Journal of STEM Teacher Education

Volume 58 | Issue 1 Article 6

October 2023

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Recommended Citation

Campbell, Laurie O. and Damico, Nicole (2023) "Investigating an Instructional Model for Integrated STEM in Teacher Education," *Journal of STEM Teacher Education*: Vol. 58: Iss. 1, Article 6.
DOI: https://doi.org/10.61403/2158-6594.1512
Available at: https://ir.library.illinoisstate.edu/jste/vol58/iss1/6

Journal of STEM Teacher Education
2023, Vol. 58, No. 1, 70-86

Investigating an Instructional Model for Integrated STEM in Teacher Education

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Abstract

Active learning experiences that incorporate technology, design, and making combine to form an important and necessary pedagogical approach that supports the 21st century skills of collaboration, communication, creativity, digital literacies, and computational thinking as a problem-solving framework. Active learning experiences in teacher preparation serve as a model for future educators to follow, while building the educators' efficacy to conduct future implementations with their own students. In this study, a multidisciplinary Pop-Up Makerspaces activity was conducted as an active hands-on approach to interdisciplinary STEM education. The intersectionality of English language arts with integrated STEM through design and making included: (a) enriching language and integrated STEM literacy, (b) scaffolding and supporting pre- and inservice educators through well-designed active learning as these opportunities help to develop self-efficacy, and (c) exploring new models and frameworks for transdisciplinarity.

Keywords: STEM; Makerspace; Active Learning; Teacher education; mixed methods

National and international imperatives to solve complex and pervasive world concerns like disease, energy depletion, and natural disasters have heightened the call to prepare a workforce equipped to find solutions for global and interdisciplinary problems. In the United States, integrated science, technology, engineering, and mathematics (STEM) education has been identified as an educational priority for the purpose of cultivating a prepared workforce to face these global challenges (NAE & NRC, 2014). Integrated STEM includes multidisciplinary skills, content knowledge, and various approaches to problem solving and critical thinking. To support STEM integration, teacher educators and K-12 faculty have engaged in ongoing efforts to foster integrated STEM literacy in K-12 education (Brophy et al., 2008; Kelley & Knowles, 2016; National Research Council, 2011; Shanahan & Shanahan, 2008; Yore, 2011).

Fostering STEM literacy among students in K-12 education requires that educators are versed in integrated and interconnected STEM-based education pedagogies and approaches (Ring et al., 2017). Yet, Pre-K through 12th grade educators indicate that they lack the knowledge and self-efficacy to plan and implement interdisciplinary STEM activities that would foster STEM literacy and ways of thinking within their classes (Madden et al., 2016). Although in its infancy, professional development training and preservice education in interrelated STEM education has proven to correlate to increased confidence and self-efficacy among teachers for incorporating integrated STEM (NAE & NRC, 2014; Cantrell et al., 2003). Calls for interdisciplinary STEM education research (Li et al., 2019) have prompted teacher educators and researchers from diverse disciplines to consider ways to train teachers in integrated STEM (English, 2016).

The goal of this explorative study, which was conducted within the context of an English Language Arts (ELA) teacher education course, was to answer the need for increased research collaborations in STEM education and investigate an instructional model for exploring integrated STEM and disciplinary content knowledge through design and making. Using a mixed-method approach, we attempted to answer the following questions:

- What are preservice and inservice teachers' perceptions of self-efficacy after completing a multidisciplinary active learning design and making learning experience with an integrated STEM focus?
- What are preservice and inservice teachers' perceptions of the intersectionalities of English Language Arts and integrated STEM?

Literature Review

The term "integrated STEM" encompasses an interdisciplinary approach to the disciplines represented in STEM (e.g. science, engineering, technology, and mathematics) to a multidisciplinary perspective that includes combinations of stand-alone STEM disciplines with another non-STEM discipline (Li, 2014). In other words, disparate disciplines amalgamate towards new understandings. Integrated STEM is further characterized by authentic problem-based learning taught from an active learning approach. The following section provides an overview of integrated STEM in education.

Integrated STEM Literacy and Training

According to Zollman (2012), integrated STEM literacy encompasses three levels of understanding: (a) disciplinary content, (b) needs (societal, economic, and personal), and (c) cognitive, affective, and psychomotor learning domains. Further, integrated STEM literacy includes various ways of thinking including but not limited to: (a) design thinking, (b) computational thinking (Wing, 2006), (c) mathematical thinking, (d) critical thinking, and (e) scientific inquiry (Slavit et al., 2019). These three levels of understanding and ways of thinking coalesce to form integrated STEM literacy. While some factors of integrated STEM literacy have been identified, learner outcomes and perceptions related to integrated STEM learning experiences are understudied (English, 2016; NAE & NRC, 2014).

Developing educators' knowledge and efficacy for conducting integrated STEM learning experiences for PK-12 educators can and should occur through preservice education and professional development and practice. Yet, integrated STEM training in preservice education is limited (Shernoff et al., 2017) and professional development training is often localized. Likewise, teacher education standards to encourage training in integrated STEM are lacking (Rosengrant et al., 2019). The federal priority of the National Science and Technology Council (NSTC, 2018) of building strong foundations for STEM literacy recognizes the need for (a) building computational literacy and (b) engaging students where disciplines converge. The need for partnering with teacher educators to promote computational thinking and to contribute to STEM literacy is prevalent and necessitates that promising practices and lessons learned are investigated and disseminated.

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DOI: 10.61403/2158-6594.1512

Nadelson and Seifert (2017) asserted that teachers need to have appropriate skills, mindsets, and training to employ integrated STEM in teaching and learning. However, little research exists related to developing and accessing teachers in integrated STEM literacy. Nonetheless, research related to general disciplines can inform the instructional design of integrated STEM preparation. The design of preservice and professional development training for integrated STEM literacy should include: (a) teachers experiencing what their students would experience (Loucks-Horsley et al., 2009), (b) opportunities to explicitly identify multidisciplinary skills and ways of thinking (English, 2016; NAE & NRC, 2014, (c) ascertaining teachers' beliefs (Zollman, 2012), and (d) developing pedagogical approaches from research knowledge for classroom implementation.

Integrated STEM and Language Arts

Prior integrated STEM and language arts integrations have been studied both at the school and classroom levels. With the contemporary focus on reading informational texts and writing argumentative and explanatory texts demands that literacy be seen as a school-wide endeavor. Research indicates that students who participated in school-wide integrated STEM programs inclusive of all core subjects, including language arts, felt more prepared for college than those who did not attend a school-wide integrated STEM program (Subotnik et al., 2013).

The connections between STEM and literacy and inspired iterations of the STEM acronym like STEAM (with an added A for Arts) and STREAM (with an added R for Reading). At the classroom level, English language arts and integrated STEM classroom studies have supported and enhanced content instruction while developing other STEM skills and thinking. For example, the STEM movement has inspired that teachers of literacy to consider STEM elements like data visualization and quantitative literary analysis as discrete skills that prepare students to communicate and interact with the modern world (Lynch 2015, Alvermann et al., 2019). Cross and colleagues (2013) studied an eighth-grade class of students that developed coding sequences to demonstrate their comprehension of poetry. Outcomes of this study demonstrated that students perceived a greater appreciation for poetry, along with increased technological literacy and an opportunity to practice computational thinking skills. School-wide programs of study benefit not only students but teachers as well, as teachers will support each other in an integrated culture of learning (Lesseig et al., 2016).

Makerspace for Design and Making

Makerspaces foster hands-on opportunities to combine technology and design ideas to explore, develop, and build solutions to fictitious and real-world challenges and problems, while increasing participants' 21st-century interdisciplinary skills and extending content knowledge. The benefits of these learning experiences include interacting in an interdisciplinary learning space (Hlubinka et al., 2013), fostering inclusivity in STEM (Brady et al., 2014; Harvin, 2015), inspiring independence (Barron & Barron, 2016), and increasing motivation (Han et al., 2017). These physical spaces for designing, making, exploring, building, and problem-solving have become a part of the educational landscape and are known as Makerspaces, design labs, fab labs, and other physical spaces. Makerspaces afford a means for learners to use, modify, and create content (Lee et al., 2011).

While these exploratory spaces can provide active and meaningful learning opportunities as a curricular support or learning extension, limitations to incorporating a learning experience in these spaces include limited access to physical locations (if the school has one dedicated space), the cost of developing a space, allocating time to use the space, the purchase of high-tech tools, and limited implementation knowledge. As a result, schools and classrooms with limited resources may not have the means to include these valued learning experiences. One solution to limited resources includes employing *Pop-Up Makerspaces*.

Pop-Up Makerspaces are flexible and overcome typical classroom constraints such as space, time, and resources. As a result, more teachers can incorporate design and making activities that can improve students' interdisciplinary skills and increase student accessibility (Campbell & Heller, 2019). In commerce, small pop-up shops appear for a short time to provide access to products. Like a pop-up shop, mobile design Makerspaces appear in a classroom for a limited time and aim to extend curriculum, to practice and develop curricular related ideas, and to foster interdisciplinary connections. These spaces do not include high-tech tools but do include simulated challenges and recyclable and or low-cost materials. The mobile *Pop-Up Makerspaces* discussed in this study, provide a model for preservice and inservice educators to consider in their own teaching.

Incorporating Computational Thinking

Computational thinking, a concept derived from the field of computer science, provides a framework for "solving problems, designing systems, and understanding human behavior" (Wing, 2006, p. 33). Components of computational thinking include pattern recognition, decomposition, abstraction, and algorithmic design. While evidence of explicit instruction of computational thinking as a framework for problem-solving may not be realized, educators would benefit from developing their own efficacy in computational thinking in order to foster students' computational thinking (Jaipal-Jamani & Angeli, 2017; Yadav, et al., 2014).

Purpose and Research Questions

The framework for STEM teaching and learning considered in this study was grounded in Merrill's (2009) definition that STEM teaching includes (a) authentic content and problems, and (b) using hands-on, technological tools, equipment, and procedures to solve human problems. To learn more about multidisciplinary integrated STEM in teacher education, the following exploratory study was conducted to investigate an active integrated STEM design and making learning experience with secondary language arts preservice and inservice teachers. Objectives of the study included: (a) demonstrating a low-cost model of an integrated STEM design and making activity, (b) fostering preservice and inservice teachers' self-efficacy towards integrated STEM literacy, (c) introducing integrated STEM pedagogical knowledge for transferability, and (d) promoting computational thinking awareness. Therefore, the following study investigated an activity to build integrated STEM literacy in preservice and inservice education.

The following research questions guided this study:

- What are preservice and inservice teachers' perceptions of self-efficacy after completing a multidisciplinary active learning design and making learning experience with an integrated STEM focus?
- What are preservice and inservice teachers' perceptions of the intersectionalities of English Language Arts and integrated STEM?

Methods

A mixed method study was conducted to investigate STEM-based *Pop-Up Makerspace* in a literacy-based context. Both qualitative and quantitative data were collected simultaneously and

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DOI: 10.61403/2158-6594.1512

then combined to compare the perspectives of the participants. Both types of data were weighed equally.

Participants

The study took place within the context of an English Language Arts education course taught by one of the researchers. The course enrolled a hybrid population of both undergraduate and graduate students, for a total of 22 participants (fourteen women and eight men ranging from 21-40 years old). The undergraduate students (n=15) enrolled in the course were secondary English Language Arts education majors and preservice teachers enrolled in required concurrent practicum experience in English language arts. The graduate students (n=7) were inservice educators teaching in English language arts public school classrooms taking the class for teacher certification, recertification, or to earn a graduate degree. The content of the course centered around methods of teaching English Language Arts, with a particular focus on teaching Young Adult (YA) Literature. During each class, students were expected to come prepared by having read a common YA text (e.g., *The Hate You Give*, *The Absolutely True Diary of a Part-Time Indian*, and *The Lord of the Flies*) and discuss pedagogical implications and practical approaches for teaching the focus text.

To set the stage for this study, two researchers from different disciplines (English language arts education and learning sciences, respectively) conceptualized a *Pop-Up Makerspace* seminar with an integrated STEM focus based on one of the course novels, *Lord of the Flies*. Researchers developed problem-based learning activities that incorporated themes from the YA text with STEM integrated tasks like interacting with informational texts and researching and cataloging using digital technologies. Participants arrived for the class session and were seated in groups of four and five peers. Researchers presented the participants with five problem-based activities related to the main themes and symbols of the Lord of the Flies. These activities included: Shelter Building, Digital Sketchnoting, Flag Design, Raft Building, and developing a Museum Artifact Box.

Data Sources

Pre and Post Surveys. All participants took an entrance survey to ascertain what the teachers knew about computational thinking, the participants' level of confidence for teaching disciplinary science, and their level of confidence for teaching STEM-integrated concepts. A Likert-type scale of 1 (lowest) to 7 (highest) was utilized. At the end of the learning experience, participants completed a post survey. The exit survey asked which activities from the design and making learning experience they enjoyed the most and why, and to rate the overall experience on a scale of 1 to 5 (1 being "I had a terrible time" to 5 being "I had the time of my life"). Further, the exit survey asked the participants to identify factors of computational thinking and to identify the disciplinary context of each activity within the design and making learning experience.

Lord of the Flies STEM Activities. In a full class discussion led by researchers, participants reviewed and reflected on aspects of the novel that were important to its themes and discussed how these themes translated into modern day culture. They reviewed definitions for computational thinking and considered how it may be evidenced in a non-computer science setting. Reusable shopping bags full of supplies were placed on five different tables around the room. Groups seated at the table were instructed to find the problem-based learning challenge card inside the bag and use their supplies to solve the problem indicated on the challenge card. In cases where the challenge required access to an online program, participants either used a class-provided device or personal mobile device like a smartphone, tablet, or laptop. Each challenge took approximately

20-25 minutes to complete and was based on some aspect of the novel *Lord of the Flies*, inviting students to make inferences about what they read while employing computational thinking and design principles, in addition to STEM-integrated elements. Further, the activities and challenges in these integrated STEM-infused literacy themed Makerspaces were designed to encourage communication and collaboration while incorporating aspects of computational thinking for problem-solving. General supplies provided to the participants in the bag included paper, scissors, tape, glue, recycled cardboard, containers, markers, crayons, pens, and pencils. Some of the bags included more specialized items like fabric scraps, popsicle sticks, straws, pipe cleaners, duct tape, string or yarn, a glue gun and glue sticks, or decorative material. Most of the materials for the activities were leftovers recycled from other projects. Items like popsicle sticks and straws were purchased at a dollar store. After each activity, students completed activity reflections where they answered open-ended questions including: (a) What would you like to tell us that we did not ask?; and (b) Please indicate other ways that you could incorporate an activity like the one you participated in today.

Other Data Sources. The University systematically collects students' perceptions of instruction at the end of each semester. Students are able to provide comments related to instruction on that survey. At the end of the semester, some participants provided voluntary comments on their university overall course evaluations about the Makerspace enrichment learning experience. These comments were unsolicited and anonymous and were provided to the researchers eight weeks after the course was concluded. All comments related to the Makerspace learning experience included on the students' perceptions of instruction were included for analysis.

Shelter Building. The shelter building activity tasked the participants to role play that they were stranded on the island that appears in the *Lord of the Flies* novel. They were directed to use the recycled materials to build a shelter no taller than one foot that would withstand the known elements of destruction found on the island depicted in the *Lord of the Flies* novel. They were challenged to encounter and use STEM principles to problem solve constraints like size, materials, and building strength. They were provided digital images of several types of shelter such as a tent, yurt, log cabin, and a camper. During this activity, participants incorporated digital technologies as a documentation tool to take pictures with their smartphones and posted them to a class digital media curation website to document the building process. Further, they solicited feedback through social media outlets from their friends who may have not been at their table but were in the classroom working on another activity. It was anticipated that the problem-solving strategies evidenced through this activity would include decomposition, algorithmic design, and abstraction. Other activities included (a) raise your flag, (b) build a raft, (c) museum artifact box, (d) digital sketch noting, and (e) online corkboard. See Table 1 below for descriptions:

Research Design and Data Analysis

The purpose of this mixed-method, convergent research study was to explore participants' perceptions after engaging in an active learning, literacy-focused, technology-infused *Pop-Up Makerspace* learning experience. The learning experience was designed to contribute to preservice and inservice educators' efficacy for integrating STEM ways of thinking in literacy. Both quantitative (closed questions) and qualitative data (open-ended questions) were gathered to provide a greater understanding of the participants' perceptions for future research and to inform present and future transdisciplinary frameworks for design and making activities. Data were collected through surveys, activity reflections, and end of course feedback.

Table 1

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DOI: 10.61403/2158-6594.1512

Activities with Integrated STEM Components

Activity	Description	Integrated STEM Components
Raise Your Flag	For the flag activity, the participants worked in teams and created a flag that represented each member of the team in some way.	The factor of computational thinking for problem-solving expected to be employed during this activity was pattern recognition.
Build a Raft	Participants were challenged to build a raft with only ten popsicle sticks.	The task required participants to employ algorithmic thinking and pattern recognition to effectively persist towards the solution.
Museum Artifact Box	Participants were challenged to create and annotate a museum-type artifact box include four compartments, display symbols (artifacts) that represented important details from the story.	Each of the artifacts were contained in a box with a lid. The participants were challenged to incorporate Math and Engineering skills in building their box to have equal partitions.
Digital Sketchnoting	Sketchnoting is a method for taking notes and heavily augmenting the notes through visuals to improve retention (Mayer, 2008). Using online whiteboards and mobile digital devices the participants created sketchnotes portraying aspects of living on the island.	In this ELA activity, participants documented their perceptions of island living by employing digital devices and conceptual visualization techniques.
Online Corkboard	The virtual corkboard served as a digital repository of the activities for both the researchers and the participants. The ease of use and the accessibility of the digital tool supported reflections as the participants only needed a link and not an account to contribute.	The online corkboard activity allowed participants to utilize various technologies that are helpful as an integrated STEM planning tool.

Quantitative data obtained from Likert-type questions were averaged based on single constructs. The qualitative data obtained from the open-ended responses to the survey, activity reflections, and end of course surveys were analyzed through content analysis. To determine the initial coding schema for the content analysis, outcomes from prior integrated STEM literature were considered through a constant comparison coding method (Glaser & Strauss, 1999). The coders read through a sample of three participants' comments and classified each response according to the predetermined categories. The coders met and discussed the resulting bracketing and determined there were three overarching themes. Themes included: (a) affective/social connections, (b) perceptions of experience, and (c) cognitive association. The coders then coded all of the responses. If there was a difference in coding, the coders discussed the difference for consensus.

Results

To provide context about the participants' disciplinary knowledge, participants were asked about their confidence level for teaching disciplinary content and their knowledge of computational thinking. The participants' confidence levels were the strongest for language arts and minimal for other STEM subjects (see Table 2).

Table 2
Students' Confidence Levels for Teaching or Integrating Ways of Thinking from Other Disciplines

	Average (1-7 Likert Scale)	Male	Female
Science	2.6	3.4	2.2
Engineering	2.33	3.6	1.7
Language Arts	6.29	----	----

Note: Confidence levels for Language Arts were not broken down by gender as they were similar.

Next when asked to define the term computational thinking, only two participants, one male and one female, representing approximately 13% of the sample, indicated that they understood the term computational thinking. Both participants connected their understanding of the definition to computer coding and *Hour of Code*, as they had participated earlier in the school year at an *Hour of Code* coding awareness event. The results of the study are presented in the order of the research questions. First, the quantitative results are presented followed by the qualitative evidence.

Research Question One

What were the participants' ratings of the activities and self-efficacy perceptions after completing a multidisciplinary active learning design and making learning experience? To determine the preservice and inservice teachers' perceptions after completing an active learning, literacy-focused, technology-infused Makerspace, the teachers were surveyed. Questions included both Likert-type questions and open-ended questions. The descriptive results for the question: "Rate your experience today from 1 to 5 (1 being "I had a terrible time" to 5 being "I had the time of my life.")" are provided. Sixteen responses were recorded with a mean score of 4.19, the mode was 4 and the range was 3-5. In general, all written comments about the *Pop-Up Makerspaces* experience were positive. Words used to describe their interactions included: fun, motivating, interactive, and promoted creativity. However, there was recognition that some participants were challenged by the activities. For instance, one preservice educator claimed, "some activities were infuriating to accomplish, but it was still fun." Another said, "I was so stuck on one task, but I finally got it. If it had not been for my classmates, I would have never finished."

Open-ended comments were coded utilizing the following themes: affective/social connections, cognitive associations, and perceptions of experience (see Table 3). Affective connections included the feelings felt or expressed and social connections included statements that indicated collaboration or isolation. Cognitive associations were "ah ha" moments, evidence of ideas that were crystallized, and beliefs that were confirmed or rejected. Perceptions of personal experience included statements that were indicative of the participants' experiences of the activities. The English language arts participants favored the urban planning/shelter building

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activity. In this activity, the participants solved the challenge by making shelters for themselves that would survive weather challenges found on an island.

Table 3
Participant Response to the Learning Experiences by Activity

Source	Response	Theme
Survey	"the shelter…allowed me to **work together** and be creative"	affective/**social connections**
Survey	"…the urban planning activity included **collaboration** we were able *to create an amazing space that could actually be lived in*,"	*affective*/**social connections**
Survey	"*We love*d the urban planning activity the most because of the **collaboration**. We had <u>fun with it."</u>	*affective*/**social connections** <u>perceptions of experience</u>
Activity Reflection	"We *absolutely loved* the urban planning activity as we used it to **collaborate and <u>work together</u>** <u>to create a strong and effective ho</u>use that was also glamorous."	*affective*/**social connections** <u>perceptions of experience</u>
Survey	"Doing the difficult task of building a raft got me in the ***<u>mindset of how it feels to be a frustrated student</u>***, *how persistence pays off* and ***<u>how will I encourage</u>*** a student who gets frustrated and wants to just give up,"	*affective connections* ***<u>cognitive association</u>***

Note: *affective coding (italics),* social connections (**bold**), <u>perceptions of experiences</u> <u>(underline)</u>, cognitive association *(**<u>bold, italics, and underline</u>**)*

Participants' self-efficacy related to conducting and designing an activity like this on their own were ascertained by the participants indicating their confidence level for integrating English/Language Arts with other subject areas as a teacher and a course designer (see Table 4).

In general, the participants indicated that they were less confident to design these types of experiences and more confident to be the instructor in a pre-designed hands-on integrated learning experience. Further, non-STEM subjects were more favored for integrated learning experiences over integrated STEM and individual STEM subjects.

Research Question Two

First, the participants were asked to what degree they believed that they could identify the interdisciplinary aspects of the activities. On a five-point scale the average response was a 4.89 meaning that the participants were overwhelmingly confident that they could identify multiple learning objectives. Next, the participants were asked to identify what disciplinary content was evident in each challenge activity. In the top half of the table, participants indicated the disciplines that they perceived were necessary to complete the *Lord of the Flies* interdisciplinary challenges.

In the bottom half of the table, participants' average responses were tabulated by percent. More than one discipline could be selected by participants (see Table 5).

Table 4
Instructor Confidence for Integrating STEM and English/Language Arts

	Confidence to be the instructor	Confidence to design these types of experiences
ELA and Art (all types)	4.32	4.10
ELA and Social Science	4.40	4.07
ELA and STEM	4.12	3.54
ELA and Science*	4.28	3.80
ELA and Technology*	4.10	3.90
ELA and Engineering	3.04	2.22
ELA and mathematics*	3.37	2.03

Note: Science, mathematics, and Technology content were interpreted based on the participants' own determination (e.g. Biology, Physics, and Chemistry). Not everyone considered each subject collectively or holistically but rather based their understanding on one aspect of the subject (e.g. Algebra I or Computer Application).

Table 5
Participants' Perceptions of Multidisciplinary Content

Percentage*	Mathematics	Science	Engineering	Technology	Integrated STEM	Language Arts	Other
Flag	25%		62%	18%	43%		Art
Raft		62%	87%		93%	43%	Physics
Sketchnoting	43%			100%		100%	Art
Shelter Building	50%	37%	100%	37%	100%	31%	
Artifact Box	56%	43%	87%		100%	68%	Origami

Note * The percentage of the respondents who indicated that discipline was needed to solve the problem-based challenges.

Next, the participants were asked to identify what factors of computational thinking were employed in the activities. While most did not indicate they knew what computational thinking was prior to the learning experience, they were able to recognize aspects of computational thinking in their problem-solving approach when provided a list of the factors (see Table 6). The activity

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that most participants indicated included all factors of computational thinking was the shelter building activity. In the case of the flag project, 94% of the participants recognized that pattern recognition was involved to complete the project activity.

Table 6
Participants' Identification of Factors of Computational Thinking by Activity

Activity	Pattern Recognition	Decomposition	Abstraction	Algorithmic Design
Flag	94%	--	43%	62%
Raft	56%	--	--	88%
Sketchnoting	--	56%	75%	--
Shelter Building	56%	80%	43%	62%
Artifact Box	62%	--	--	94%

* Participants could choose more than one factor for each activity.

For research question two, participants' written responses were analyzed. All of the inservice and most of the preservice participants recognized the versatility of *Pop-Up Makerspaces* to explore multiple content objectives, to promote 21st century skills, and to enrich traditional literacy instruction. Further, they identified the potential for *Pop-Up Makerspaces* to inspire and motivate learners to explore content in a new way. The same three themes from research question one were considered: affective/social connections, cognitive associations, and perceptions of experience (see Table 7).

In the final course evaluation, one teacher education student noted "learning in language arts is not all about reading and writing, as we traditionally think about them. We can offer our students VARIETY and CHOICES!" Another inservice teacher educator felt like the *Pop-Up Makerspace* activity afforded seamless integration of digital as well as physical tools in an ELA environment. One preservice teacher summed up their impressions of the course experience by stating, "the most memorable part that will stay within the recesses of my mind will be the makerspace lesson. I know a lot of students would like the hands-on approach, just as many would not appreciate this. It's interesting how the centers[activities] involved some sort of literacy and STEM, but even though they were hands-on, literacy did get lost."

Table 7
Perceptions related to the integrated of English Language Arts, Technology, and an Integrated Makerspaces

Source	Response	Theme
Activity Reflection	"Awesome experience! ***I was struggling with ways to incorporate Makerspaces in an ELA classroom with technology***."	***cognitive association*** perceptions of experience
Activity Reflection	"I enjoyed making. More than that, I ***enjoyed the connections that were drawn from the projects*** to the text to technology,"	***cognitive association*** perceptions of experience
Course Evaluations	"I valued ***looking at literacy through a different lens.*** The Makerspace was *my favorite activity*. I even **discussed the concept of this with other teachers I know**. We are going to try do one in the Fall.	***cognitive association*** *affective*/**social connections**
Survey	"Makerspace ***allowed text to translate into new ways,*** especially engineering."	***cognitive association***
Survey	"It works." "***Makerspaces can be incorporated into ELA curriculum***." "It ***was possible to*** actually do this in ELA not just STEM!!! *So excited now!*"	***cognitive association*** *affective connection*

Note: *affective coding (italics),* **social connections (bold),** perceptions of experiences (underline), cognitive association (***bold, italics, and underline***)

Discussion

A multidisciplinary, problem-based, hands-on active learning activity to promote integrated-STEM literacy was conducted in a secondary English language arts course with preservice and inservice teachers. The objective of the study was to model to the current and future educators' ways to incorporate making and design educational experiences by utilizing a hands-on design-based approach that was multidisciplinary and multifaceted. Integrative STEM literacy was introduced and practiced. The purpose of the research was to determine the participants' perceptions of (a) the activities, (b) their ability to identify the multidisciplinary aspects of the experience, and (c) their self-efficacy to replicate the experience. Data were collected through a pre and post survey, observation, and reflection comments that included both qualitative and descriptive quantitative data.

All participants explored their perceptions of the Makerspace activity in relation to themselves and their teaching practices. They indicated that the experience itself was positive, and the activity promoted interdisciplinary learning objectives and pedagogical skills. Similarly, Stevenson and his colleagues (2019) noted that teachers increased confidence to conduct a Makerspace while building their capacity for technology and STEM-integrated ways of thinking. Complementary to

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Sheffield and colleagues (2017), learners in this study practiced 21st century skills like collaboration, communication, critical thinking, and creativity while building computational thinking skills through a Makerspace.

Educators reported greater self-efficacy in facilitating an integrated STEM activity when they were included in the design process of the curricula. They attributed low levels of self-efficacy in STEM instruction to the following factors: (a) the time, creativity, energy, and collaboration with others that designing a multidisciplinary activity entails; and (b) the previous expectations of their role as merely facilitators of STEM activities without much input on the design of those activities. Research has indicated that there are improvements in the implementation of learning activities when educators re-design or co-design those learning experiences (Cviko, McKenney, & Voogt, 2014). In addition, educators who demonstrate greater self-efficacy are more confident in both facilitating and designing instruction, especially when prior knowledge and experience is activated (Holzberger et al., 2013).

A longitudinal analysis. Journal of Educational Psychology, 105(3), 774.The participants' recognition of computational thinking increased after the intervention. In part, this was attributed to the introduction to computational thinking before the design and making mention of computational thinking during the instructions. Moreover, the facilitators engaged in explicit conversation with the participants about computational thinking. Explaining the importance of computational thinking as a component of integrated STEM literacy heightened the preservice and inservice teachers' understanding which can lead to increased transferability to other contexts. Similarly, Soules et al. (2014) encouraged that more time should be spent explaining connections to improve instructional benefits.

Participants identified the disciplinary components that comprised the multidisciplinary problem-based challenges. By identifying the activity purposes, multidisciplinary awareness and explicit curricular connections occurred. The importance of this reflective activity may contribute to the degree teachers employ integrated STEM as knowledge of explicit connections are a key indicator of integration (Dare et al., 2018). The participants' responses indicated that the learners made positive affective/social and new cognitive connections related to conducting future multidisciplinary integrated STEM activities.

The perceptions of integrated English Language Arts and STEM through design and making included: (a) enriching language and integrated STEM literacy, (b) scaffolding and supporting pre- and inservice educators through well-designed active learning as these opportunities help to develop self-efficacy, and (c) exploring new models and frameworks for transdisciplinarity. For these reasons, continued efforts should be made to increase integrated STEM and non-STEM literacy-based design and making experiences in teacher education.

Implications for teacher educators to build capacity for integrated STEM literacy includes: (a) developing active learning multidisciplinary activities and practicing the activities with teacher educators, (b) designing implementation plans with teachers specific to their classroom situation, and (c) explicitly identifying connections and ways of thinking. Limitations of this exploratory mixed-methods study included: (a) the instrument used to collect the pre and post data, (b) varying understandings of the constructs being measured, and (c) the size of the sample. The instrument was not vetted for construct and content validity. The constructs did not have robust descriptors for the participants to have shared meaning. The instrument was used solely for the context of this study. While the study focused on the teachers and one Language Arts novel as the context, in future studies, institutional factors such as resources to support the teachers, time for development, and school culture need to be addressed to ensure better cohesion to integrating STEM in multidisciplinary contexts (Loucks-Horsley et al., 2009). Likewise, other novels that focus on STEM based problems could be considered in future replications of this study.

Conclusion

In this study, a multidisciplinary *Pop-Up Makerspaces* activity was conducted as an active hands-on approach to interdisciplinary STEM education. The potential of these hands-on active learning experiences included: (a) extending and supporting disciplinary content, (b) making interdisciplinary connections, (c) increasing the appropriate use of digital technologies, and (d) integrating multiple integrated STEM objectives beyond English language arts. Further, preservice and inservice educators benefit from these hands-on design experiences to build their own pedagogical knowledge and efficacy of how to increase design and making experiences and access. As preservice and inservice teachers observe making and design as a pedagogical affordance, they are more apt to include these needed learning experiences with their own participants.

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