. Oftentimes, we saw preservice teachers mentoring their collaborating teacher just as much or more than the reverse. Our research indicates that a STEAM education focus may indeed act as a "leveler" of sorts, putting novice teachers on par with seasoned educators in one way as they both learn new educational approaches and explore trying them out in the classroom.

Our research reveals that STEAM education supports collaboration not only among preservice teachers but among inservice teachers and community. As a part of the training, teachers should be allowed to experience a working STEAM school. As shown in our study, when preservice teachers participated in the site visit, they were more likely to notice and value the important role of family and community engagement and improved literacy connections that are supported by STEAM education. They began to realize that the approach was indeed possible and that student outcomes could meaningfully be improved. The experience functioned to help preservice teachers to connect the theoretical with reality, resulting in a firmer foundation on which to build practice.

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