Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #45483

Two Years' Comparison from Industries of the Future Research Experience for Preservice Teacher Summer Program

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Abstract

This paper reports two years' experience from our implementation of the NSF project titled "Industries of the Future Research Experience for Preservice Teachers in STEM Settings." The goal of the project is to host 10 high school preservice teachers each summer to participate in Industries of the Future (IotF) research fields and then convert their experience into high school curriculum. IotF topics include artificial intelligence (AI), quantum information science (QIS), advanced manufacturing, advanced communications, and biotechnology. In summer 2023, the first cohort of 8 preservice teachers (PST) from the UH teachHOUSTON (*t***H**) PST program participated in the RE-PST program at UH Cullen College of Engineering (CCOE). In summer 2024, the second cohort also had 8 PSTs. This six-week program sought to advance future educators' knowledge of concepts in IotF as a means of enriching high school curriculums defined in the Texas Essential Knowledge and Skills (TEKS) standard. Enrichment activities included research workshops, field trips to local companies, and lesson plan design. Compared to the first year, the research mentors were more experienced in assigning research topics and working more closely with PSTs in the second year of the program. This paper provides details on the commonality and changes in the second year's implementation, in comparison to the first year. Some follow up activities from the first cohort is also reported. Overall, PST participants found the research experience with their mentors beneficial not only to them, but also to their future students according to our findings from interviews.

1. Introduction

The Industries of the Future (IotF), comprising artificial intelligence (AI), quantum information science (QIS), advanced manufacturing, advanced communications, and biotechnology were recommended by the President's Council of Advisors on Science and Technology (PCAST) to the President of the USA [1]. The IotF topics are critical for future industry development and thus the workforce development in these areas is of great importance. Meanwhile, K-12 education requires enhanced STEM content in high school curriculum as part of the graduation requirement [3]. Therefore, it is imperative to train secondary school teachers to be better prepared for more advanced learning engineering modules. One way advocated by National Science Foundation is to provide authentic research experiences to preservice teachers in a STEM setting. The mission of this project, Industries of the Future Research Experience for Preservice Teachers in STEM Settings, is to provide research experience to 10 preservice teachers each summer under the three-year NSF grant.

The project plans to host 10 high school preservice teachers each summer to participate in Industries of the Future (IotF) research fields and then convert their experience into high school curriculum. The objectives are to 1) Recruit 10 high school PSTs from the students in the teachHOUSTON (***t*H**) program to engage in IotF research; 2) Provide interdisciplinary and hands-on research experiences to these PSTs; and 3) Develop course modules based on the research experience and meeting Texas Essential Knowledge and Skills (TEKS) standards [3,4,5]. ***t*H** is UH's secondary STEM teacher preparation program and addresses the critical need for highly qualified STEM teachers in Texas and across the country [7].

The rest of the paper is organized as follows. Section 2 compares preservice teacher recruitment for two summers. Section 3 compares the RE-PST activities. Section 4 compares the results from the RE-PST program assessment for the two summers. Section 5 has the conclusion for the paper.

2. Comparison of Preservice Teacher Recruitment in Two Summers

Preservice teacher (PST) recruitment is a difficult process. In the first year that the program was offered, potential participants are uncertain about what this program can bring to them. The RET 3-fold flyer was created and a dedicated website for RE-PST program was set up to promote the summer program. A presentation was prepared and distributed by ***t*H** faculty to their students. Ms. Matter, the main ***t*H** liaison for the project, made several presentations in the classrooms. Then, Dr. Zhu, the PI, visited several ***t*H** classes and talked to ***t*H** faculty and prospect PSTs. As a result, we received 11 applications and accepted 10 PSTs into the summer 2023 RE-PST program. However, one student dropped out due to family emergency at the last minute and the other student dropped out due to ineligibility. The cohort consisted of 2 male and 6 female PSTs; 3 Asian and 5 Hispanic. Five of them were with a biology background, two were from math background, and one was in civil engineering.

After this experience, we speculated that it was probably because students are not sure about what to expect from the summer program and dare not apply even though they are interested. Thus, we felt that our second summer recruitment would be easier if the first cohort

can share their positive experience with their classmates. It turned out to be not true. Ms. Mateer distributed the information to ***t*H** faculty, and the ***t*H** instructors gave the presentations to their students. This proved to be ineffective as no students applied at all after the effort. By early March 2024, Dr. Zhu decided to step in and visited many classes in March 2024 to explain the summer with technical programs. This proved to be more effective as students felt more confident after they listened to an explanation from an engineering technology professor. We received 9 formal applications and accepted 8 of them. We also verbally turned down the requests from a few students from the summer 2023 who would like to participate again in summer 2024, as we hoped to recruit a more diverse group of students. The 2024 cohort consisted of 5 male and 3 female PSTs; 1 African American, 1 Hispanic, 2 Asian, and 4 Caucasian. Three of them were with a biology background, four were from math background, and one was in Computer Science.

Comparing two years' experience, it was obvious that recruitment will never be easy even though with the information dissemination with different channels. The key is to start early with updated information. It is critical for engineering professors to walk into the PST classrooms to assure potential participants that this program is designed for them. Taking these into consideration, we have started the recruitment activity in fall 2024 for summer 2025.

3. Teacher Activities

One week before the summer program started, Ms. Mateer offered two training sessions, each for 3 hours, to the research mentors and research assistants. The training prepared the mentors to learn how to better work with the PSTs.

In summer 2023, the first cohort of 8 PSTs participated in the summer research and education program from June 12 to July 21, 2023 at UH Cullen College of Engineering. In summer 2023, some potential students reported that while they are interested in this opportunity, they have other commitments with other programs that overlap with our program in June 2023. In order to minimize the 'competition' with other summer programs, in summer 2024, the second cohort of 8 PSTs participated from May 13 to June 21, 2024.

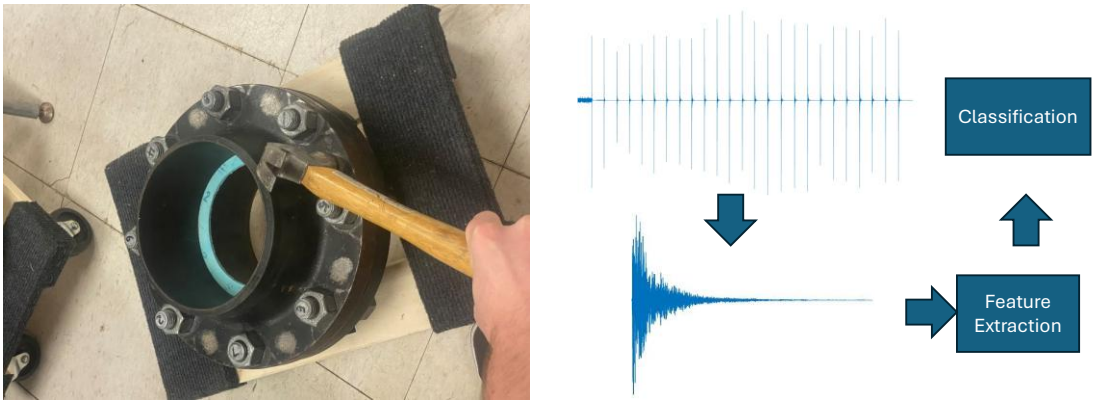
In both summers, the first one and a half days were the orientation in which PSTs were given an introduction to the program, introduction to faculty research topics, lab safety, curriculum development expectation, and teachengineering.org website. The PSTs signed an agreement for payment and IRB review purposes. A special 3-hour lab safety session was given by UH Environment, Health and Safety Program Managers. At the end of the first day, each PST spent about two to three hours assembling a 3D printer with assistance from Research Assistants.

Engineering professors provided workshops during the summer program. In summer 2023, six UH professors (five mentors and one instructional professor) each provided one week of workshops. The topics of these workshops included advanced manufacturing, biotechnology, SolidWorks geometric modeling, Artificial Intelligence (AI), Quantum Computing and Energy System Modeling, and Communication and IoT (Internet of Things). In summer 2024, besides research mentors, we also reached out and invited more than 10 professors to cover a more diverse set of research topics. These professors were from mechanical engineering, electrical

engineering, industrial engineering, construction management, biotechnology, and computer information systems.

In summer 2023, the 8 PSTs were assigned to five professors' research labs. In summer 2024, the 8 PSTs (4 pairs) were assigned to four research groups. Assisted by student research assistants, each professor mentored one or two PSTs on various projects. The assignment of preservice teachers to mentors was based on the background and interest of PSTs as evidenced by their resumes and essays from the application process. It is challenging to design the projects for the PSTs because the projects should be manageable in six weeks. The support from mentors and RAs is critical throughout the summer experience. Three project examples in summer 2024 are provided as follows.

1. Two PSTs (one biology student and one math student) were assigned to work on using machine learning (AI algorithms) in mechanical engineering applications. They first investigated percussion-based method to predict flange integrity (**Figure 1**). During the experiments, an electric torque wrench is used to tighten or loosen bolts on the flange to certain torque. Then a hammer is used to tap the bolts and an iPhone is used to record the sound signals. The PSTs learned how to use Matlab codes to analyze the acoustic signal and build a model to establish the relationship between the signals and the torque on the bolt. Based on this experience, they are developing a lesson plan in mathematics.
2. Two PSTs (one math student and one biology student) were assigned to work on protein extraction from microalgae and make media for microalgae and mushrooms. They cultivated *nannochloropsis gaditana* in the lab and measured their growth every day. They also investigated algae wastewater reuse. Based on this experience, the math student is developing a course module in Algebra I and the biology student will implement a module in biology.
3. Two PSTs (one math student and one biology student) were assigned to measure the force needed for the gripper to pick up mushrooms in the mushroom robot project. They learned how to program with the Arduino board and conducted the experiments. Based



(a) Hitting bolt for flange experiments (b) Signal processing for AI

Figure 1. Flange bolt looseness detection using sound percussion and trained with machine learning

on the experience, they design a race car course module which involves SolidWorks modeling, 3D printing, sensors, motors, and Arduino microcontrollers.

In summer 2023, the first cohort participated in industrial field trips to local companies including Samson Controls, TechnipFMC, Beckhoff Automation, and SLB (Schlumberger). In summer 2024, the second cohort visited Samson Controls, NASA Johnson Space Center, ARC Specialties (Industrial Robot), Halliburton Research Center, and Emerson Valve Manufacturing Site (**Figure 2**). According to feedback, these field trips were the favorite part for PSTs. Samson Controls at Baytown, Texas, is one of the leaders in pump design and manufacturing. It surprisingly uses a lot of Artificial Intelligence for pump maintenance. ARC Specialties is an industrial robotic company and excels in robot-based welding. Emerson is a large international company. We visited their state-of-the-art manufacturing facilities which are only about 15 minutes from our Sugar Land campus. Not all companies allow taking pictures in their facilities.

(a) Field trip to NASA Johnson Space Center Mission Control Center

(b) Field strip to Halliburton Research Center in Houston, Texas

Figure 2. Industrial field trips to local companies in Houston

In both summers, the PSTs worked with the *t***H** lecturer, Ms. Mateer, to apply their learnings to lesson plans. Each week, they met with Ms. Mateer to discuss options for curriculum development. Course module templates downloaded from teachengineering.org were used to guide course module development. PSTs also met weekly for Brown Bag PST seminars to share their experiences and discuss curricula. The participants shared their progress in research and knowledge learned. On the final day of the program, the PSTs presented their curriculum prototype for the field teaching to the group and received completion certificates. Ms. Mateer also follows up with these PSTs on the course module implementation in the long semester. The program assessment was led by a professor in human resource development at UH.

Besides the official RE-PST site website set up by the research team, a Facebook page and a LinkedIn page have been established for the RET site program to disseminate the activities information.

4. RE-PST Program Assessment

Each PST was given one pre-program survey at the beginning of the summer and one post-program survey after the summer program was over. Both the pre-program survey and the post-program survey measured the participants' perceptions of their knowledge of IotF technologies and their perceptions of self-efficacy and intentions towards high school STEM teaching. The pre-program and post-program data allowed for within-subjects comparisons to assess the changes in IotF knowledge and skills between orientation ("pre-program") and the end of the summer program ("post-program). Due to the small sample size, we can only report descriptive statistics to compare the survey results within a given year.

For the summer 2023 cohort, all eight participants complete the pre-program survey during the first week of the program. Five of the participants completed the post-program survey at the conclusion of the program. Therefore, we report pre-program and post-program data for those five RE-PST participants. Of the five participants included in this report, three identified themselves as women and two identified as men. Two participants self-identified as Asian/Asian American, one participant self-identified as Hispanic, and two participants self-identified as White.

For the summer 2024 cohort, all eight participants complete the pre-program survey during the first week of the program and the post-program survey at the conclusion of the program. In the survey, two participants self-identified as Asian/Asian-American, one participant self-identified as Mexican, one participant self-identified as Jewish, one participant self-identified as Black and Asian, and three participants self-identified as White.

At the conclusion of the summer 2023 program, a subset of the PSTs were also interviewed by the independent evaluator, Dr. Greer, a professor in human resource development. All participants were invited to an interview, four PSTs opted to participate in an interview. Additionally, Dr. Greer selected two faculty mentors to interview at the end of the summer. At the conclusion of the summer 2024 program, Dr. Greer conducted a focus group interview that included all eight participants.

a. Preservice Teachers Improving Technical Knowledge

In both cohorts, all PSTs came in with little knowledge about the background in the research topics and almost all the IotF fields. The RE-PST participants had STEM backgrounds mainly from various disciplines in math and biology. Most students were in junior or senior standing. Overall, they lacked the background knowledge needed for conducting engineering research. In the interview, one 2023 PST admitted:

> "*I came in very unprepared. The whole point of this program was to do research and I did absolutely none of it because I didn't know the basics. I didn't know what a matrices was until they taught it to me. I didn't know the very basic principles of quantum physics until they taught it to me. I feel like I could have done some good research if I had known the basics beforehand. I know the RA was trying to send me materials before the program started. But, that really didn't happen so when I got there I had no idea what I was going to do.*"

Similarly, a 2024 PST commented:

> "*Everything we learned I've never heard of before, like quantum machine learning and like AI or biotechnology, I've never learned any of that in high school. So, it was something new. It was good and bad. It was good because I like learning new knowledge. I gained new experiences, but it*

was kind of bad a little bit because some of the things [the presenters] taught us were too advanced and it was too hard."

However, through the RE-PST workshops, all participants obtained basic information in the IotF research areas. Then they obtained in-depth knowledge in certain fields with their mentors. All PSTs completed assembling a 3D printer and some used it in their summer research.

In the pre-program and post-program surveys, knowledge of the IotF research areas was assessed using a 5-point Likert scale [1=strongly disagree; 5=strongly agree] on the following survey item for each research area: "*I have knowledge of the latest advancements and trends in the technologies listed below*". As shown in Table 1, most participants across both cohorts mostly reported increased knowledge of the IotF research areas at the end of the program. Furthermore, the average scores across the two summers show an increase in knowledge for all five IotF technologies. The greatest perceived increase in knowledge occurred for knowledge of Advanced Manufacturing, whereas, the smallest perceived increase in knowledge occurred for knowledge of Communications and Internet of Things.

Table 1. Pre-Program and Post-Program Knowledge of IotF Research Areas

	Knowledge of Artificial Intelligence and Machine Learning		Knowledge of Quantum Information Science and Energy System Optimization		Knowledge of Advanced Manufacturing		Knowledge of Communications and Internet of Things		Knowledge of Biotechnology and Sustainability	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
PST-A (2023)	4	5	4	5	4	5	4	5	2	5
PST-B (2023)	4	2	3	3	2	2	3	2	3	3
PST-C (2023)	1	5	1	4	1	4	1	4	2	5
PST-D (2023)	1	4	1	3	3	4	2	5	4	5
PST-E (2023)	2	3	1	3	4	5	3	5	4	5
PST-F (2024)	5	4	5	5	5	4	5	4	5	3
PST-G (2024)	4	5	2	4	2	4	2	4	4	4
PST-H (2024)	1	3	1	3	1	5	1	3	1	3
PST-I (2024)	2	5	1	4	1	4	1	1	1	5
PST-J (2024)	4	4	1	4	1	4	1	3	3	4
PST-K (2024)	3	4	3	1	3	4	3	1	3	5
PST-L (2024)	4	4	4	3	2	4	2	4	2	4
PST-M (2024)	1	4	1	4	1	4	1	1	1	5
AVERAGE	**2.8**	**4.0**	**2.2**	**3.5**	**2.3**	**4.1**	**2.2**	**3.2**	**2.7**	**4.3**

The interview data also supported the notion that the participants' knowledge of the technology areas grew as a result of participating in the RE-PST program. For example, one 2023 PST expressed:

> "*[The program] expanded what I had already been studying. Since I'm a biology major, I had always learned about certain lab techniques. And it wasn't until I was in the lab that I got to do some of those techniques for the first time.*"

b. Preservice Teachers Using New Knowledge to Improve Teaching

In the pre-program survey and post-program survey, participants reported their knowledge of how to translate research in the IotF areas into curriculum content for high school STEM courses. This self-perception was assessed using a 5-point Likert scale [1=strongly disagree; 5=strongly agree] on the following survey item for each research area: "*I know how to translate research in the following areas to improve high school STEM curriculum*". As shown in Table 2, across both cohorts, most participants perceived that they had more knowledge in this area at the end of the program compared to the beginning of the program. The averages for each area of technology showed an increase in knowledge with AI/Machine Learning and Advanced Manufacturing showing the largest increases in knowledge.

Table 2. Pre-Program and Post-Program Knowledge of Translating Research to High School Curriculum

	Knowledge of Artificial Intelligence and Machine Learning		Knowledge of Quantum Information Science and Energy System Optimization		Knowledge of Advanced Manufacturing		Knowledge of Communications and Internet of Things		Knowledge of Biotechnology and Sustainability	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
PST-A (2023)	4	5	2	5	4	5	4	5	2	5
PST-B (2023)	2	3	2	2	2	2	2	3	2	4
PST-C (2023)	2	5	1	3	2	5	1	5	2	5
PST-D (2023)	1	4	1	2	2	5	1	4	4	5
PST-E (2023)	2	5	1	3	1	5	1	4	2	5
PST-F (2024)	5	4	5	5	5	4	5	4	4	3
PST-G (2024)	1	5	1	3	1	3	1	3	1	3
PST-H (2024)	1	1	1	1	1	5	1	3	1	2
PST-I (2024)	1	4	1	2	1	5	1	1	1	4
PST-J (2024)	4	5	2	4	2	4	2	3	4	5
PST-K (2024)	2	5	2	1	4	4	4	2	4	5
PST-L (2024)	3	4	2	3	3	4	4	4	2	4
PST-M (2024)	1	4	1	4	1	4	1	2	1	5
AVERAGE	**2.2**	**4.2**	**1.7**	**2.9**	**2.2**	**4.2**	**2.2**	**3.3**	**2.3**	**4.2**

In the pre-program survey, PSTs were asked which technologies they wanted to add to their instruction when they become a teacher. At the start of the program, the preservice teachers focused on a relatively narrow variety of technologies, with an emphasis on 3D printers. For example, the 2024 cohort was particularly grateful for the opportunity to use 3D printers during the program experience. One 2024 participant expressed:

> *"The 3D printer we got could be something that I could just keep in my classroom just to kin of show students about it, maybe make some stuff throughout the year."*

However, when asked about using technologies in their teaching at the end of the program, the PSTs demonstrated intentions to integrate a wider range of technologies in their future teaching. Presumably, this is a result of the exposure to the IotF technologies and potential instructional applications during the RE-PST program. The data suggest that the RE-PST program created new possibilities related to cutting edge technologies for these preservice teachers, which will ultimately impact the students that they teach in the future.

Furthermore, at the end of the RE-PST program, the participants were asked about the most important things that they learned over the summer. The participants' responses mainly focused on technology application in teaching and learning. For example, one 2023 PST responded:

> "*[The most important things I learned from this summer research experience were] how impactful what you learn in math and science in High School can be in the real world and how to incorporate current technology into a lesson plan.*"

Another 2023 participant commented:

> "*We, as teachers, can bring relevancy though inquiry in our lessons. While as STEM teachers we will be able to directly promote STEM fields of study that doesn't mean it needs to be the same degrees and more so the same jobs.*"

A third 2023 participant noted:

> "*I think the most important thing I learned is how to simplify a complex topic to spark students' interest in the industries of the future.*"

These responses provide some evidence that the participants were making connections and actively thinking about how the new technologies can be used to enhance their instruction in STEM classrooms, which is one of the primary objectives of the RE-PST program.

One 2024 participant offered a different perspective, noting that the program experiences focused more heavily on learning the technical aspects of the IotF technologies and did not place enough emphasis on using these technologies in their teaching. Notably, one 2024 participant commented:

"I expected to come in and learn a little bit about engineering and kind of see what engineers actually do. But the program is really advertised as something specifically for preservice teachers - I mean, that's the name. And it's like it really lacked in the curriculum development part that I was hoping to get out of this because we didn't really get realistic coaching on our lesson plans. Any time that we had that coaching it was cut off or it was shortened because of miscommunication. So, I didn't get that part of this program that I really wanted to get. But it met expectations of learning about engineering and what labs do in that sort of stuff. Like what are we gonna do with it? It's just like, how do you do it? But what do you do with it?

c. Preservice Teachers Learning Real-World Applications

The PSTs were positively impacted by the opportunities to see real-world applications of the new technologies that they were exposed to during the RE-PST. There is some evidence that the new recruiting strategies implemented in 2024 influenced some participants to join the RE-PST program because of the potential to learn real-world applications. For example, one 2024 participant commented the following:

"So I feel like that's what really sold me on [the program] and also wanting to do research and get hands on experience with Dr. Zhu. He presented the RE PST program to the class I was in at the time and he's saying that you'll be able to get experiences like engineering and the engineering process, and that's something I was really interested in. That was why I wanted to be in the program."

In the interviews, participants commented on how the RE-PST program encouraged them to make connections between their previous knowledge and new knowledge of the IotF technologies. In particular, one 2023 PST said:

"*Learning is one thing but, to see it in action with your own eyes is a completely different experience. And it shows you that everything you're learning has an application. You're not learning it just to fill up your time as a student but, there is actual practical purpose.*"

Identification of real-world applications during the RE-PST program was especially driven by the field trips and the research projects. For example, one 2023 PST mentioned:

"*For me, I didn't have much trouble connecting my research to a topic in biology. But, I saw a lot of peers were having a lot more difficulty with that. But, they could do it…and they did. We would talk and help each other brainstorm and I think that productive*

struggle is what helped me realize that you can connect anything to your lesson."

Another 2023 PST added:

"*I really enjoyed the first field trip to Samson. I feel like I learned a lot, especially because I could apply what I learned in communications about deep learning and artificial intelligence to what they were talking about.*"

Participants in the 2024 cohort suggested that the positive impact of the field trip experiences can be maximized by ensuring that the field trip content is tailored to the participating PSTs as noted here:

"Four out of the five field trips we went on, the person giving the tour asks if we are engineering students and it really just made me feel like you didn't explain at all why we're here. But with all that said, I do think one of the best experiences was the field trips."

Importantly, by learning real-world applications, the PSTs are better equipped to share these applications with their own students. As one 2023 PST noted:

"*In the workshops, they did a really good job of connecting all the material we're learning in our research together, and connecting that with current issues in technology that I think would be very interesting and something we definitely have to take into account, and have our students become aware of. Because technology is such a big thing in our current society and it keeps improving and I believe it's important for students to be aware of what's out there, how it works, and how it can potentially impact us.*"

Another 2023 PST also viewed the real-world applications as an opportunity to share more information with future students:

"*For me, I really enjoyed the workshops and the field trips, since they correlated. You got to learn about the technologies in the workshops and then on the field trips, you got to see those technologies in action. I'm a first-generation student so, I didn't know a lot of professionals while growing up. And I didn't know a lot about those occupations so, it was really cool to see that and to have more things to talk to my students about. So, they won't be like me and not know those jobs exist. They will know from the beginning*."

d. Preservice Teachers Realizing New Professional Opportunities

The RE-PST program seemed to open new options in STEM education and was potentially career-altering for some of the PSTs. For example, a 2023 participant stated:

> "*I was completely set on teaching – high school teaching – and getting a Master's in Education. But I think my perspective has changed. Graduating with a biology degree, I really wanted to be a biology teacher, But, after this program, I can see myself being a science teacher, whether it be they want me to teach physics, chemistry…up to some mechanical engineering. I would definitely feel more comfortable going into any field rather than just staying focused on my degree*."

Similarly, a 2024 participant shared the following:

> *"I think a pretty good thing about this experience is that I was kind of on the fence whether I wanted to just teach math or to teach physics and math. I think they put me over the edge where I'm all in to do the physics part because of the engineering aspect of a physics class. So, this really helped me steer my course for the rest of my career here. So, it's a good thing that happened. Yeah, it made me realize that. But while I enjoy math, physics is also really fun because that's what engineers do. So that's what I was hoping to get out of this program and it's something that I got out of this program."*

At least one 2023 participant is now considering the option of attending graduate school after participating in the RE-PST program:

> "*I joined the program because I was very interested to see what it would be like to participant in research….it was challenging but, it was definitely a fun experience. And I feel like it just really opened my eyes to the entire research program, and definitely I want to go to graduate school. I still don't know what field I'll specialize in but, I definitely want to go to grad school.*"

These data indicate important aspects of growth and development for these future teachers. By widening their view of what is possible, they can do the same for their students.

e. Preservice Teachers' Satisfaction with the RE-PST Program

Overall, the participants reported positive experiences and highlighted the positive aspects of the program. One PST specifically noted that the program was more difficult than expected but, it turned out to be a better experience than originally anticipated:

> "*As teachers, we always talk about how our students are supposed to struggle a bit. But, not like completely struggle. As a student, I felt like coming into this, I was a student who had to learn everything. And I had to feel that struggle and I eventually learned how to deal with that struggle*

and learn from it. So, I think that was a big addition to this – that we had to experience that."

Another PST also appreciated being stretched by the program:

"*I'm glad the program stretched me because it showed me that I don't need to stick to just biology. I can extend to other fields. And another thing I really appreciate was defining the interconnectivity of branches of science. And I did find one between quantum physics and biology!*"

The PSTs reported the best aspects of the program included the program faculty and industry partners. One student expressed:

"*We enjoyed the enthusiasm and the love that they had for the subjects – from the professors that gave our lectures and then the people where we went to our field trips. Anybody that was in the companies…you could tell that they loved what they were doing. It was really cool to see their enthusiasm, because of course we're enthusiastic about teaching. We don't really understand the other side – the business aspect. But, seeing how we could all find what we want to do and thrive in it was pretty cool for us.*"

The positive experiences, including learning and developing beyond their initial comfort zone, outweighed the concerns that the participants had about the program. In the interviews, they definitively stated that they were glad they participated in the program, it will positively impact their teaching in the future, and they would recommend the program to future preservice teachers. However, there is room for improvement for next year's cohort.

5. Lesson Learned

In summer 2023, for some of the faculty mentors, this was their first experience of mentoring high school teachers through the RE-PST program. In summer 2024, taking the lessons learned from the cohort, our mentors adjusted the strategy and level of knowledge and research skills to better accommodate the PSTs. The PSTs also provided their comments on improvement through an anonymous survey and interview. The lessons are classified into two categories as below.

A. For the Mentors

1) Recruitment for PSTs is never easy. Even though we have the positive feedback from the first cohort, it still takes a lot of effort to recruit the second cohort. Most PSTs are math and biology undergraduate students. They do not have exposure to engineering and technology which is much needed in high school teaching. Therefore, even though the RE-PST program was designed for PSTs, it is necessary to explain the program clearly on a one-on-one basis. They should start with some basic training at the beginning of the summer program.

2) Communication between faculty mentors and teacher participants prior to the RE-PST program start is critical. Research tasks and the expectation should be clearly explained to the PSTs at the beginning of the summer program. This will help avoid surprise or frustration during the program.
3) For the success of the program, there are a lot of things to be prepared. It should be noted that the preparation is not just limited to teaching and research. For example, the PI had to make arrangements with stipend payment procedure and field trip arrangement.
4) Getting the students to complete the course module development is not an easy task. So far, only one student has completed all the course module development tasks, attended conferences, and presented the work in conferences. It takes a high self-regulated student and consistent support from the tH program to make it happen.
5) Shifting the time to be four weeks earlier to start from mid-May does not help much in recruitment. It caused other conflict in the student plan.

B. For PSTs:

1) Getting a good curriculum specialist can greatly help teachers in preparing their course modules. It is necessary to keep the communication channels between mentors and curriculum specialists to tune the research tasks. In the weekly PSTs' conferencing call, the PSTs were given half a day to meet together, share their research experience, and discuss how to convert their experience into curriculum.
2) The psychological changes of the PSTs must be considered and watched during the progress of the RE-PST program. Research tasks may need to be tailored to be compatible with teachers' backgrounds to be more relevant and meaningful. It is also helpful to ask PSTs to help each other.
3) PSTs enjoyed the field trips very much and considered them as the critical components of the summer research to get real world engineering experience.

6. Conclusion

The 3-year project started in 2023. Two cohorts of PSTs have completed their summer program. Compared to the first summer, our mentors are more experienced in mentoring the students and can adjust the research task scope to the level that can be accepted by the PSTs. The PSTs were exposed to a more diverse set of research topics through workshops from many more guest speakers. There is a list of lessons learned from this past summer. A few important changes we are going to implement for the third cohort will include:

1. Plan much earlier in the student recruitment and match teachers and faculty based on their mutual interest.
2. Define research tasks more clearly for PSTs before the summer starts and make sure both teachers and faculty mentors understand the expectation.
3. More closely follow with the students after the summer on the course module implementation.

4. We will go back to the original dates to start the summer from early June to the end of July.

Acknowledgment

All authors and faculty participating in this project are sponsored by the National Science Foundation grant #2220683. Their support is greatly appreciated. W. Zhu acknowledges the funding from the University of Houston Advanced Manufacturing Institute, University of Houston Division of Research, the support from National Science Foundation grant #1855147, #1950036, #2141674, US Department of Education grant P116S230007, and US Department of Agriculture grant #13111855, #13424031, and National Academy of Science grant #200011064 to the University of Houston.

References

[1] "Recommendations for Strengthening Amercian Leadership in Industries of the Future," The President's Council of Advisors on Science and Technology, , 2020.

[2] Dawn Tilbury, "Industries of the Future," National Science Foundation, 2020. [Online]. https://www.nsf.gov/attachments/300069/public/ENG_AdCom_Industries_of_the_Future_2020_Spring-508.pdf

[3] Livebinders. [Online]. http://www.livebinders.com/play/play?id=1130191

[4] TEA. Science, Technology, Engineering, and Mathematics at TEA. [Online]. https://tea.texas.gov/about-tea/laws-and-rules/texas-administrative-code/19-tac-chapter-130

[5] TEA. Science, Technology, Engineering, and Mathematics. [Online]. https://tea.texas.gov/sites/default/files/ch112c.pdf

[6] TEA. Science, Technology, Engineering, and Mathematics at TEA. [Online]. https://tea.texas.gov/about-tea/laws-and-rules/texas-administrative-code/19-tac-chapter-111

[7] National Academy of Sciences, *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington DC: National Academy Press, 2007.