2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34771

Utilizing an Engineering Design-Based Research Approach to Study and Strengthen a Teacher Preparation Program in STEM at the Secondary Level (Work in Progress)

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Dr. Gretchen Fougere is an inventor, technology leader, and educator. Her broad, interdisciplinary training prepared her well to have a successful career in industry-based technology development as well as education. Dr. Fougere has spent her career engaging people of all backgrounds to understand how engineering and design can enhance their lives. A significant fraction of her effort has focused on expanding STEM reach and impact through partners in industry, universities, and nonprofit entities. Her firm, STEM Leadership Advisors, is proud to have collaborated with WPI for this NSF-funded project and she also serves as Vice Chair of the Science Club for Girls.

Dr. Fougere has had dual careers in education and technology development. In education, she is the Engineering director of research alliances for Northeastern University's Roux Institute. The Roux Institute is creating an innovation hub in Portland, ME, based on applied research and graduate education. Dr. Fougere works across NU to create teams of faculty who partner with corporate and nonprofit organizations to fulfill strategic needs. Previously, she was the inaugural Associate Dean of Outreach and Diversity in the College of Engineering at Boston University. Over the 6+ years, she launched and spearheaded a nationally-impactful initiative called the Technology Innovation Scholars Program, where a cadre of highly-trained engineering undergraduates engaged secondary students in hands-on engineering challenges, reaching over 17,600 students. She partnered with funders, such as AT&T, NASA, Accenture, Genzyme, and the National Science Foundation, and created inquiry-based STEM programs that inspired and challenged diverse students with a variety of learning styles, often in underrepresented and underserved communities. The Massachusetts high tech community recognized Fougere as a Mass Tech Woman to Watch and Carnegie Corporation/100kin10 appointed her as one of 20 national Fellow. She advised the Society of Women Engineers and Graduate Women in Engineering and Science. She actively collaborated with the Engineering and Education Faculty at BU and beyond and secured over $25M in grant funding. Additionally, she was a senior leader at The Possible Project, and at the ground-breaking Engineering is Elementary (EiE) program at the Museum of Science where she worked on partnerships, curricula and professional development.

Dr. Fougere also has a decade of technical and managerial experience in technology innovation. Her industrial experience includes leading a 20+ person, advanced Research and Development organization at Duracell and developing technical products and new business in high tech (Motorola) and aerospace (Pratt & Whitney Aircraft Engines) sectors. She received her Ph.D. in Materials Science and Engineering in the field of Nanotechnology from Northwestern University and was elected to Sigma Xi. Her research was conducted at the Argonne and Oak Ridge National Laboratories. She received bachelor's degrees in Biomedical Engineering and Mechanical Engineering from Vanderbilt University. She holds three US patents.

An Engineering Design Approach to Study and Strengthen a Teacher Preparation Program in STEM at the Secondary Level (Work in Progress)

Introduction

A study about the Teacher Preparation Program (TPP) at Worcester Polytechnic Institute (WPI) was conducted to examine the barriers of its graduates from entering the classroom as math, science, or tech/engineering teachers. We sought to better understand the experiences and thought processes of potential and current pre-service teachers to improve recruitment strategies in efforts to grow and diversify teacher candidates that will ultimately teach successfully in high-need schools. This project is part of a Noyce Capacity Building grant [1] to strengthen our program to better prepare our TPP students to teach in urban, high-needs schools and support their students in inclusive and relevant STEM. Our TPP is somewhat unique in that it is not associated with a School of Education since our university does not have one. However our Center consists of former middle and high school teachers and staff with science and engineering education backgrounds.

An engineering design [2] research approach (Figure 1) was taken to address the shortage of STEM teachers at the secondary level, and in this Work in Progress paper, we share the initial stages of identifying the needs ("ASK"), researching the problem, and imagining some possible solutions. Because our institution emphasizes solving problems through an engineering design approach, we have adopted this methodology for our grant work and engage others in this approach.

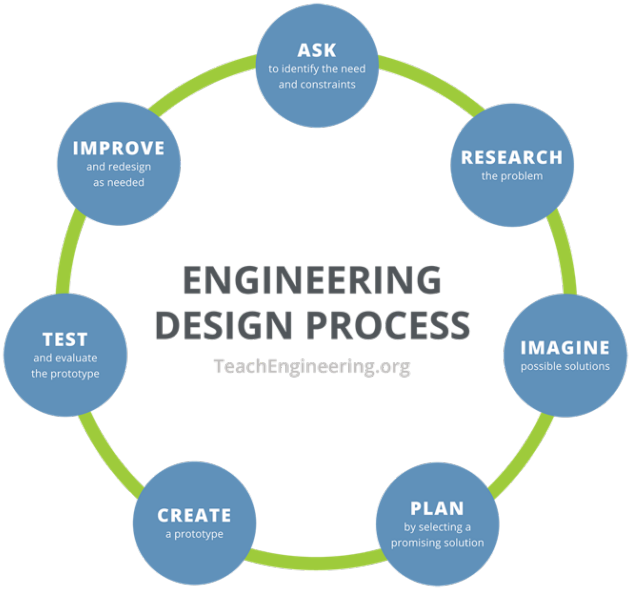

Figure 1. This study reports the first three steps of the engineering design process in improving a teacher preparation program to yield more STEM teachers at high-need secondary schools.

Identifying the Needs and Constraints (ASK)

The number of students in our Teacher Preparation Programs is relatively small, yet the need for math, science, and tech/engineering teachers in our region and state is substantial. Due to our strong undergraduate programs in mathematics, sciences, and engineering, the state values our TPP for secondary level technology/engineering, mathematics, and science (chemistry, biology, physics). The TPP cohorts based on graduation year typically ranges from 7 to 14 students, and at the time of the study we had 26 total students in the program. Approximately 80% of the TPP students are white, and 13% were from underrepresented groups. While the total number of our TPP students might seem small, they could be impactful teachers with their strong STEM

content knowledge, culturally responsive pedagogy training, and project-based, real-world experiences. A single teacher can have a ripple effect by affecting many students over their career, especially in high-need schools [3]. We hope to eventually increase the number of completers to 12 per year, with at least half of them entering the classroom within 5 years of graduation. Through this study, we aim to gather information to increase the number of TPP students and the number that will choose to go into teaching at high-needs schools.

While we had many ideas on the barriers and challenges of our TPP graduates becoming classroom teachers, much of the information resided with the TPP Director and through anecdotal information. The Noyce Capacity Building grant allowed us to intentionally examine the landscape, ask thoughtful research questions and have the data analyzed and recorded. For instance, we had hypothesized that the financial cost of attending WPI and choosing to become a teacher instead of a STEM professional in industry might represent some of the barriers preventing graduates from becoming STEM teachers. In addition, the added course work associated with TPP is often considered a barrier for students who need to ensure that they can finish their degree within four years. The misconception that all K-12 teachers earn low salaries and would be unable to pay off school loans creates additional barriers to students considering teaching [4,5]. Thus, we wondered – *Is it a "luxury" to be in our TPP and to become a teacher; is it only possible if one doesn't have the burden of large loans?* We also wondered how and when the students made their decisions about entering the TPP and choosing their career path with their B.S. degree in a STEM field. To frame our project, we asked the following research questions to gather information to prepare the proposal for a Noyce Track 1 Program:

- *Do Teacher Preparation Program teacher candidates have unmet needs?*
- *Where do they have barriers preventing them from becoming secondary STEM teachers?*

Researching the Problem

The RESEARCH involved understanding "users" who are experiencing the TPP system such that the system can be improved to better meet their needs. (In our grant, we also researched the needs of the mentor teachers and hiring managers of high-needs schools, but those findings will be reported in a future publication.) A mixed method (i.e., quantitative and qualitative) approach was used. A Qualtrics survey was administered to students attending TPP info sessions (99 total of 1st and 2nd year students) and a different Qualtrics survey was sent to all the students currently in the TPP. Out of the 26 total number of TPP students (representing 3 cohorts), 23 (88%) responded. Factors affecting interest and decisions about teaching included family influences and support, teaching-related experiences, internships, financial aid, etc. The likelihood of teaching right after graduation was also asked.

From the surveys administered during the info sessions (before students apply to TPP), 60% said the lower salary in teaching could prevent them entering teaching, and 13% said their parents would not allow them to do so. What we don't know is how many STEM students dismiss the idea of the TPP or teaching early on in their career decision process, and if the Noyce scholarships (if we were successful in obtaining the grant) would make a difference.

In addition to the quantitative data collection, an external consultant led interviews with the TPP students. Sixteen (16) current TPP students were interviewed, as well as two alumni who are now teaching in the classroom (with one in a high-needs district). Some of the prompts during the interviews are in Table 1, and common themes emerged during analysis.

Table 1. Example of the interview questions for the Teacher Preparation Program students.

How did you first hear about the Teacher Preparation Program?
What teaching experiences did you have before TPP?
Tell me about a time when you knew you wanted to teach.
Tell me about a time when you had doubts about teaching in K-12 schools.
Do you have any concerns about being a secondary school teacher?
Do you feel prepared to teach?
If you were to take a job teaching, please describe the teaching position (including student demographics, location, etc.).
What is most important in your decision to accepting a job? (e.g., location, salary, societal impact, loan forgiveness, colleagues, career opportunity, job content)

Some of the interesting findings from the TPP student interviews were that paying off loans was secondary on their list of concerns, even though an analysis of their financial aid packages revealed unmet need. TPP students make up the financial gap to attend school through means such as working during school and summers, and/or taking out private loans. Since paying off loans did not rank highest in their list of concerns, it may be that the students who do decide to enter the TPP (and the few who have gone onto become classroom teachers) have already accepted the fact that they will have loans to pay off and that the teaching experience outweighs the financial concern, as expectant value theory would suggest [6,7].

During the interviews, the TPP students gave multiple factors for their motivation to teach. Their responses were coded by the consultant according to typical motivations for pre-service teachers, according to several sources [8,9]. The codes were then grouped into 4 pre-set motivational factors:

1. Intrinsic (intellectual challenge, love of kids)
2. Extrinsic (family-friendly schedule, job security)
3. Altruistic (good for society, shape kids' future)
4. Working Environment (autonomous role, develop a professional network)

We found that a trend in how the first and second-year students responded was different from the third and fourth year TPP students, with the teaching practicum most likely the big difference. The students earlier in the program were generally most motivated to give back to society (Altruism), while the 4th year students were motivated by the working environment and then the intrinsic nature of the job. For these students, they may be thinking more about the practical realities of post-college life, as many talked about their desire to be close to family or significant

others after graduation. Also important to them were the salary (an Extrinsic factor) and their colleagues (Working Environment). Through the human-centered design approach of this study, we realize that how we recruit and support TPP students should take into account how they evolve during their undergraduate years, and how we might leverage their motivations.

From the TPP info session surveys by students deciding whether to apply to TPP, 53% were "exploring teaching" and 27% professed "to go into teaching after working in industry," and 13% said they were "interested in becoming a teacher immediately after graduation." In contrast, out of the current TPP students interviewed, 13 of the 16 students (81%) intend to teach secondary school at some point. In fact, four TPP students indicated that they had matriculated to WPI because of the TPP. With these data, we see that the students who end up doing the TPP are quite committed to teaching.

Because many of our TPP students plan to wait before becoming teachers in the classroom, it was important to understand why. They were asked in the interview what they wanted to learn first before teaching. Analysis of common themes revealed that they want to make themselves better teachers by gaining:

- **real-world experience** to bring into the classroom to be relatable to students
- **additional training in education** (e.g., classroom management, lesson planning, culturally responsive teaching, and reaching specific age groups with content knowledge)

They see themselves as a potential teacher as well as a STEM professional, and they may have developed an identity as a STEM teacher [10,11]. The practicum experience not only was the hands-down favorite teaching experience associated with the TPP, but it was also the source of experiences that affirmed their desire to teach. They expressed sentiments of how much urban students need support and love, the joy in getting a bored student to become engaged and learning, and how every day in the classroom is different (as opposed to an industry job).

Most important, the study revealed concerns that the TPP students have in becoming effective teachers in the classroom, and thus we may be able to address them and design them into the Noyce program proposal. The most common challenge related to their ability to reach all students with differentiated learning, which is common to most novice teachers. About half of the responses from the TPP students related to their confidence in their classroom and behavior management skills. The students genuinely desire to improve their ability to reach all students and to be a good teacher. These findings about pre-service teacher motivations and concerns can be used to create user personas for future steps of the design process.

Imagining Possible Solutions

Based on the research findings, we are able to advance the design process and use the analysis to IMAGINE and brainstorm prototypes to implement now in efforts to purposefully PLAN, CREATE, TEST and IMPROVE the components of the Teacher Preparation Program for a Noyce Track 1 proposal. A team of the PI, co-PI, and consultant had multiple meetings to analyze the data, explore other teacher preparation programs, review the literature, and

brainstorm improvements. The imagined design solutions fall into the stages of the TPP program of recruitment, pre-practicum experiences, and practicum support.

There was no one common way that TPP students found out about the program, and thus multiple strategies are needed to advertise the program and to gather supporters (e.g., department heads, faculty, academic advisors) to increase the visibility of the program. Since our goals are to not only increase the number of TPP students, but to also increase the diversity, we propose to work with the Director of Multicultural Affairs to promote the TPP to students from under-represented groups and express the value of K-12 teaching, especially in high-needs schools [12,13,14]. We are also considering how to frame our TPP in terms of social justice [15, 16]. The information conveyed in recruitment materials should tap into the intrinsic value and highlight the favorable working environment of teaching, as well as dispelling myths about salaries [17].

We learned about the need for the teacher candidates to feel better prepared to work with students in urban high-needs schools, which are often times very different their own personal experiences. A possible way to overcome this barrier is for the TPP students to spend more time with the youth in our local community-based organizations in informal contexts [18]. Thus, we imagine authentic, immersive pre-practicum experiences in our local city, such as tutoring and participating in afterschool programs that serve the K-12 students from low-income and highly diverse areas [19, 20]. Guided reflection and discussions are also to accompany these field experiences [21]. While these "real-world" experiences might not be what the TPP students had in mind during their interviews, the ability to connect or relate any STEM content or skills they wish to teach to their students requires the understand of their students' lives. We also imagine building clear pathways to teaching at the secondary level for our TPP alumni who decide to go to industry upon graduation and who could bring in valuable real world experience and perspectives (i.e., industry career) into the classroom for their students.

Ideally, we also imagine that pre-practicum experiences could happen at the high-needs school where the teacher candidate will do their practicum (e.g., tutoring, mentoring robotics teams). In addition, by pairing the teacher candidates with their mentor teacher earlier in the TPP cycle, more observations and familiarity with the school culture and students could occur [22].

Brainstorming prototypes to help pre-service teachers be successful in the classroom resulted in piloting "equity, inclusion, & antiracism in STEM" and "culturally responsive teaching" [23,24] seminars in TPP. We see the need to build in more support, practice, and reflections for differentiated instruction [25] and practical classroom management during the practicum.

Through our Noyce Capacity Building project, we have gone through the initial steps of the engineering design process of asking research questions, collecting data from students through surveys and interviews, and imagining possible solutions guided by the literature. For our TPP graduates to feel prepared and plan to teach in urban, high-needs schools, we propose to infuse culturally responsive pedagogy and authentic field experiences throughout the TPP curriculum. The next stage ("PLAN") is to select particular solutions from our design process to implement as the project plan for the Noyce Track 1 proposal.

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