A Case Study Exploring Transfer of Pedagogical Philosophy from Music to Engineering

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Abstract: This Research Work in Progress paper presents a case study that demonstrates how a secondary school teacher with a non-STEM background identifies parallels between the engineering design process and music creation to embrace teaching an engineering course for the first time. Multiple interviews and classroom observations were open coded using a two-cycle coding approach to reveal four themes: overcoming imposter syndrome, connections between engineering and music, challenges encountered, and changes in practice. These themes highlight the processes involved in transferring a pedagogical philosophy that can inform future efforts to explore the necessary preconditions for bridging seemingly disparate and unconnected content areas. Further exploration building on these findings will inform efforts to broaden the pool of teachers capable of teaching pre-college engineering classes.

I. INTRODUCTION

Engineering education is continually growing as a topic of study in pre-college education [1]. A growing challenge associated with such efforts is building capacity by identifying willing and qualified teachers to teach these emerging engineering classes [2]. Few teacher preparation programs are geared toward teaching engineering [3]. The argument can be made that schools should consider broadening the diversity of potential teachers by considering all kinds of content backgrounds when identifying someone to teach engineering. Such broadening expands the pool of potential candidates and supports the interdisciplinary nature of the engineering field.

Enacting a broader approach to selecting teachers for pre-college engineering classes requires that teachers be supported as emerging engineering educators. This has been effectively accomplished through inclusive, sustained teacher professional development (PD) programs that empower teachers and build the necessary self-efficacy and skills needed to teach pre-college engineering classes [4], [5]. Such opportunities are not always made available to teachers [6], [1].

This work is part of an ongoing nationwide effort in the United States to develop a secondary-level engineering class designed for *all* students and teachers alike. The course specifically explores the interplay among society's need for engineering, engineer's intentions, and impacts of engineering using inquiry-based learning [7]. Students learn engineering design through progressively larger project experiences and iterate to create a solution to a global sustainability problem that is applicable in the students' local context.

This National Science Foundation-funded project to create the Engineering for Us All (E4USA) course was pilot tested during the 2019-2020 academic year. The initial cohort of teachers (n = 9) included teachers with diverse backgrounds and experiences ranging from music and history to engineering. This case study investigated a non-science, technology, engineering, or mathematics (STEM) teacher's challenge to overcome his own assumptions and gain the self-efficacy required to teach engineering content. The specific research question was: *How does a high school teacher with a non-STEM background embrace teaching an introductory engineering course?*

Prior research suggests that engineering and science projects situated in music and arts contexts often lead to more engaging experiences for students [8]. Charyton and Snelbecker [9] concluded that there are no significant differences in scientific creativity between engineering majors and music majors. Studies examining experiences of non-STEM teachers teaching secondary level STEM subjects are limited. A recent study examined how a music teacher with a non-engineering background embraced teaching computer-assisted engineering design [10]. The study concluded that appropriate PD and encouragement from administrators combined with personal drive can empower teachers from non-STEM disciplines to teach engineering content. The current study adds to the conversations around STEM versus non-STEM beliefs, perceptions, and practices.

II. METHODS

A single case research design [11] was selected to document and analyze one of the teacher's detailed experiences teaching the new E4USA course. The nine teachers in the cohort included seven teachers who had taught engineering classes before and two who had not. The two teachers who had not were a history and music teacher, respectively. A case research approach was used involving purposeful sampling to explore the unique qualities of case(s) and promote understanding of the phenomenon under research [12]. The music teacher was identified as a single case for this study due to proximity. This allowed the research team to gather a rich dataset using classroom observations and interviews throughout the year.

A. Setting

Contextual conditions are critical to understand the phenomenon of the case [12]. The single case for this study is Mr. Matthew Rogers (pseudonym) who has been teaching music for the past 22 years with extensive background in symphony orchestra. He runs a Creative Musical Arts & Sciences (CMAS) program at a public high school in the southwestern United States with a fully open creative platform and record label run by students. Mr. Rogers' high school is one of five in the school district; all four other high schools have had engineering course offerings. The school administration and the district decided his school should also offer an engineering course, but made the decision at a point in the year where it was difficult to hire another teacher. Mr. Rogers was tasked with teaching this course due to his availability and was subsequently signed up for PD associated with a nationally recognized K-12 engineering education program. His application was rejected due to a lack of experience in STEM. The administrator for that program recommended Mr. Rogers apply for the new program discussed in this paper. Mr. Rogers approached the E4USA team and signed up for PD in the first cohort of teachers.

Mr. Rogers participated in a week-long face-to-face E4USA PD in June 2019. The course was offered in fall, 2019 at his school and 38 students (21% females) enrolled. The class meets five days a week for 55 minutes each day. Mr. Rogers' classroom is larger than average size due to the space required for instruments and equipment (e.g., stage, drum kits, guitars, amplifiers, etc.) for his music class. The walls are adorned with pictures of artists and a few quotes about creativity in music. Computer stations line the walls of the room for student use. The current study took place during the fall 2019. Here on, we will use the terms 'the participant', 'the teacher' and 'Mr. Rogers' interchangeably.

B. Data Collection and Analysis

Data sources for the study included multiple semi-structured interviews and classroom observations. Data was analyzed inductively using a two-cycle coding approach [13]. Two members of the research team identified essential idea(s) in each of the participant's interview statements and labeled them with descriptive codes, while also looking out for repeated instances of codes. The coding scheme was reviewed by another member of the team throughout the iterative process of qualitative coding. Codes and definitions were revised as needed. Finally, codes were merged to yield major themes of interest. Observations were used to further interpret data and triangulate the results.

Member checking [14] was used during the interviews to verify interpretations. For further credibility, this manuscript is co-authored with the participating teacher.

III. RESULTS

Analysis resulted in four major themes that depict a non-STEM teacher's experiences teaching an introductory engineering course. The themes highlight the processes involved in the transfer of pedagogical philosophy from the content area of music to engineering. The following subsections describe the themes with embedded participant quotes that collectively answer our research question: *How does a high school teacher with a non-STEM background embrace teaching an introductory engineering course?*

A. Overcoming Imposter Syndrome

Mr. Rogers started the PD with much apprehension about his abilities to teach an engineering class. He said, "I went into the [PD] not skeptical about the program, but skeptical about myself." He admitted, "I thought that engineering was not fully applicable to me; let alone to any students I would be teaching, or more appropriately I should say my ability to facilitate a viable educational experience." He was also concerned about the parents. He did not have "a reputation for teaching math or science and here [he was] teaching engineering!" Mr. Rogers participated in all PD activities often admitting his discomfort but also showing willingness to learn. He made a realization within a day or two of the PD that "the whole point of this [course] in some respects is first and foremost to knock that wall down. Not just for me, but for everybody." He further explained the transformation, "Once I bought into that, it was really transformative. The idea, that the things that you think are limitations are actually benefits and are actually resources." He provided an example, since everyone knows him as "the music guy, they don't know what to expect in [his] engineering class. There are no preconceived notions, which helps."

There were of course, moments of anxiousness. A day before the first day of the class, he said, "I am anxious in the sense of I've never facilitated a class like this before." He kept wondering about the pacing of lessons and how to make it all work. He was concerned that even though his classroom is "pretty cool, it doesn't scream engineering [especially] if you have in your head the stereotype that we're trying to break. It is going to be weird." The very next moment he put a positive spin on his concerns when he stated, "There's an opportunity here for these students and for me to do something that's kind of unprecedented, but that's the whole point of doing this. Like, we're getting the chance to be in on the ground floor of something that will, you know, ten years from now, this could be everywhere, and we will have been part of it at the beginning. How wonderful is that?"

B. Connections between Engineering and Music

As Mr. Rogers started learning about the engineering design process, he was surprised, "this is exactly the same thing I do with my music students." He clarified that engineering design is ultimately a creative and iterative process and "it's the heart, the heart of what I do in the music side. I call it a creative process. You change just a little bit of the jargon, and you have the engineering design process. They are virtually identical!" He elaborated, "To me, it's more about the collaborative skill element. The life skill elements stuff. In one case, it's manifesting in the world of music. In another case, it's manifesting in the world of engineering." He provided a few specific examples: "You have a collective goal when you are part of an ensemble musically, you have a collective goal when you are part of a design team. In both cases you have other factors involved that may or may not be out of your control [such as] the quality of your musical instrument. Despite all of my musical ability, and I might be able to compensate, to some extent, but my performance is going to suffer. In the design class, it is kind of the same concept if you have, you know, a substandard element." The biggest parallel was working in teams as "if a member of the ensemble has not practiced their part, you know what I mean. It all kind of relates." He talked about the hierarchy connection in that "there's a bigger engineering project that has got multiple projects all around it. You might also have a project manager. So, to me, that's very much like sections of an orchestra." Another huge parallel was iteration. He explained, "It is the exact same [process] with musical ideas and concepts. We create music, then we listen to it, we evaluate it and then we take that piece and we go back to refine it until [we are sure] it will reach the audience."

Knowing these parallels between music and engineering allowed Mr. Rogers to be able to leverage projected-based pedagogical elements of his music classes to teach the engineering course. Engineering students in his class started multiple group projects related to sound engineering that enrolled music class students as clients. Talking about his teaching philosophy, practiced over the years, he said, "I'm a big believer in throwing the kids kind of into the deep end. With the understanding as the facilitator that this may not end the way we'd all like it to. But if they come out of the experience a little further ahead in their bigger picture understanding, it is okay." Observations indicated that students liked autonomy, collaborative nature of the class, and open-ended problems. Mr. Rogers agreed that "the more advanced engineering by nature is going to differ. But the level one curriculum, the things we're doing, the amount of parallels is just overwhelming."

C. Challenges

Improved self-efficacy and 22 years of teaching experience did not mean all challenges were alleviated. For example, Mr. Rogers has a mixed group of 38 students in the engineering class from freshman to senior level. His music classes are always a mixed group like this, but he explained, "this time the [experience] of having such a mixed group of students has been different. And what has become very clear to me is that the range is way bigger. The maturity level and the prior experience matters a lot more than it did in my music classes."

Managing 9 to 12 group projects for 38 students in 55 minutes of class time is another challenge. He elaborated, "In the music classes [sometimes] we just spend nearly the entire class on having an incredibly important viable conversation that I did not plan for. Losing that day is a lot easier to make up." This was not the same with the engineering class. He felt it was not as easy to deviate because "I've got some things where I'm going just like my nephew's wedding, and whatever I'm missing a day here missing a day there for whatever reason. And I'm looking at the map and I'm going oh, man, I don't know. I don't feel like I can."

D. Changes in Practice

Mr. Rogers believes that "it all comes down to this issue of perception, how far can you open up your ideas?" This is what he tries to teach his students in the introductory engineering class, "How far are you willing to look at a topic that may not directly appeal to you but see if you can find a connection to something else." One of the things he admits he had to change is the emphasis on professional skills. He explained, "…the design course, by its very nature are skills that are going to apply very concretely. Your ability to collaborate, your ability to iterate, your ability to analyze; [these] are going to be critical in any field you go into, even if you are a stay at home parent. But music education in the traditional sense, doesn't always push that as a priority. It is always a secondary thing." He is "looking at a lot of the activities, and trying to find where can [he] put in the collaborative moment?" Mr. Rogers wants his students "to get to a situation where they start to really understand what it means to have a team and what a team really is, which takes time and takes some frank conversations and frankly, some failure." Observations confirm that he is de-emphasizing homework, emphasizing collaborative groups, and underlining active participation. His music classes are more free-flowing (students come and start practicing and playing instruments), but for the engineering lessons, he has adopted "a formula, where there's an intro, and then there's instructions, they do something, they reflect on it, either in groups or individually, and then we move on to the next one."

IV. DISCUSSION

The results demonstrate a non-STEM teacher's efforts to challenge his own assumptions, find connections across different content areas, and build self-efficacy to teach engineering content. The circumstances at the school created an entry point for Mr. Rogers, but his success in teaching the course is really tied to his willingness to step outside his disciplinary comfort zone and the intentionally designed curriculum to be inclusive for all students and teachers. He was able to find connections between music and engineering at multiple levels to seamlessly transfer his pedagogy from one to another. As mentioned earlier, Mr. Rogers is a highly experienced teacher. He was able to leverage his existing pedagogical skills and project-based teaching philosophy to impart engineering content. This experience may not be as effective for teachers with less teaching experience. As Shulman [15] described, pedagogical knowledge and content knowledge augment each other to lead toward teachers' understanding of the complexity of relationships among students, content, and practices.

Pre-college teachers are not required to have an engineering degree or significant engineering coursework to teach engineering [16]. Engineering classes are typically taught by mathematics, science, or technology teachers because engineering is also perceived as esoteric, steeped in mathematics and science [17]. These perceptions tend to lead to the overemphasis of math and science, which undermines other professional aspects of engineering (e.g., design, craftsmanship, collaboration, communication, and societal context) [17]. According to Hynes, Mathis, Purzer, Rynearson, and Siverling [16], if we want diverse groups of students to pursue engineering, we also need a diverse group of teachers to teach K-12 engineering classes. The diversity does not end with diversity of gender and ethnicity, but instead includes diversity of content areas and experiences. The dearth of willing and qualified teachers to teach K-12 engineering classes [17, 18] suggests that it is time to invite and include teachers beyond the closed circle of mathematics, science, and technology. This requires equipping non-STEM teachers with appropriate PD and supporting them in ‘knocking the walls down.’ Our goal in presenting this study is to provide added focus on the empowerment of a diverse group of teachers to teach pre-college engineering classes and to contribute toward the future design of PD programs.

We acknowledge that single case research design leads to the limitation of generalization. It is possible that with another participant, different themes could emerge. The goal of any case study research is not to prove something through aggregation and generalization, rather it is to develop the nuanced view of the reality and learn [8, 9].

We will continue data collection for the rest of the 2019-2020 school year and into the following school year to further understand Mr. Rogers' facilitation of the culminating student projects. There will undoubtedly be impacts to teacher experiences based on required changes caused by the COVID-19 disruption. Future plans also include similar detailed studies with other non-STEM teachers participating in the program to explore the necessary preconditions for transfer across other seemingly disparate and unconnected content areas. We aim to understand what does and does not transfer. Such information could help address the growing challenge in pre-college education regarding scarcity of teachers to teach engineering classes.

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