Using Design Thinking to Integrate Mathematics, Science, Engineering, and Technology in a Pre-service Elementary Education Program

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Introduction

The focus in education on teaching and learning science, technology, engineering, and mathematics (STEM) has created a strong incentive to examine how these disciplines can be purposefully taught in an integrated manner. There is a need for more effective STEM instruction in pre-service teacher (PST) education (Radloff & Guzey, 2016); in addition to helping students see connections between each content area, a more integrated STEM education program augments the development of students' creative and critical thinking skills, their ability to collaborate and communicate, and fosters an innovative mindset (Berisha & Vula, 2021; Reagan, 2016).

Below we showcase how Mathematics, Science, and Technology methods instructors modeled an integrated STEM education experience in classes taken by elementary PSTs. In 2020, we, the instructors of the methods classes, developed a STEM block for junior and senior PSTs in our program. The aims were to introduce the principles, theories, and pedagogical knowledge of STEM and that the PSTs would be able to enact what they were learning in their concurrent practicum placements and in their future classrooms. In summer 2021, we began researching ways to implement STEM education. We eventually decided to hold a 2-day STEM integration workshop at the end of the semester. In an effort to connect current global challenges to the work our PSTs did in their methods courses, we looked for real-world problems with which we believed our students would connect. In 2021, there were several natural disasters, including a snowstorm in Texas, a heatwave in Greece, and a rainstorm in British Columbia (B.C.). This work aimed to challenge PSTs to research and construct plans that would help the people involved in these natural disasters using the Design Thinking process.

Design Thinking

The process of design thinking involves identifying challenges, gathering information, and creating solutions to problems (Razzouk & Shute, 2012). The commonly adopted 5-stage approach (Luka, 2014) described below allows designers to engage in human-centered problem solving by focusing on the needs of people in a real-world context. Connecting STEM education to design thinking provides opportunities for learners to authentically engage in the application of STEM through problem solving in a hands-on and human-centric manner. Design thinking as a pedagogy can enhance mathematical exploration through the process of experimentation and creation (Li et al., 2019).

Implementation

The instructors planned four 100-minute classes for PSTs to work through the design process; three of the classes were dedicated to in-person work, while one class was reserved for PSTs to work on their own to create a culminating presentation, an iMovie trailer. We first provided the PSTs with a review of the design thinking process and the purpose of each of the 5 phases. They are (1) **Empathize:** Ask, “Who are we trying to help and what problem are we trying to solve?” During research, keep empathy centered in the work by observing, listening, and asking questions, (2) **Define:** Analyze research to help define a specific problem and translate this into a “how might we…” statement, (3) **Ideate:** Generate as many ideas as possible that might be used to solve the problem and decide on one to pursue, (4) **Prototype:** Build a model of the solution chosen to address the “how might we” statement, and (5) **Test and Reflect:** Test the model and fix issues that emerge; share the prototype with others and solicit feedback to help further refine the solution.

PSTs then began to work through each phase of the design thinking process. During the ***empathize*** phase, PSTs were presented with the three climate-related issues described above. Each issue was purposefully selected for the range of problems faced by individuals in the geographic area. The instructors provided resources, such as links to videos and news articles, and PSTs explored each with a goal of choosing one and empathizing with those involved. After PSTs decided on the people and problems to address, they were tasked with refining their focus and ***defining*** one problem statement. PSTs generated statements such as, “How might we design a system to send information to Texas residents without using electronic communication or in-person communication?” and “How might we ensure that the electricity stays on to keep people safe and warm?” This further process emphasized empathy by drawing from what the PSTs discovered about the needs of the people in their selected case.

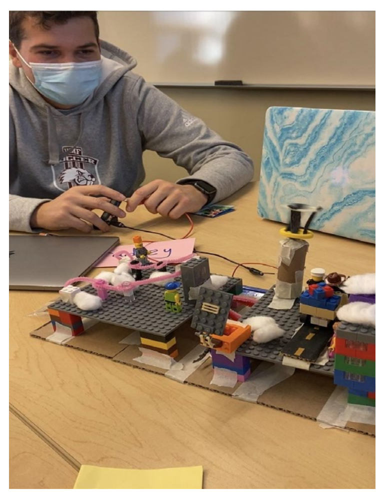
PSTs then turned their attention to ***ideating.*** We stressed that there are multiple ways to engage in this process including brainstorming, challenging others’ assumptions, mind mapping, and sketching. Each group approached this stage differently. For example, one group chose to individually brain-dump, then collectively share before building off of ideas, while others chose to work through the ‘worst possible idea’ strategy and shape those ideas into plausible solutions. During this phase, the instructors challenged the PSTs to consider how they would intentionally use mathematics and science to solve their problem.

PSTs then chose one of their ideas and developed a ***prototype*** using makerspace materials (Figure 1). PSTs developed prototypes for an energy efficient house, cooling stations, a bridge that removes excess water, a solar powered energy grid, a battery powered robot, and a method for burying power lines.

Figure 1. *PSTs work on their prototypes of a bridge to reduce the impact of flooding (left), and an underground power system to help with electricity loss during a storm (right).*

Finally, the instructors combined groups to ***test and reflect*** on solutions. This allowed for one group to demonstrate their prototype while the other group acted as the user. See the example in Figure 2. Groups gathered feedback through a series of prompts given to the users: What worked? What might need to be changed? What ideas do you have? What questions do you have? Based on the feedback, groups revised their prototypes to alter and refine their designs.

Figure 2. *PSTs test their bridge against flooding (left), and their windmill to supply energy to their underground power station (right).*



A commonly adopted sixth step of this process involves the implementation of the prototype or solution. The instructors modified this stage to further engage the PSTs in communication and creativity through the production of an iMovie trailer that described their processes and solutions. The 1-minute trailers were shared with the class as the culmination of the project.

Feedback and Discussion

Because this was our first attempt at an integrated lesson, we asked PSTs for their feedback. Overall, it was very positive. PSTs said that they appreciated the low stakes nature of the activity. When asked directly if it would have been useful to have some sort of evaluation criteria to guide the process, the PSTs universally indicated they felt that would stifle their creativity and make them anxious about doing the “right” thing. PSTs indicated that they were now thinking about how they could implement a similar integrated experience for their own future students. The PSTs also offered suggestions for improving the activity in the future. They felt we spent too much time introducing the activity and reviewing the aspects of the design thinking process. They agreed it was important to have these reminders but felt time could be better spent building their prototypes, testing them, and providing feedback to one another.

PSTs told us that they felt unsure about our expectations for incorporating mathematics and science content. While many recognized that they used both mathematics and science knowledge when designing and building their prototypes, few were specific about this in their movie trailers. One trailer identified angles and measurement as concepts necessary for designing a bridge. A second trailer explicitly referenced using scale when the group developed a battery-powered robot to travel through a city providing emergency announcements. None of the other four groups shared mathematics or science concepts in their presentations. We know that we need to be clearer about this expectation in the future, as we aim for PSTs to identify which mathematics and science content they are engaging with and to name that in their presentations.

We believe that our STEM exploration days were valuable for learning how to integrate STEM in elementary classrooms. We have room to improve as we begin our second iteration of the work but are pleased with the outcomes and are now looking for new ways to strengthen our integrative teaching approach. It was always clear to us why the PSTs were taking our courses simultaneously. We felt that crossover activities had occurred throughout the term and expected that the PSTs had identified these as well. But as often happens, what was clear to us was not clear to the PSTs, and they were not innately building connections. After our STEM integration days, a PST told another faculty member: “Now I finally understand why we took these classes together.” This underscores the necessity of continuing to develop and build on our integrative work in the future.

References

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