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Engaging Secondary School Teachers in Engineering Design: Lessons Learned and Assessment of a Research Experience for Teachers Program*

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Early exposure to engineering research and design experience is crucial for students as they enter college. However, this has been limited to the secondary school curriculum, as the majority of secondary school teachers lack the engineering background and experience. Addressing this challenge, this paper presents an engineering research experience program that took place over a span of three years to better prepare 36 secondary school teachers with support from 7 engineering faculty members. This program provides the teachers a broad overview of engineering design enhances their hands-on design abilities, and educates them to translate their learnings from engineering design experiences to lesson plans for their respective classrooms. Through the numerous feedback surveys, reflection sessions, lesson plans designed, outreach and dissemination activities, it was evident that 36 participant teachers were able to gain a better understanding of engineering design, enhance their respective classroom instructional modules, and improve their overall teaching effectiveness in secondary schools.

Keywords: engineering fundamentals; K-12 outreach; project-based-learning; secondary-school curricula; teacher education

1. Introduction

Increasing performance and enthusiasm of secondary school students in engineering have been a rising challenge for engineering educators. Responding to this call, numerous educators have created programs to train more and better students. Roehrig et. al [1] has shown that it is vital to reach out and better expose students to science and engineering concepts while in their K-12 schools. The National Academy of Engineers recommended that engineering education standards be infused and mapped into existing core content standards in K-12 programs [2]. Accordingly, several schools have responded by agreeing to update the K-12 content per the Next Generation Science Standards (NGSS) [3]. However, research shows that lack of exposure and experience to engineering severely limits the K-12 educators' influence on STEM learning [4]. The majority of the K-12 science and mathematics educators have content knowledge in their respective domains, but just a superficial knowledge of engineering, leading to a superficial understanding of engineering concepts in their respective students.

Engineering practices as defined in the NGSS include defining problems, developing models, planning investigations, analyzing data, using mathematics, information technology, or computational thinking, designing solutions, and engaging in argument from practice [2]. A clear understanding of these concepts among the in-service teachers (ISTs) and pre-service teachers (PSTs) translates to a better understanding among the K-12 students [5]. As these ISTs and PSTs have the most influence on K-12 student education, it is vital to provide them with the respective engineering education and professional development opportunities. Key factors to be considered while designing these professional development programs include (i) active engagement through hands-on engineering design; (ii) inclusion of platform to collaborate, share, and exchange best practices; (iii) collegial interactions with college level educators, and (iv) active participation in pedagogy based workshops. Further, these professional programs need to respond swiftly to rapidly evolving educational system [6].

Two engineering concepts that have seen unprecedented progress over the past few years are electronics and programmable devices, allowing designers to accomplish set tasks at a much rapid rate. Simultaneously, the complexity in learning curve for these concepts has reduced profoundly through an abstract representation of engineering problems [7–10]. This provides an opportunity for the secondary school teachers to teach electrical and computer engineering principles such as circuit design, fundamentals of programming, optics, types and applications of sensors and actuators, etc.

Building upon this progress and recommendations from the Council of Chief State School Offi-

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cers report [11], the presented Research Experience for Teachers (RET) program at Central Michigan University (CMU) has been designed with a key focus on several pedagogical elements including active learning, coherence, content focus, duration, collaboration, and collective participation [12]. Overall, this paper is organized as follows. Section II presents the theoretical foundation and previous work on teacher preparation programs in engineering disciplines. Section III presents a description of the teacher preparation program, including a sample of engineering research/design based projects completed. Section IV presents an evaluation of the program through pre— and post— participant perceptions, and feedback surveys, and Section V draws conclusions.

2. Background

Several universities have created scholarship and summer bridge programs to better prepare the students before they enter college. While these programs have been partially successful, the impact of these programs has not been significant. Accordingly, engineering educators are now required to play active and prominent roles in student preparation before they start college. As ISTs and PSTs are often the first sources of information and education for the K-12 students, it would be most efficient to train these teachers in engineering disciplines, so they could better prepare these students for college. Simultaneously, the requirement for such teacher preparatory programs in engineering is profound as a majority of ISTs and PSTs have knowledge in science disciplines, but just a superficial knowledge and exposure to engineering disciplines and the engineering design process.

Identifying the needs and challenges in preparing the current (IST) and future (PST) K-12 teachers in engineering, several universities have implemented appropriate programs. The physics RET program at the Georgia Institute of Technology shows that teachers improved their ability to encourage high school students to pursue science or engineering degrees [13]. Vanderbilt University has implemented a RET program, where ISTs engaged in intensive engineering research project under the supervision of an engineering faculty, and also taught how to translate their learnings into K-12 lesson plans [14–16]. A similarly common program model is that used by Southwest State University's Science/Math/Technology Education Institute: summer research with lesson development for the following academic year [15–17]. Clemson University engaged teachers in polymer research [18]; Tennessee Tech University teamed an IST, PST, ES, and faculty member to work on manufacturing research [19]; and the University of Dayton teamed K-12 teachers with industrial or community sponsors for team-based engineering design projects [20]. Texas A&M University designed a program with a primary focus on providing an exposure of engineering disciplines to K-12 students [17], leading to higher student recruitment in engineering. University of Pittsburgh [21] presented a RET program where ISTs engage in a research project and implement their learnings in their respective classrooms. The Marine Ecology for Teachers program at Florida State University required teacher applicants to provide a videotape of an inquiry-based lesson, so as to assess what the teachers viewed as inquiry [22]. Outside of RET programs, teachers can also find professional development workshops on engineering, such as those analyzed by Avery and Reeve who make several recommendations based on their findings [23].

Although these teacher preparatory programs in engineering differ by their unique activities, they share the same goal of better preparing the future engineering workforce, through the school teachers. While each of these programs was beneficial to a certain extent, they fall short in two categories, limited follow-up activities to translate engineering research experience to a K-12 classroom; and no demonstration of correlation between engineering projects and NGSS. Addressing these limitations, and with a focus on efficiency, the proposed RET program has been designed through (a) engaging participants in cutting-edge engineering design and/or research project in electrical and computer engineering (ECE) through a vibrant team of engineering faculty mentor, IST, PST, and undergraduate engineering student; (b) developing skills and abilities of participants related to their roles as education leaders, curriculum developers, and assessment designers; (c) establishing academic year follow-up mechanisms to ensure implementation of newly developed curriculum modules with an emphasis on ECE; (d) disseminating findings to other educators through publications; (e) outreach event to engage secondary school students in ECE engineering disciplines.

3. RET Program

3.1 Program description

Most secondary school teachers are not trained to incorporate engineering concepts into their curriculum, presenting a huge gap of limited engineering curricular content in secondary education [24]. Comprehensive educational and professional development programs for ISTs and PSTs are necessary and should be designed to educate teachers in fundamental engineering concepts, and help trans-

Table 1. Schedule of orientation activities during week-01 of RET program

Monday	AM	Welcome RET Participants; Greetings from Campus Representatives; leadership team presents an overview of program goals, objectives, components, and expectations; Participants describe their background, previous research experiences, and expectations from the RET Site program; conduct pre-program assessment
	PM	Leadership team describes the general process of engineering research, effective communication methods; tour CMU facilities including Park Library, Bovee University Center, faculty research laboratories, computer facilities; Research presentations by faculty mentors; Welcome Reception
Tuesday	AM	Laboratory safety practices training; half in classroom, half through hands-on practice
	PM	Participant experience developing standard-compliant curriculum modules from research experiences; team building
Wednesday	AM	Previous participants present strategies and lessons learned in panel discussion
	PM	Background on research projects; safety training for appropriate research projects
Thursday	AM	Understanding science and engineering practices
	PM	Engineering research project
Friday	AM/PM	Engineering research project; weekly program reflection

late their learnings to the secondary school curriculum. Key factors identified for professional development of ISTs and PSTs include engaging them in cutting edge engineering topics through hands-on activities, assessment and observation of learning, exchange of ideas and best practices, build upon teachers' current work with students and provide support through coaching and technical support for problem-solving.

Building upon this rationale, the presented six-week RET program began with a three-day orientation as presented in Table 1. This included participant introductions and their respective experience in STEM, coaching on collaborative learning, engineering programs at CMU, engineering design process, presentation of engineering projects by faculty mentors, and selection of teams for active engagement in research. With hands-on engineering design/research being the fundamental skill participants were being introduced through this program, participants were grouped in teams (one IST, one PST, one engineering student, and one) engineering faculty), and immersed in an intensive engineering project for 25 hours per week starting week-02 as presented in Table 2. In order to encourage critical thinking and collaborative learning each week, teams were required to share their research findings, explain how they intend to translate these learnings to their respective classrooms for instructional purposes. While each group and project had diverse deliverable requirement and participants worked towards them, all participants were introduced and required to follow the engineering design process of identifying the need and constraint, research the problem, identify and develop multiple solutions, select the best solution, build, test and evaluate the prototype, communicate the solution, and redesign as necessary. With a focus on highlighting significance of ECE disciplines in the community, few of the project's participants were involved through the RET program include, localization of an indoor mobile tour guide robot, autonomous waste sorter for a recycling center, fabrication of micro-scale sensors, teleoperation robots, computer vision based space perception and navigation assistance etc.

Table 2. Schedule of activities during week-02 to week-06 of RET program

Monday	AM	Engineering research project
	PM	Professional Learning
Tuesday	AM	Engineering research project
	PM	Professional Learning
Wednesday	AM	Engineering research project
	PM	Professional Learning
Thursday	AM	Engineering research project
	PM	Professional Learning
Friday	AM	Engineering research project
	PM	Tour research labs, weekly program reflection

As professional learning is also important to engineering design for the secondary school teachers, they engaged in extensive seminars and workshops spanning a diverse range of topics. These include educational technology, effective teaching, next generation science standards, time management, collaborative learning, critical thinking, classroom flipping techniques, and others as identified by participants on a weekly basis. In order to encourage collaborative learning, participants were engaged in weekly reflection sessions, where each team presented their respective learnings, sought feedback from others, and discussed how these learnings would be translated into lesson plans in their respective classes.

One key and effective component of the RET program is a translation of teacher's engineering learnings towards the development of lesson plans for their respective classrooms. Accordingly, these participants engaged in several coaching sessions led by an educational consultant, who helped them better understand the correlation between engineering concepts and the respective school science and math standards and concepts such as motion of objects, forces and motion, forms of energy and energy transformations etc., Building upon this understanding and support from the engineering faculty, each teacher participant were able to design lesson plans, including but not limited to series and parallel circuits for voltage and current selection, design of astable multivibrator to mimic pacemaker operation, rotational motion and torque of an automobile during incline, smart-phone based digital microscope to relate function to structure etc.

3.2 Engineering design projects & curricular alignment

Design has been a central part of engineering education due to its profound influence and has been ubiquitously adopted by almost every engineering program at the college level. While several studies [17, 21, 22] have presented ways to incorporate engineering into K-12 classrooms, they have done so in an ad-hoc manner, with minimal effort on ensuring alignment with respective secondary school science standards. Identifying significance of design, the NGSS presented a three-dimensional framework, with eight steps in scientific and engineering practices that align well with the engineering design process of identifying the need and constraint, research the problem, identify and develop a possible solution, select the optimal solution, build, test and evaluate the prototype, and communicate the solution. Focusing on these design elements, the teacher participants actively engaged in several ECE focused design projects. Building upon this technical foundation, with support from a curriculum specialist, the teacher participants have designed lesson plans per the NGSS three-dimensional framework.

One of such ECE design projects in the CMU RET program is the *design of space perception and haptic feedback system for the visually impaired* as in Fig.1 [25]. The engineering design process for this project includes (i) identifying the need for navigation assistive devices for the visually impaired and constraints of portability, low power usage, and providing user feedback; (ii) research the problem through literature search, classify the sub-systems; (iii) identify diverse hardware for space perception such as using ultrasonic sensors, stereo vision cameras, Microsoft Kinect sensor; and feedback actuators such as Bluetooth headset, haptic actuators in a waist belt and gloves; (iv) select the best solution of Kinect sensor and haptic gloves through customer needs based ranking; (v) building the prototype; (vi) test and evaluate the prototype using statistical design of experiments, and (vii) communicating the solution to peers in the scientific community. Detailed technical information is beyond scope of this manuscript as they have been published, and the reader is referred to [25].

Centered on this design experience, teachers learned fundamentals of the circuit design using passive and active components, designed H-bridges to activate tactile motors, fundamentals of programming an embedded system, types of sensors, space perception, and kinematics, etc. Building upon this technical foundation, a lesson plan was designed to demonstrate the relationship between the potential and kinetic energy and their respective transformations, as in Fig. 2. The teacher programmed this system to track a ball position on the ramp using infrared sensors, calculate it instantaneous potential and kinetic energy, and activate appropriate number of LEDs. Implemented in a secondary science classroom, this lesson plan aligns with the NGSS of PS2A-forces and motion, PS3A-definitions of energy, PS3C-relationship between energy and forces.

The *design of a portable autonomous waste sorter* as in Fig. 3 [12] is one other ECE based project in the RET program. While working on this project, teacher participants learned how to define an engineering problem and identify deliverables; program microcontroller to interface sensors and actuators; evaluate performance of sensors for applications such as space perception, material detection, and actuators for user feedback, material transport; design and analyze an embedded system; analyze and interpret data using mathematics and computational concepts; communicate findings through presentation of design solutions and evaluation methods.

Development of a sweat-based miniature hydration sensor as in Fig. 4 is another ECE based project

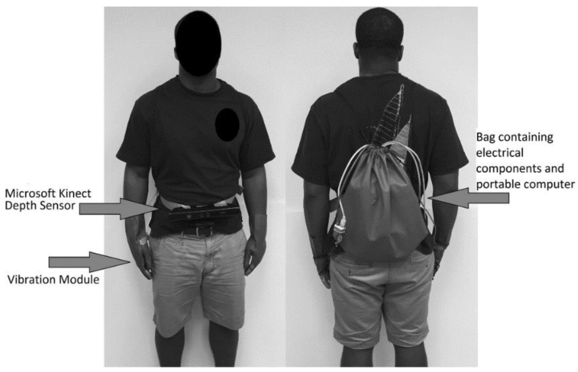

Fig. 1. Space perception and haptic feedback system.

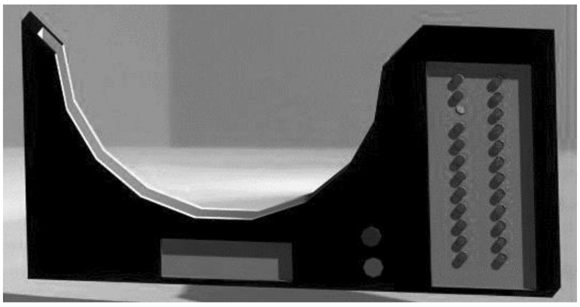

Fig. 2. Technology aid to demonstrate translation between kinetic and potential energy.

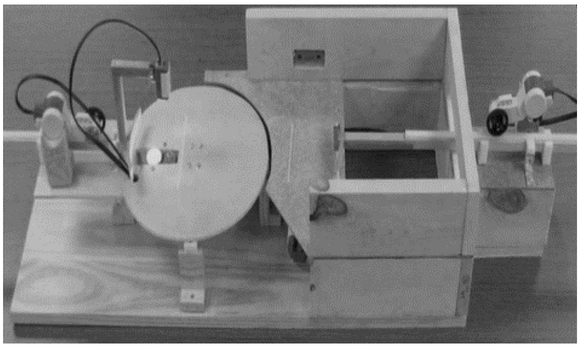

Fig. 3. Design of a portable autonomous waste sorter using LEGO Mindstorms kit and shop wood.

in the RET program. The engineering design process for this project include (i) identifying the need for hydration detection to optimize peak performance in athletes and soldiers; (ii) extensive literature review on existing devices and materials available to build a hydration sensor; (iii) build a prototype incorporating a commercially available sweat collector and a stand-alone sodium sensor; (iv) analyzing the prototype for advantages and shortcomings for optimization (v) designing straps and sensor combinations for performance optimization; (vi) identifying the ideal solution for 3D printing a custom sweat collector utilizing plastic polymer based microfabrication, evaluating system performance through scientific procedures; (vii) presenting the research findings to faculty peers for constructive feedback. Detailed technical information is beyond scope of this manuscript as they have been published, and the reader is referred to [26].

Centered on this design experience, teachers learned fundamentals of optics, conductivity, and resistivity, leading to exploration of circuit design, data collection, and analysis using engineering software such as MATLAB. Building upon this technical foundation, the teacher participants designed a microscope as in Fig. 5 to educate secondary school students on how diverse engineering concepts can be infused to learn about different science concepts, such as the function of the structure at various organization levels of life. This digital microscope project helped teachers and is currently helping K-12 students (multiple versions of these stages were deployed into teachers' respective classrooms) understand the physical dimensions at milli-, micro-, and nano-scale.

One of the strong components of the RET program was developing lesson plans for secondary school curriculum. In year-1, the curriculum development specialist introduced NGSS to participants and demonstrated the design of NGSS-compliant lesson plans. Each PST developed a basic lesson, which PSTs and ISTs refined prior to implementation in the IST's classroom during the academic year. While partially successful, a lack of trial runs prior to implementation has presented minor challenges. Accordingly, in year-2, each lesson developed by PST went through a trial run with ISTs as students. Feedback obtained was used to refine the lesson, which was then implemented in the classroom accordingly. During year-3, in order to provide even better instructional delivery, participants designed and fabricated physical instructional design aids to support their lesson plans. These design aids have proven to be a great resource as students could visually see the operation of a STEM concept, and learn effectively. Over the duration of these three years, 26 lesson plans have been developed and incorporated into the secondary school curriculum. A sample of these lesson plans includes: energy transformation; newton's 2nd law for uniform circular motion; studying reactions in thermochemistry; smart digital microscope to relate function to structure; Rube Goldberg machine to study motion and reaction; fruit batteries; electric circuits through water etc.

4. Results and discussion

One of the primary outcomes from this RET program is the development of engineering project-based lesson plans for middle and high school curriculum. Through the professional development activities, ISTs and PSTs were introduced to the NGSS and were taught how to design NGSS-compliant lessons for the secondary science curriculum. Accordingly, under the guidance of engineering faculty, the PSTs developed a lesson plan and implemented it in the IST's classroom during the fall semester. Feedback obtained was used to refine the lesson plan and enabled broader adoption in the other ISTs classroom. Further, to provide better instructional delivery, participants designed and fabricated physical 3-dimensional (3-D) models to support their lesson plans. These 3-D models have proven to be a great resource as students could

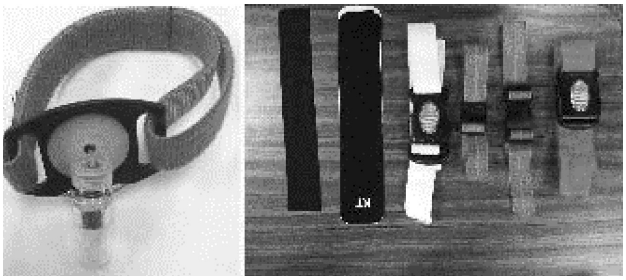

Fig. 4. Proof of concept—hydration sensor and its iterative concepts as developed by RET participants

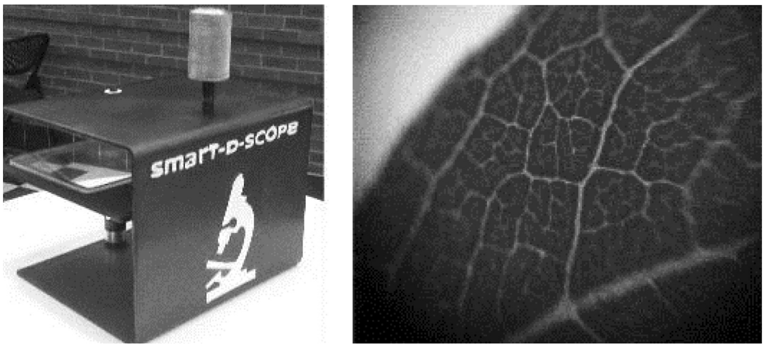

Fig. 5. Technology aid (Smart microscope where a user's smartphone serves as a microscope) and sample photograph of a leaf taken from the smartphone.

visually see the operation of an ECE concept, and learn effectively. Sample lesson plans developed for middle school curriculum by the participants include energy transformation; Newton's 2nd law for uniform circular motion; smart digital microscope to relate function to structure; Rube Goldberg machine to study motion and reaction; fruit batteries; electric circuits through water etc.

In order to reach out to a broader range of middle-school students and introduce them to engineering design activities, while at the same time provide an authentic teaching experience for the PSTs, numerous outreach activities have been conducted through this RET program. The ECE concepts taught during these design activities include voltage selection in DC circuits, switching transistors for control of DC voltages and motors, quantitative reasoning through the combinational circuit design, diode operation and applications for robust system design, estimating buoyancy for flotation, etc. Further, in order to introduce students to methods through which a cellphone could be used to enhance their learning while at the same time showcase the diverse opportunities available in college, a one-day STEM camp was hosted on the university campus. During this camp, 150 middle-school students were exposed to the engineering design process and were engaged in a team-based hands-on design activity to build a smart digital microscope using plexiglass, wood, cell phone, and other household material within a couple of hours. This design activity proved to be highly successful as evident through the numerous completed digital microscopes, and broader dissemination of findings through 1000+ Twitter tweets and retweets, 20,000 hashtag usage, reaching out to 28,142 people, and leaving 150,282 impressions in one day.

Formative and summative assessment of this RET program has also been conducted through pre- and post-perception surveys, weekly surveys, interviews, and interactive discussions. The pre- and post-survey was provided to all teacher participants with the statements in Table 3, and are evaluated on a scale of 1–5 (1-strongly disagree, 5-strongly agree). Results from these perception survey are presented in Fig. 6 for ISTs and Fig. 7 for PSTs. Through extensively engaging in engineering design, participants were able to realize that engineering skills could be implemented and nurtured at an abstract level without requiring extensive education. In the pre-survey, PSTs stated that memorization is crucial while learning basic STEM concepts. Accordingly, engineering activities in the RET program have been designed to follow the four steps of effective learning such as remember, understand, apply, and analyze, per the revised Bloom's taxonomy. Effectively, by the end of RET program, participants were able to realize that understanding is more crucial and effective than memorization in engineering concepts.

Table 3. Statements in pre- and post-survey to quantify variation in teacher perceptions from RET program

No.	Statement
1	Amount of education required applying engineering concepts
2	Importance of memorization to understanding basic STEM concepts
3	Importance of teaching students to think/communicate about science
4	Importance of student confidence in applying engineering
5	Confidence in teaching science concepts effectively
6	Confidence in teaching engineering concepts effectively
7	Confidence in answering student questions related to science
8	Confidence in answering student questions related to engineering

As the significance of effective communication has been imparted in the PST's curriculum, their perception of scientific communication has been very high. However, a significant difference has been observed in the ISTs. Through working in diverse teams of individuals with different educational background, the ISTs realized the significance of effective communication as they had to periodically complete the task by the respective timeline. In the pre-survey, participants stated that they are not highly confident to answer student questions related to engineering. Through this RET program, participants were able to learn and better understand engineering concepts, communicate effectively through publications and presentations, engage in a scientific dialogue with peers, and gained confidence in being able to answer questions related to engineering, as evident through the post-survey.

In addition, in the post-survey, teacher participants were also asked to provide their perceptions on meeting the RET program objectives. Evaluated on a scale of 1–5 (1-Not accomplished, 5-Accomplished), a summary of the results is presented in Table 4. This data demonstrates that the RET program was able to establish a successful relationship between the secondary school teachers and university engineering faculty, leading to the effec-

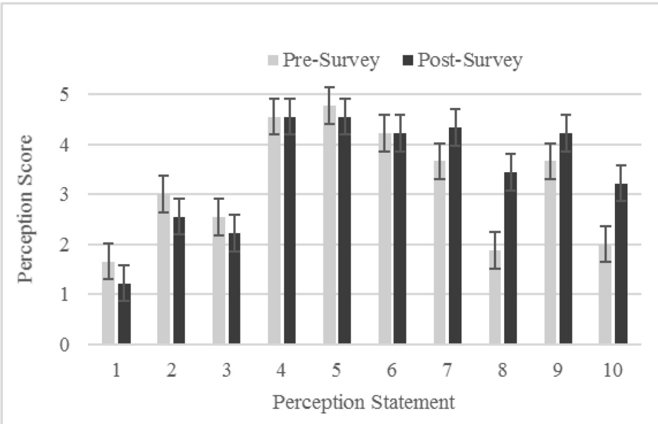

Fig. 6. Improvement in IST perceptions as related to science and engineering as a result of RET program (n = 21).

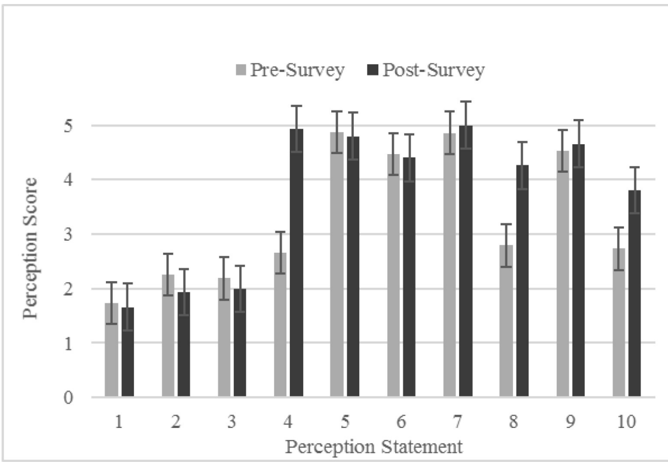

Fig. 7. Improvement in PST perceptions as related to science and engineering as a result of RET program (n = 15).

Table 4. Participant perception of meeting RET program objectives (n = 36)

	Year-01		Year-02		Year-03	
Objective	**IST**	**PST**	**IST**	**PST**	**IST**	**PST**
Working relationship with engineering faculty	4.7	4.4	4.1	4.7	4.7	4.8
Develop leadership, curriculum development, assessment skills	4.4	4.4	4.3	4.0	4.0	4.2
Development of STEM-based instructional materials	4.0	4.2	4.2	3.7	3.8	3.6
Understanding when and how to use scientific language	3.7	4.2	3.7	4.5	3.0	4.4
Coaching on curriculum development with new standards	3.5	4.2	4.2	3.7	4.4	4.8
Professional development on effective teaching	2.7	4.8	3.2	4.0	3.5	4.7

Table 5. Engineering faculty evaluations of participant teacher competencies in critical thinking skills (n = 7)

No.	Competency Dimension	M	SD	SE_M	% Met
1	Brainstorming Solutions	3.57	0.78	0.29	100%
2	Designing within requirements	3.42	0.78	0.29	100%
3	Troubleshooting Errors	3.28	0.95	0.36	86%
4	Calibrating the system	3.33	0.51	0.21	100%
5	Analyzing Tradeoffs	3.57	0.97	0.37	86%
6	Devising Workarounds	3.42	1.13	0.43	86%
7	Prototyping	3.66	1.03	0.42	100%
8	Engineering Design Process	3.14	0.37	0.14	100%
9	Mathematics Concepts	3.57	0.53	0.20	100%
10	Communicating Concepts	4.00	0.81	0.31	100%

M = Mean, SD = Standard deviation, SE_M = Standard error in mean.

Table 6. Engineering faculty evaluations of participant teacher competencies in ECE skills (n = 7)

No.	Competency Dimension	M	SD	SE_M	% Met
1	Design/build/troubleshoot a circuit	3.0	0.44	0.16	80%
2	Identify and utilize sensor for data collection/analysis	3.5	1.03	0.38	83%
3	Utilize microcontrollers	3.33	1.16	0.43	67%
4	Fundamental Programming	3.85	0.69	0.26	72%
5	Sub-system integration	3.20	1.37	0.51	67%

M = Mean, SD = Standard deviation, SE_M = Standard error in mean.

tive design of engineering-based curriculum in secondary schools. Participants stated that their ideas on best practices and approaches to content have been heavily influenced by the interactions with engineering faculty members. Through extensive design experiences, and developing skills and abilities in curriculum development and assessment, participants stated that they created a model that made a difference in understanding for their respective students. As a result, participants also stated that their respective secondary school students became more interested in engineering, and they now have the background knowledge to mentor students accordingly. Overall, participants stated that the presented RET program had a positive influence towards enhancing their classroom instructional practices and were able to better prepare their secondary school students for a career in engineering.

One other method used in the RET program evaluation is through university engineering faculty feedback on teacher competencies in critical thinking skills and abstract level ECE skills at the end of the program each year. An advantage of this evaluation method is that it relies on the judgment of engineering project experts, rather than participant self- perceptions. Accordingly, at the end of each year, engineering faculty members were provided a survey to evaluate teacher competencies in both critical thinking skills and ECE skills as presented in Table 5 and Table 6. In this survey, engineering faculty assigned a score of "1" or "2" on the competency if the participants were unable to follow instructions and/or apply the respective skill to their projects. A score of "3" was assigned if participants were judged to be able to recognize the need for applying this competency skill, and a score of "4" was assigned if participants were able to recognize the need for and apply this skill proficiently. Finally, a score of "5" indicated that participants were strongly able to both recognize and understand the competency beyond simply following instructions. A summary of the competencies and results are presented in Table 5 and Table 6,

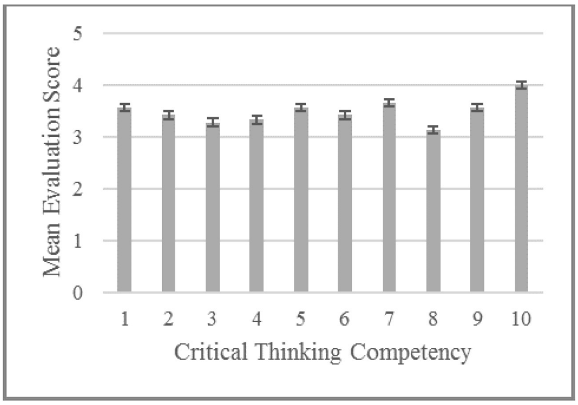

Fig. 8. Engineering faculty evaluations of participant teacher competencies in critical thinking skills (n = 7).

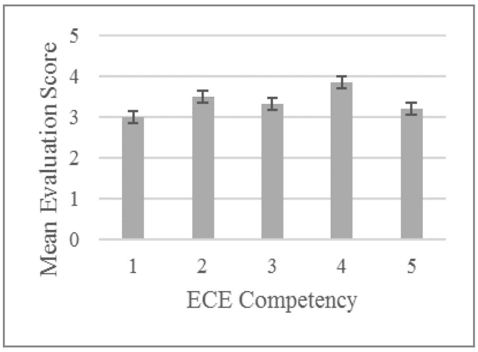

Fig. 9. Engineering faculty evaluations of participant teacher competencies in ECE skills (n = 7).

with graphical representations in Fig. 8 and Fig. 9. Using these scale anchors as a reference, a score of '3' or higher was treatment as the requirement for acquiring a competency. Results show that participants met or exceeded expectations across every dimension.

While the mean scores met the expectations, the last column in Table 5 and Table 6 show that some participants did not meet the expectations. This is acceptable as the participants are taught to acquire the respective skill at an abstract level so as to better prepare their secondary school students in engineering education, but not become experts in engineering within a span of few weeks. Through the broad range of ECE focused lesson plans and technology aids newly designed by these teachers, it is evident that RET program has a positive influence on increasing learning of secondary school students in engineering.

5. Conclusion

This paper has shared the experiences and observations of establishing a collaborative research platform for active engagement of 36 secondary school teachers and 7 university engineering faculty members. Leveraging an integrated and inclusive framework and using several pedagogical methods, the presented research experience for teacher program was able to better educate and prepare them for engineering design. Additionally, by engaging in engineering research projects, teacher participants were able to become familiar with key electrical and computer engineering skills such as design/build/troubleshoot a direct circuit, identify and utilize a sensor for data collection/analysis, utilize microcontrollers, and learn fundamental programming to control an embedded system. This learning experience combined with the support from a curriculum development specialist helped teacher participants to design, test, and implement several new lesson plans that are in alignment with NGSS, contributing towards the enhancement of K-12 education.

Overall, this research contributes to the literature by filling existing gaps in engineering education by providing a collaborative platform for secondary school teachers and university professors for the education of future engineers.

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