Empowering Future Educators: Designing a STEM Lab to Enhance Elementary Teacher Preparation

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Abstract

To support beginning teachers in developing practical knowledge and experience with implementing effective STEM lessons, we created a STEM Lab within our university's elementary teacher education program. The STEM Lab consisted of a lending library of STEM materials and equipment common in many elementary schools. We report on three goals we established to engage teacher candidates with materials from the STEM Lab. Those goals included (1) engaging with STEM materials as learners, (2) practicing teaching with materials to peers, and (3) teaching with materials to elementary students. We describe specific actions we took as teacher educators using the STEM materials to meet these goals and the learning opportunities teacher candidates were afforded as a result. Actions highlighted include facilitating material exploration and instructional rehearsal experiences in methods courses and supporting teacher candidates to teach with the materials within their field placements and informal STEM events. As a result of these actions, teacher candidates were able to deepen their understanding of STEM concepts, develop the instructional practice of questioning, observe student engagement, broaden their perspective of STEM lessons, and interact with families and communities. We conclude by sharing survey results from the 1st year of project implementation, challenges we experienced, and recommendations for other STEM methods instructors on designing future resource lending programs.

Research has demonstrated that a key challenge for beginning teachers of science, technology, engineering, and mathematics (STEM) is to transfer their planning ideas into achievable learning experiences that they can implement effectively (Bartels et al., 2019; Berisha & Vula, 2021; Sahin-Taskin, 2017). One critical area of concern for effective implementation is a lack of access to and knowledge about physical supplies, materials, and equipment needed to teach the STEM disciplines. Among the 919 elementary teachers surveyed in the National Survey of Science and Mathematics Education (Plumley, 2019), only 49% considered their instructional technology to be adequate, and just 39% felt the same about their science equipment. It is challenging for teachers to develop practical knowledge for implementing effective STEM lessons if they cannot both learn from and teach with the materials and equipment inherently needed for STEM learning experiences (Shernoff et al., 2017).

Recognizing the importance of access to materials, we acknowledged that our elementary teacher education program was critically under-resourced for supplies that would be used to teach activities aligned to the Next Generation Science Standards (including engineering education), integrated STEM, and computer science education. This led us to apply for a grant that awarded us a wide range of STEM materials and equipment for our university courses. Such a lab would provide teacher candidates with the resources and time needed to engage with the materials as learners, practice teaching with their peers, and use the materials when implementing lessons with elementary students. The purpose of this article is to share information about the creation and application of the STEM Lab, how it influenced our actions as science and STEM teacher educators, the subsequent opportunities those actions have afforded teacher candidates, and the challenges we have experienced and continue to navigate.

The STEM Lab

Our grant proposal was funded by the Hawai‘i State Department of Labor and Industrial Relations and allowed us to spend a little more than $37,000 on STEM materials and equipment, not including indirect costs to the university. A full breakdown of the project’s budget and specific materials purchased can be viewed in Appendix A. To decide what to purchase, we consulted elementary schools and districts across our state. Table 1 provides the rationale and selection criteria that informed our purchasing decisions.

Table 1
Selection Criteria for Purchasing STEM Materials and Equipment

Selection Criteria	Examples of Materials Purchased
Elementary-Specific	Reusable plastic cardboard construction tools made for safe use in elementary learning contexts.
Job-Connected	Dash™ robots are affordable robots used in several local schools to teach engineering and technology skills.
Applicable for Single-Subject and/or Cross-Disciplinary Learning Experiences	Whereas foam Cuisenaire rods were selected to support learning experiences in mathematics, Vernier™ sensor probes and Chromebooks were selected to allow for the design of upper elementary integrated STEM lessons that focus on using technology to design scientific experiments and collect/analyze mathematical data using graphing software (e.g. a unit focused on testing water quality)
Immediately Usable	Magnet and electricity materials were targeted because they could immediately enhance instructional units already designed by several STEM methods instructors
Sustainable	High-quality digital balances were selected over low-quality plastic balances to ensure longevity

Material selection supported two views of STEM education that inform our elementary teacher education program's approach to STEM teacher preparation.

1. Discipline View: STEM education includes the development of students' learning within the disciplines of science, technology, engineering, and mathematics, with an acknowledgment that there are distinct goals, aims, and knowledge structures that comprise each discipline. For example, we want our teacher candidates to support their students´ evidence-based explanations about magnetic forces through the use of magnets in science and to support their students' understanding of place value through the use of base 10 blocks in mathematics.
2. Integrated View: STEM education includes the engagement of students in learning experiences that support them in constructing cross-disciplinary concepts or using knowledge and practices from two or more STEM disciplines to solve a problem or address a vexing issue. For example, we want our teacher candidates to explore ways of leveraging robots to intentionally integrate science and engineering practices with technology learning goals (i.e. using an engineering design process to modify a roving vehicle that can complete simulated Mars missions through a well-sequenced coding program).

In many cases, we found that a material could be used to support either a discipline or integrated view depending on the goals of a particular learning experience; in some situations, a robotics lesson may need to focus on computer science skills (technology) only, and in other cases, it can helpfully target the integration of technology with other disciplines. Throughout this article, we present examples of using materials to support both a discipline and an integrated view of STEM education.

We housed all materials in one classroom on campus. This location served two purposes. First, it allowed for the conversion of that room to a STEM Lab, in which we could easily access the materials when teaching our methods courses. Second, it allowed us to structure the Lab as a lending library, with opportunities for teacher candidates to borrow materials. We created a sign-out Google form and advertised the opportunity to check out materials in our various methods courses. Teacher candidates have coordinated material pick-up with one of us as needed.

Goals, Actions, and Opportunities

When this project was conceptualized, we articulated three primary goals for the STEM Lab. In the following section, we describe each goal, the major actions we took as teacher educators to achieve that goal, and the corresponding opportunities for learning that were afforded to teacher candidates. A summary of goals, actions, and opportunities can be found in Table 2. Throughout the ensuing discussion, we provide a few examples of teacher candidates' written reflections from their science or STEM methods courses as well as photographs of them working with the materials and teaching in elementary learning contexts.

Table 2

Project Goals, Actions, and Opportunities for Teacher Candidate Learning

Project Goals	Teacher Educators' Actions	Opportunities for Teacher Candidate Learning
1. Engage with STEM materials as learners	Facilitate material exploration in methods courses	Deepen understanding of STEM concepts
2. Practice teaching with materials to peers	Facilitate rehearsal experiences in methods courses	Develop the instructional practice of questioning
3. Teach with materials to elementary students	Support teacher candidates to teach with materials at field placements and informal STEM events	Observe students' engagement Broaden perspectives of STEM lessons Interact with families and communities

Goal #1: Engage with the STEM Materials as Learners

The first goal of the project was to increase elementary teacher candidates' engagement with materials that can be used to teach STEM subjects. In this section, we explain how the STEM materials have been incorporated into the science and integrated STEM methods courses we taught within the elementary teacher education program.

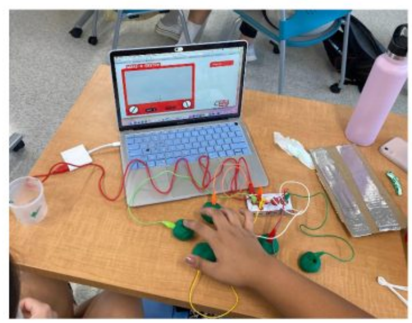
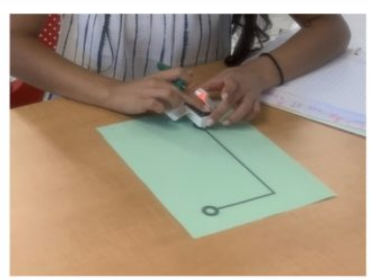
Action: Material Engagement In Methods Courses*.* Materials and equipment from the STEM Lab have been used in at least one science, math, or STEM methods course each semester within our elementary education program since the project's inception in Fall 2021. As methods instructors with pre-designed courses representing a broad range of intended outcomes, we had to negotiate how to select and integrate specific materials. A practical strategy was to use a particular material to supplement pre-existing lessons. For example, all of our science methods courses previous to this project included a mini-unit focused on teacher candidates' exploration of circuits and energy transfer. Therefore, exposing the teacher candidates to additional materials beyond the typical battery-bulb-wire set seemed achievable and exciting. Teacher candidates across the science methods courses gained new opportunities and extended their understanding of energy transfer through an exploration of Squishy Circuits^{TM}, Makey Makey^{TM}, and Snap Circuits^{TM}.

In other cases, we were inspired to design new learning experiences within methods courses that enabled teacher candidates' to apply disciplinary concepts more effectively when access to a wider range of materials to explore was made available. For example, the MakeDo^{TM}

tools allowed teacher candidates to apply their understanding of structure & function, material properties, and mathematical scale and proportion as they engaged in newly designed cardboard construction activities. Furthermore, the robotics equipment (e.g. Push Bots, Dash^{TM}, and Sphero^{TM}) allowed teacher candidates to explore the connection between coding and the actions of a physical object that enhanced our past sole reliance on web-only tools like Scratch. Table 3 presents specific examples of how materials were incorporated into specific learning experiences, with aims to develop the teacher candidates' knowledge both within and across the STEM disciplines.

Table 3

Examples of Incorporating Materials in Methods Courses with Page Break

Materials	Targeted STEM Disciplines	Lesson	Photo
Vernier™ sensors and Chromebooks	Science Technology Mathematics	Teacher candidates explored sound energy in multiple stations, one of which utilized Vernier™ sound sensors. This new station allowed them to use features of a graphical analysis app (technology) and proportional reasoning (mathematics) to make claims about waves change based on volume and pitch (science).	
Squishy Circuits™	Science Engineering	Teacher candidates created and designed electric circuits using conductive dough (similar to Play-Doh). This experience allowed them to prototype, test, and improve their final products (engineering) to explain energy transfer within a working circuit (science).	
Makey Makey™ Circuit Kits	Science Technology	Teacher candidates learned how a computer (technology) can become both the power source and output in a circuit (science) to create interactive experiences. For example, teacher candidates learned to use the alligator clips to connect the Makey Makey to conductive objects that, in turn, become the new keyboard. They were able to use conductive dough as different keys to play specific musical notes.	
Push Bots	Technology	Teacher candidates learned to write basic coding programs, figuring out the need to consider every possible movement of a push bot and its corresponding code.	
Dash Robots	Technology	Teacher candidates learned to develop a multi-step coding	

		program to perform tasks more complex than what push bots can perform. The Dash robot included challenge cards - for example, asking them to maneuver their robot around certain obstacles to travel from point A to point B.	
Ohaus™ Digital Scales and Measuring Kits	Science Technology Engineering Mathematics	Teacher candidates took on the role of an employee at Consumer Reports™, a non-profit company designed to protect consumers. The teacher candidates prototyped and iterated (engineering) fair tests (science) to carry out on different brands of paper towels, using digital scales and measuring kits. They engaged in quantitative reasoning and data analysis to determine if a brand that costs more money is actually the better value (mathematics) and developed digital data representations (technology) to present their findings.	

Opportunity for Teacher Candidate Learning: Deep Understanding of Subject-Specific Concepts*.* We learned that explorations of STEM materials' features can lead to class discussions that aim to deepen and refine teacher candidates' understandings of subject-specific concepts. For example, engaging in circuit stations allowed for a substantial amount of grappling with the components of a circuit and the energy transformations that occur within them. Teacher candidates worked in small groups to explore a material (Snap Circuits™, Paper Circuits™, Squishy Circuits™, Makey Makey™, and the Basic Circuit Kit) and how it could be used to extend their knowledge from a basic circuit to a more complex circuit that could incorporate multiple loads or a parallel circuit design. They were able to apply their scientific knowledge of simple circuits to a new situation and explain their thinking to one another as they built their circuits, some of which worked and some that did not. Each group encountered challenges along the way, such as learning that an electric current must operate in a closed circuit and that a set of new materials had to be connected in a particular manner to close the circuit. As one teacher candidate stated, "*the light only lights up when it's put in the right way so it goes with the flow of the circuit*" (teacher candidate's notebook). Throughout the discussion, it was evident that the opportunity to work first-hand with the materials provided the teacher candidates with the opportunity to deepen their explanations of energy transfer and circuit design because those explanations applied to more than one set of materials.

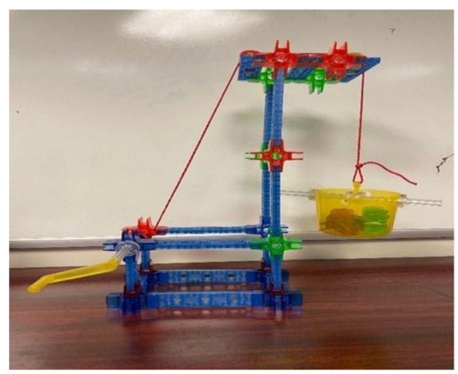
In another example, when teacher candidates used the MakeDo™ tools to engineer a chair made of cardboard in a STEM methods course, it led to a discussion about avoiding the bias of functional fixedness. Specifically, they learned to explain that the same material can be used for more than one purpose (a sheet of cardboard can be transformed into a leg or a seat, and a screw can be used for joining two materials or as a lever to swing one piece of cardboard around another). As a third example, the robotics equipment helped facilitate discussions about coding concepts beyond building a program. The hands-on coding card of VEX 123™ bots allowed teacher candidates to directly move around different coding instructions when their original program did not work, leading to a direct conversation about the computer science concepts of troubleshooting and debugging.

Goal #2: Teacher Candidates Practice Teaching With Their Peers

After teacher candidates became exposed to STEM materials, our project's second goal was to provide teacher candidates with opportunities to practice teaching with the materials in low-risk environments. Content methods courses often have the aim of supporting teacher candidates with actualizing and operationalizing teaching practices (Sickel & Witzig, 2017). One strategy we used to accomplish goal #2 was the facilitation of instructional rehearsal. During teacher candidate-led mini-lessons, a teacher candidate practices teaching a phase of a lesson with their peers role-playing as learners. Rehearsal allows the teacher candidates to experience a science or STEM lesson in the role of both learner and teacher, thereby providing opportunities to consider the components of a lesson phase, the practice of questioning, and the reasons why a particular material might be paired with specific learning objectives.

Action: Rehearsal Jigsaw*.* After receiving the new STEM materials, instructional rehearsal began to serve as a foundational basis for planning our teacher education program's integrated STEM methods course. Teacher candidates engaged in three primary units of instruction: 1) integrating science with engineering; 2) integrating mathematics in STEM learning experiences; and 3) integrating technology into STEM learning experiences. For each unit, the class was divided into three materials groups, with each group receiving a particular set of materials that could highlight science and engineering, mathematics, or technology. Each teacher candidate designed a mini-lesson that: (1) included a driving question or task aligned with standards, and (2) used the assigned materials. The teacher candidates then participated in a jigsaw process, forming groups of three for which there was a representative from each set of materials. The teacher candidates participated in three rounds of rehearsal, with each person teaching with their assigned material for one round and serving as a learner for their peers' materials in the other two rounds. As an example, the three sets of materials for the science and engineering mini-lesson included: (1) Keva Planks™, (2) Lego Bricks™, and (3) Brackitz™. Table 4 presents example tasks that teacher candidates developed for each material.

Table 4
Example Tasks and Engagement with Materials from a Rehearsal Jigsaw

Materials	Task	Reasoning About the Material's Affordances and Constraints	Photo
Keva™ Planks	Build a bridge using the same-sized planks with only two pillars and no fastening materials (cantilever bridge).	Constraints: no fasteners or interlocking systems Affordances: the planks are easily stackable and can be positioned incrementally to distribute load.	
Lego™ Bricks	Build houses or structures for different purposes and that are suited to particular environments.	Constraints: interlocking parts can prevent flexible movement Affordances: specialized pieces allow for representation of a wide range of real-world structures	
Brackitz™	Build a device that can lift objects using a set of supplies from an engineering kit (elevator pulley).	Constraints: plastic pieces do not allow for a substantial amount of load-bearing Affordances: parts allow for dynamic movement (e.g. using a pulley)	

Opportunity for Teacher Candidate Learning: Develop the Core Practice of Questioning*.* Managing the discourse of a classroom through questioning has been identified as a core instructional practice (Grossman, 2018) that is difficult to develop. In addition to exploring how the materials could be integrated into a lesson, a central aim of the mini-lesson jigsaw was for teacher candidates to practice creating and implementing questions to promote reasoning. Teacher candidates were asked to create a lesson script, identifying key questions for when their learners were both exploring and explaining a solution to a task. Table 5 presents a teacher candidate's questions from their Brackitz™

mini-lesson plan that focused on designing a lifting device. The teacher candidate's questions span multiple components of an engineering design process, including a focus on initial design, integrating science concepts, and reflecting on improvements.

Table 5

Teacher Candidate's Questions Designed for a Mini-Lesson in a STEM Methods Course

Lesson Phase	Focus of Teacher Candidate's Questions (from the lesson plan)	Teacher Candidate's Specific Questions to Use During Teaching Rehearsal
Explore	Design considerations	*Does it matter where you place your weights?*
	Trouble-shooting design challenges	*What do you think could be the possible reason that your elevator is hitting the supports?*
Explain	Using concepts to explain the design	*What simple machines are used in your compound machine?*
	Reflecting on challenges and improvements	*What challenges did you encounter when constructing the elevator?* *Is there anything you changed in your design that made the elevator function better?*

Through discussion of the science and engineering mini-lessons, teacher candidates realized that thinking deeply about questions to support student learning naturally leads to direct considerations about why certain materials might be selected for a particular task or design challenge. An examination of constraints and affordances inherent in the design of each material is critical (see Table 4). In one class, teacher candidates reflected in a whole-group conversation that:

- Keva™ planks allow for exploration of how to use one type of material to build support structures, i.e. cantilever,
- Lego™ allows for explanations of design ideas with specialized pieces, i.e. complex housing structures, and
- Brackitz™ allows for designing simple yet dynamic machines, i.e. pulley systems.

Therefore, discussions about materials' affordances and constraints have the potential to support teacher candidates' developing pedagogical content knowledge, in this case highlighting the integration between knowledge of instructional strategies and knowledge of curriculum (Carlson et al., 2019). It would have been challenging to facilitate these pivotal discussions about questioning and task design without access to a diverse set of engineering supplies specific to elementary education, which was afforded by the creation of the STEM Lab.

Goal #3: Teacher Candidates Teaching Elementary Students

After teacher candidates became exposed to the materials and practiced teaching with them, our final goal for the project was for them to use the STEM materials when teaching elementary students. We approached this goal by supporting teacher candidates to incorporate the materials into teaching experiences in formal and informal contexts.

Actions: Supporting Teacher Candidates To Use Materials In Elementary Classrooms and Informal STEM Events. As part of the design of our elementary teacher education program, all teacher candidates in our methods courses were concurrently placed in a field setting – specifically, a grades K-6 elementary classroom at a local school under the supervision of a mentor teacher and university-based field supervisor. As part of our methods courses, we offered teacher candidates the opportunity to check out STEM Lab materials they could use for their field placement lessons (see Table 6).

Table 6

Examples of Field-Based STEM Lessons and Materials Used from the Lending Library

Material	Grade Level	Targeted STEM Disciplines	Lesson Synopsis
1. Code and Go Mouse	Kindergarten	Technology Mathematics	Students used direction cards to plan a short sequence (technology) for the Mouse to travel around a 10-frame. Students used counting skills (mathematics) to understand that each step is one action in a coding sequence.
2. Grow Lights	3rd Grade	Science	Students conducted an experimental lesson and compared regular tomato seeds and ones launched in space by SPACEX. (Tomatosphere™)
3. MakeDo™ Tools	4th Grade	Engineering	Students completed a five-step engineering process to design a chair that could be used in a Kindergarten classroom. After imagining different designs and selecting a final one, students used the tools to build a prototype chair and then improve it after a feedback phase.

During the most recent iteration of our program's integrated STEM methods course, 10 of 22 teacher candidates formally checked out a set of materials to use as part of a STEM lesson they taught in their concurrent field placement or during their next semester of student teaching. Figure 1 showcases a teacher candidate from that course introducing the MakeDo™ tools to her 4th grade class during her student teaching semester.

Figure 1

A Teacher Candidate Introduces the MakeDoTM Tools for an Engineering Project

The action of encouraging teacher candidates to use the STEM materials at their field placements originally represented our sole focus for achieving Goal #3. However, we quickly learned that this approach would not reach as many teacher candidates as we would have preferred. A number of teacher candidates had difficulty finding opportunities to teach science or integrated STEM and/or felt uncomfortable introducing new materials into another teacher's classroom. In the face of this challenge, we took additional action.

Prior to this project, we had a few experiences of engaging teacher candidates within our methods courses in developing short learning centers or stations at informal STEM events for elementary students (e.g. a 'STEM Day' sponsored by external organizations or after-school STEM events at a school). However, the new materials propelled us to leverage opportunities at informal STEM events and connect our teacher candidates to both the STEM Lab materials and teaching elementary students with those materials.

Table 7

Examples of Informal STEM Lessons

Type of Event	Event Description	STEM Materials Used
1. City-Wide STEM Day	A STEM event offering hands-on activities and STEM workshops for grades K-3 students and families in the state.	VEX 123™, SPHERO™, VEX Go™, Dash™,
2. School-Based Family STEM Night	First STEM night for students and families from the school. The event featured hands-on activities with a focus on Robotics and STEM	VEX 123™, VEX Go™
3. Migrant Community After-School STEM Learning Event	Community Service Learning event for a K-6 tutoring program in the community. The program serves students from diverse cultures, including Chuukese and Marshallese families.	VEX 123™, Push Bots, Squishy Circuits™, Snap Circuits™

Whereas we have less purview and influence over the teacher candidates' field classrooms, we were able to take on a more directive role with the informal STEM events. Often, we coordinated directly with the informal STEM event organizers or school administration to ensure that all teacher candidates within a methods course could design a learning center or station to be facilitated at the event. We then organized those stations by providing a set of materials from the STEM Lab to each group of teacher candidates. By offering teacher candidates the opportunity to engage in diverse community-based experiences using STEM materials, we believed teacher candidates would gain important experiences beyond the traditional course (see Table 7). Figure 2 showcases a teacher candidate setting up a learning station at a community-based STEM event.

Figure 2
A Teacher Candidate Sets Up a Snap Circuit at an Informal STEM Event

Opportunities for Teacher Candidate Learning: Observing Students' Engagement, Broadening Views of STEM Lessons, and Interacting with Communities. Based on our interactions with teacher candidates and an examination of their end-of-course written reflections (with examples provided below), teacher candidates benefited from teaching elementary students with the STEM materials in three important ways. First, they were able to directly observe their students' engagement and excitement. Examples of their comments are provided below:

- *"It was really fun having them [students] interact with the VEX robots because, for some, it was their first interaction with coding. Having a cool technology for students to explore was really impactful to their learning and highly engaged them."*
- *"The students were excited to use the materials [Zoomy microscope] and were engaged throughout the lesson."*
- *"I learned that Lego can be used in a product[ive] way to create models without students getting distracted."*

During the early years of their paths to becoming licensed, professional educators, teacher candidates are often concerned about navigating issues of classroom management and students' disengagement or distracted behaviors (Akdağa & Haser, 2016; O'Neill & Stephenson, 2012). While teacher candidates discussed the importance of explicit instructions ("*You have to be very explicit when using technology"*) and scaffolding, ("*Starting students off with fewer materials than in the individual kit helped them to understand the contents and their functions"),* those who used STEM materials in schools had the opportunity to witness high interest from their students. Beyond the notions of students' joy and intrigue, our conversations with teacher candidates have clarified that they are beginning to conceptualize how the materials can generate investment and productive learning as well.

Second, teacher candidates started to broaden their views of what a STEM learning experience can entail, particularly thinking beyond traditional subject-specific lessons. This outcome was enhanced in the informal learning environments because they had autonomy over the design of the activities. For example, a teacher candidate reflected on the experience of designing an engineering station focused on building cars using VEX Go^{TM} kits:

"*I never thought I could teach a lesson with buildable cars but now it makes me think that anything can be used and be made into a lesson and relate to the topic. I will take this experience with me when planning future math lessons.*"

Third, teacher candidates gained the experience of interacting with families and community members. We have found that engagement with families is challenging and represents a source of anxiety for many of our teacher candidates. As one teacher candidate described:

"I was mostly intimidated by the parents. Moreso because I felt like …parents had this expectation that I needed to live up to. And plus these parents don't normally get to watch their kids in an educational setting so this was their one opportunity to do so which I interpreted as more pressure on me to make sure it went perfectly."

Although the prospect of interacting with parents initially intimidated them, the experience gave the teacher candidates self-confidence and belief in their abilities to teach in front of parents: "*But in the end, the lesson went well, and I left the day with a little more confidence in teaching."*

Beyond direct parent interactions, using the STEM materials to expand their teaching in a migrant community-based setting helped teacher candidates gain skills in working with diverse groups of learners and develop empathy in teaching.

"As their student-teacher it's important for me to know what they do/do not have access to, and the sensitivities that might come with their home life. As a future teacher it's important for me to remain empathetic of my students in any learning community and to be aware of any uniqueness or needs that may come with each of them."

Having access to STEM materials enabled teacher candidates to actively engage in a variety of informal STEM instruction, thus forging a deeper connection with those with whom they worked and with diverse communities. They recognized the value of having STEM materials and understood the importance of ensuring access to these resources for students who may not otherwise have access. As shared by one of our candidates, serving their communities gave them a sense of pride and success: *"I am proud of not only myself but also my peers for putting together such a huge successful challenge. I felt accomplished and excited about how I served my community."*

Survey Analysis from 1st-Year Implementation

For the methods courses in our teacher education program that explicitly incorporated materials from the STEM Lab, we asked teacher candidates to complete a survey to understand how their perceptions about learning and teaching the STEM disciplines potentially changed during the course. We present a pre-post comparison of five items that are most closely tied to the ultimate aspiration of our project: to increase teacher candidates' confidence in and knowledge of teaching the STEM disciplines. The five item stems are:

- **Confidence**: I feel confident as a teacher of [mathematics/science/STEM]
- **Planning**: I know how to plan a student-centered [mathematics/science/STEM] lesson
- **Supporting Students**: I know how to support elementary students when they experience challenges during a student-centered [mathematics/science/STEM] lesson
- **STEM Integration**: I know how to purposefully integrate two or more STEM disciplines when designing a student-centered [mathematics/science/STEM] lesson
- **Materials**: I know the types of materials and equipment that are commonly used in elementary [mathematics/science/STEM] lessons

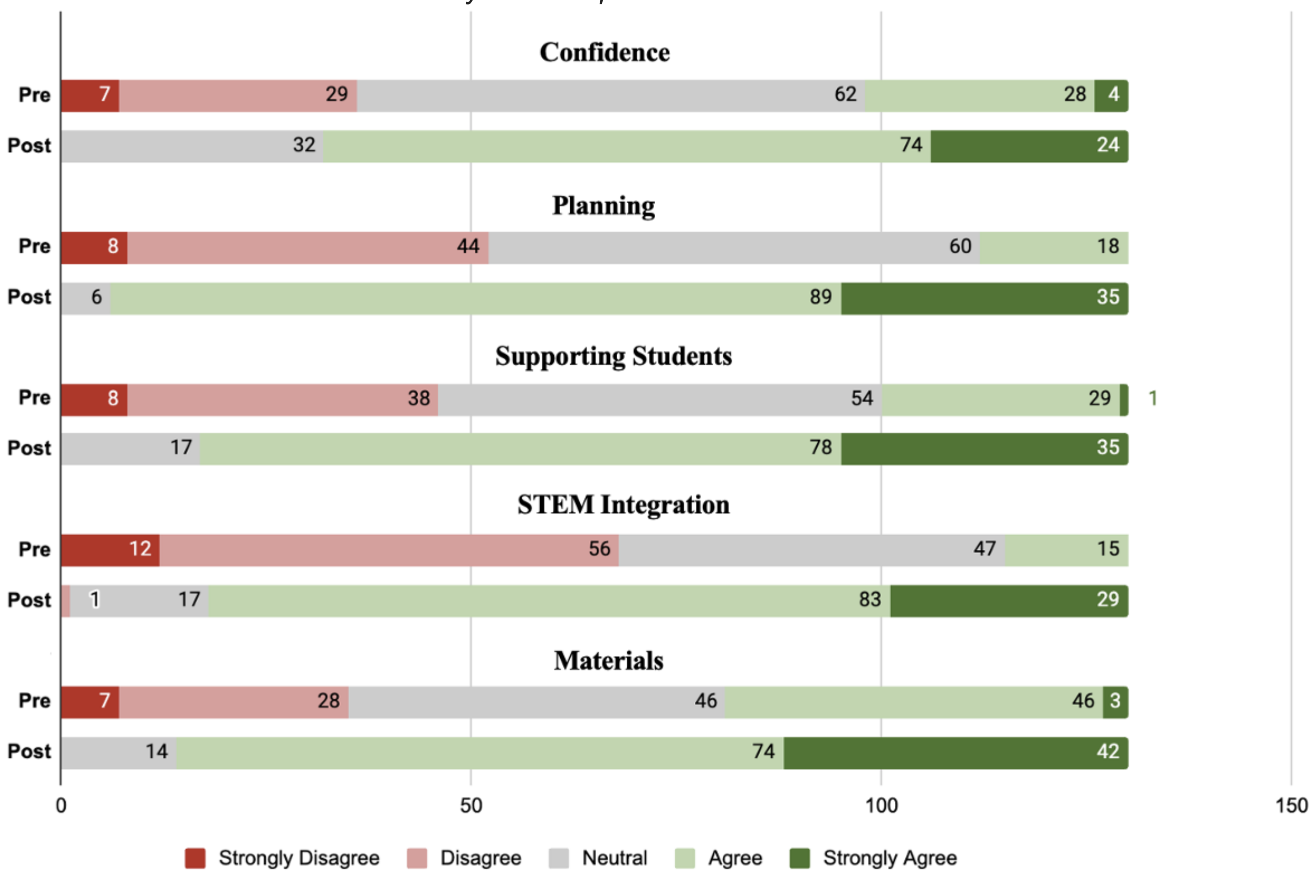
The references to "[mathematics/science/STEM]" in the descriptions above indicate that the words, "mathematics," "science," or "STEM" were paired with the particular methods course subject. In other words, the items included the word "mathematics" in the mathematics methods courses, "science" in the science methods courses, and "STEM" in the integrated STEM methods courses. Teacher candidates responded to each item by selecting from five possible responses: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree.

When analyzing individual Likert-type items (as opposed to a Likert scale), statistically comparing pre- and post-intervention means (e.g. t-test analysis) can be problematic because it assumes the response options represent an interval scale when in fact they are ordinal (Boone & Boone, 2012). While our response options include a 'disagree to agree' continuum, we cannot know the perceived distance between someone's 'agree' and 'strongly agree' response and a 'Neutral' response may imply 'between disagree and agree,' 'neither disagree or agree,' or 'unsure.' Therefore, we concur with Boone and Boone (2012) and Clason and Dormody (1994) that reporting the frequency counts of each response pre- and post-course is a useful approach given the nature of the individual Likert-type data. In Figure 3, we visually present the frequency distributions of 130 teacher candidates' pre- and post-responses to the five Likert-type items across 11 STEM methods courses from our first year of using the STEM Lab (four mathematics, six science, and one integrated STEM methods course).

Figure 3 shows a noticeable shift whereby the Strongly Disagree, Disagree, and Neutral responses are much higher in the pre-course survey, and the Strongly Agree and Agree responses are much higher in the post-course survey. The range of Strongly Agree and Agree responses (combined) on the pre-course items was 15-49 and on the post-course items was 98-124.

Figure 3

Pre- and Post-Methods Course Survey Item Responses



To provide an additional check on our visual analysis, the shift in responses was verified with a series of Bowker symmetry tests (Bowker, 1948) after collapsing the data into three categories (agree/strongly agree, neutral, disagree/strongly disagree). Using Stata software to complete the tests, p-values were only considered significant if they were less than 0.0025 (the Bonferroni correction was utilized to account for multiple tests on the same data set – Haynes, 2013). Each of the five items was found to have a significant change in responses pre to post when analyzing (1) all eleven courses, (2) only the four mathematics courses, and (3) only the six science courses. The integrated STEM course responses were not different to a statistically significant level from pre- to post when analyzed separately from the other courses; however, the course only had 13 participants and a higher amount of 'agree' responses in the pre-course survey. While we intend to conduct a deeper analysis of the entire survey data in the future, our initial examination of the 1st-year data provides encouraging STEM teacher confidence and knowledge outcomes.

Challenges

This project provided opportunities to leverage materials to support both teacher candidates and elementary students in the development of teaching and learning within STEM-related fields. While we are excited about the outcomes, we also acknowledge that there have been challenges as well. We believe it is imperative to share those challenges in this space for teacher-educator reflection. Challenges included such things as personnel and management of materials, teacher candidates' access and comfort with a wide range of materials, and our own expertise and comfort with the materials.

Personnel and Management of the Materials

One challenge is personnel and management of the materials. The three of us were excited to take on this project; however, we are all busy faculty members with the demands of teaching, research, and service. Management of the materials was done on a voluntary basis and turned out to be more than we anticipated at times. We set up systems for the organization, maintenance, and tracking of the materials. However, a more difficult aspect has been material distribution. We encourage teacher candidates to check materials out both during and after their course with us, which might mean meeting after school hours to get them the materials they need and then following up to return the materials. Since the materials are being used by young children, they sometimes need to be reorganized when returned to us as well. Although we have set expectations of returning the materials as they were delivered, we also understand the busy lives of teachers and know that well-used materials are a sign that the materials were in the hands of young learners. Eventually, we hope to work with our college's technology office to develop a website or other online platform to support a material distribution process that is easy for us to track.

Teacher Candidates' Access and Comfort with the Materials

The fact that the three of us are the primary users and stewards of the materials is another challenge, as it limits the teacher candidates who have access to the materials. Materials are stored in a classroom that is heavily utilized by many students and classes; therefore, to ensure the safe keeping of the materials, they are stored in a locked storage room, to which the three of us have controlled access. As a result, the use of materials has been mostly limited to teacher candidates who come through our courses, which is, on average, 80% of the elementary program population. Ultimately the goal is to create an organized process that could extend the use of the materials to all STEM courses/instructors. We also noted that teacher candidates check out materials that they used in class, which means it is important to provide them with as much exposure and experience as possible. In the future, we plan to invite all STEM methods course instructors to a meeting at the beginning of the academic year to showcase the Lab materials and discuss how they can utilize the materials more regularly.

Our Own Expertise and Comfort with the Materials

Another challenge we have encountered is our own comfort or expertise with the materials. We recognize that we each have materials that we know and use on a regular basis, and there are others that we do not engage with due to our own lack of experience with them. While we have jumped in and learned some materials with the teacher candidates, there are others that we have been more hesitant to use. In the beginning, we set time aside to explore the materials together, to see what they could do and how we might use them in class. We shared ideas with one another and engaged with community partners to learn from them as well. However, as time went on, we recognized that we had settled into our “comfort zone” with the materials and would benefit from taking time for our professional growth to investigate lesser-used materials or allowing teacher candidates access to all materials in order to learn from them as well. Moving forward, we have set a goal of using one new material each semester to continue to push our thinking and learning.

Contribution and Implications for STEM Methods Instructors

After searching the extant literature, we could find no peer-reviewed articles that explained a lending library of STEM materials in a teacher education program. We therefore hope our discussion of the structure, implementation, and initial insights from our STEM Lab are useful to other STEM teacher educators. We found that such a program can yield many positive outcomes for teacher candidates as they increase their knowledge of the materials’ affordances and constraints, become more flexible thinkers, and develop pedagogical skills to plan and facilitate student-centered lessons with the materials. Below we summarize helpful tips for STEM educators to consider when developing their own STEM labs.

- **Sustainable Usage** – we recommend purchasing as many materials as possible that can be used continuously across multiple years. While our Paper Circuits™ have been very useful, they are not set up for re-use and we will eventually run out. Our basic circuit kits, Makey Makey™ kits, and Snap Circuits™ are in good condition and can be used for the foreseeable future. Many of our teacher candidates take jobs at schools in the local region. A high number of materials with sustainable usage allows us to continue to offer them access into their first few years of teaching.

- **Focus on Teaching Outcomes** – The few articles we found that discuss the use of STEM materials in elementary methods courses have focused on teacher candidates using the materials as learners (Cetin & Balta, 2017; Karisan et al., 2019). We also included that focus (Goal #1) in our project. However, we found our additional goals on teacher candidates learning to teach with the supplies to be very helpful, and recommend this explicit focus for future STEM labs. It allowed the teacher candidates to think about the materials as mediators of learning that could be leveraged in their role as elementary teachers, which is authentic to their future careers.
- **Informal Teaching Events** – The extent to which we used the supplies at informal STEM events was an unintended but important outcome of the program. Without the demand for nuanced coordination with individual schools and mentor teachers associated with field placements, these experiences can increase the opportunities to connect teacher candidates and their STEM supplies to elementary learning contexts. We recommend that methods course instructors consider pairing the use of their lending library's supplies with an organized informal learning experience that allows all teacher candidates within the course to practice teaching with elementary-aged students.

Conclusion

The STEM Lab has been an exciting and fruitful endeavor for our elementary teacher education program. We firmly believe that our continual reflection and improvement should be a normalized practice for us as teacher educators, yet we also know that the competing demands of our work in higher education can result in modes of stagnation when we consistently teach the same courses over and over. While we acknowledge that many of the actions reported in this article could have been taken without the creation of the STEM Lab, we found that the sudden and substantial influx of new materials spurred in us a renewed sense of creativity, wonder, and adventure. The STEM materials supported us in making intentional changes to our practice, thereby creating new opportunities for teacher candidates to explore and teach with a range of STEM materials. Just as teachers are the ultimate gatekeepers for what their K-12 students experience, we are gatekeepers for teacher learning in our methods courses as well. Acknowledging that grant opportunities vary across universities and teacher education programs, we concur with local educators who told us to “start anywhere you can” when attempting to gain access to new materials. We have found that the creation of the STEM Lab has been a positive disruptor and professional growth opportunity for us and our teacher candidates, and we look forward to our continued journey ahead.

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