Board 369: Research Experiences for Teachers (RET): Engineering for People and the Planet as Inspiration to Teach Integrated STEM

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RET Program Overview

The United Nations Sustainable Development Goals (UN SDGs) are the intellectual focus for a Research Experience for Teachers (RET) Site in Engineering at Worcester Polytechnic Institute (WPI). The relevant and meaningful contexts of the UN SDGs (Figure 1) allow middle and high school teachers and their students to make connections between research in a university lab setting to Science, Technology, Engineering, and Math (STEM) concepts and skills in their classroom. Each teacher participating in the RET program develops an "Integrated STEM" [1,2] lesson plan inspired by their research experience connected to the UN SDGs.

High-quality, "Integrated STEM" education[3] (captured by the quote[4] below) at the pre-college level is a pressing priority for the United States,[5,6] and providing access to all students is paramount for broadening the participation in engineering.[7] A high leverage point in this effort is equipping current/future middle and high school teachers[8] in underserved areas with knowledge, skills, confidence, and support to provide high-quality STEM education for their students.

"STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to [succeed] in the new economy." (Tsupros, 2009) [4]

Figure 1. The UN Sustainable Development Goals provide real-world context for Engineering for People and the Planet, as well as teaching and learning of Integrated STEM aligned with Next Generation Science Standards. The UN SDGs are highlighted in each of the RET Site's research projects.

A six-week, full-time and in-person summer program has been running for the past 2 years with a cohort of 10 teachers at the secondary level each year and with a mix of pre-service and in-service teachers. A pair of teachers (usually a pre-service and an in-service teacher) work together in a research lab with a WPI faculty member and graduate student mentors. Throughout the summer, the RET teachers participate in two different weekly professional development series – one focused on supporting the research process ("Tuesday research coffee sessions") and one on translating the

research experience into a classroom lesson ("Wednesday morning teacher PD"). In addition, the teachers gather as a cohort for activities such as Friday group lunches, lab and campus tours, speakers, an industry panel and networking session, and other special events. The summer culminates with a RET Poster Symposium and the RET program continues into the academic year with quarterly meetings to report on the implementation of their research-inspired lesson plan in their classroom.

Continued engagement with the research mentors can result in the WPI researchers visiting classrooms or inviting the teachers back the following summer. The final deliverable for the RET participants is to finalize their lesson plan for posting on an online repository of teacher resources and to present their research experience and lesson to a broad audience (which includes the new RET teacher cohort starting that summer) at a Spring event for PreK-20+ educators. The long-term goal of the RET Site is to deepen the relationship[9] of WPI and local public school STEM teachers in order to develop a robust regional STEM Ecosystem[10] with high-quality, purpose-driven STEM education that engages students to develop real-world problem-solving skills.

The RET Site objectives (Figure 2) include:

- Increasing the RET participants' confidence and knowledge about how Engineering can benefit People and the Planet (e.g., UN SDGs), the Engineering Design Process (EDP), and Integrated STEM.

- Fostering a community of educators for mentoring and support among the WPI pre-service teachers, the Worcester area in-service teachers, WPI faculty and graduate students, industry partners, and the STEM Education Center at WPI for continued engagement.

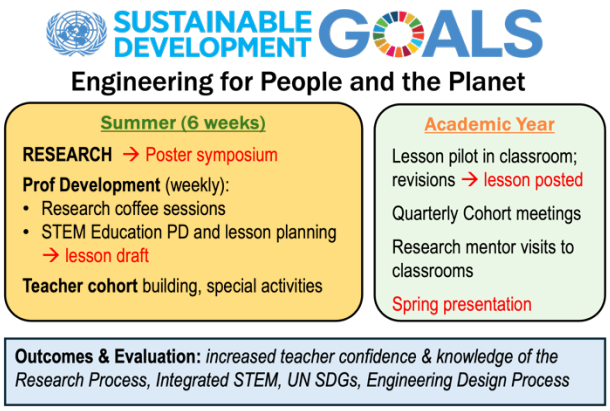


Figure 2. Overview of the RET Site components and outcomes.

Teacher Recruitment, Selection, and Participation

Ten (10) teachers comprising of both pre-service and in-service middle or high school teachers have participated in each cohort over the two years of the NSF RET grant. Employing the same strategies and best practices in hiring faculty from underrepresented groups,[11,12] we developed an inclusive announcement, advertised widely, did targeted recruiting through contacts with school principals and leaders, and developed a rubric for the RET participant selection in attempts to recruit and select teachers from underrepresented groups. The selection rubric prioritized teachers with mindsets of providing inclusive, high-quality STEM education (with a strong engineering component) and being a role model to pre-college students of diverse backgrounds. Other factors included whether they were teachers at Title 1 schools (or from schools that our Teacher Preparation Program partnered with), how they saw themselves contributing to a cohort and community with other educators, and their commitment to participate in academic year activities. Table 1 lists the number and demographics of the applicants and participants. The RET staff team

assembled the research group assignments based on the teacher project preferences stated on their application and creating a balanced lab group.

Table 1. Number of applicants and number of selected participants (and those from underrepresented groups and Title 1 schools)

Year	# applied	# accepted	# URG apply	# URG particip.	#Title1 schools	# Title1 schools
2022-23	25	10	4	2	13	4
2023-24	23	10	3	2	9	4

Over the 2 years of the RET Site, the participants represent 5 middle school and 13 high school teachers, and 2 repeating teachers. The subject areas of the teachers have been math, middle school general science, special education, computer technology, biology, chemistry, and physics. The schools of the RET participants have also varied in sizes and types: large urban districts, vocational/technical schools, and suburban schools.

Qualitative data from our RET Site collected by an external evaluator indicates how the mix of teachers at different levels is an asset of the program and has been enjoyed by the RET participants. The wide diversity of the RET participants turned out to be a highlight of the program for many of the teachers. Teacher cohort building and community was fostered through group lunches and additional activities (e.g., coordinated lab visits, behind the scenes tour of a local science museum, and industry panel). The teachers enjoyed learning from each other and being exposed to a range of different research topics and STEM disciplines. The in-service teachers enjoyed sharing their teaching experiences and advice with the pre-service teachers, and they found the pre-service teachers' younger perspectives refreshing and rejuvenating. The RET experience also helped the pre-service teachers feel more confident and excited about entering the classroom. The teachers appreciated the different perspectives of their colleagues at different grade levels, schools, and disciplines during the PD sessions. The cohort of teachers enjoyed being together (Figure 3) and several teachers keep in touch with one another throughout the academic year.

Figure 3. The RET teacher cohort and staff enjoy visiting a local science and nature museum.

Research Projects – UN SDGs

Six weeks of authentic research takes place in 5 different faculty labs each summer at Worcester Polytechnic Institute (WPI) under the mentorship of faculty and their graduate students or postdoc. Examples of the research projects include "Photocatalysis for Clean Energy and Environment," "Genetically Engineering Plasmid DNA molecules to address Tuberculosis Antibiotic Resistance," and "New Water-Based Technology for Plastic Recycling."

The faculty mentors are from both the School of Arts & Sciences and the School of Engineering. The UN SDGs and interdisciplinary research are common at WPI, and the research projects are able to accommodate different teacher's disciplinary backgrounds. Faculty are invited to participate in the RET Site, and those who have experience with K-12 outreach or working with K-12 teachers are highly encouraged to apply. Most of the faculty who have participated as RET mentors have also been mentors for Research Experiences for Undergraduates (REU) programs at WPI. Graduate students and postdocs in the faculty research labs also assist in mentoring the RET participants. We have found that it is vital to ensure sufficient research mentor support throughout the summer, especially since the six weeks goes by quickly. Mentor training[13,14] for creating an inclusive lab environment and an RET info session to establish mentor expectations are conducted before the RET program starts.

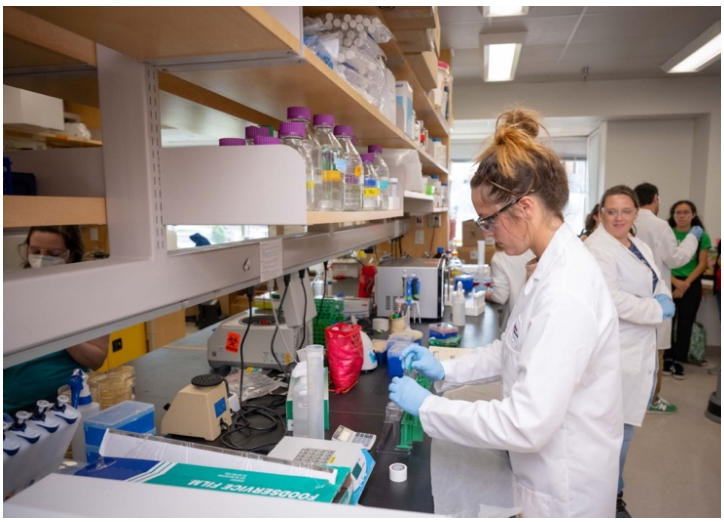


Figure 4. RET teachers are immersed in research labs for six weeks.

The RET participants become members of the lab group and attend weekly lab meetings, undergo lab safety training, and learn how to use state-of-the art laboratory equipment (Figure 4). They take data and analyze the results, and they might have to repeat multiple experiments. The research experiences are truly authentic, which can sometimes be slow or frustrating. For some experienced teachers, they might even find themselves back in "student" mode of not being the expert and being overwhelmed at the beginning of the summer.

To guide the RET participants through the research process, a weekly workshop or Tuesday "coffee sessions" (90 minutes) are facilitated by the RET Site Director and PI. With weekly assignments, the teachers are given timely milestones to make progress on their projects and to uncover any issues that can be addressed quickly. Table 2 lists some of the workshop topics and activities. In addition, the teachers create and maintain their own webpage of their research journey with weekly updates.

Table 2. Topics of the research "coffee session" workshops to guide the research projects

Week 1: **Research Proposal** with timeline; Posing a research question; Defining research goals & objectives
Week 2: Background literature reviews; Creating **webpages** to document research journey
Week 3: Ethical and Responsible research; Elevator pitches; Creating research posters
Week 4: Presenting data results; **mid-summer research presentation**
Week 5: Poster feedback session; Planning for academic year research lab connections
Week 6: **RET Poster Symposium** (open to public); Documentation and wrap up of research project; next steps (during academic year)

The closing of the RET summer program includes the RET Poster Symposium (Figure 5) that is open to the public, and the teachers' school administrators are invited. The poster session is also attended by industry partners who have just participated on a STEM industry panel for the teachers. The teachers and industry partners have a chance to network, which has resulted in guest speaker appearances in classrooms and class visits to industry tours. During the following academic year, the RET research mentors are also available to visit the teachers' classrooms.

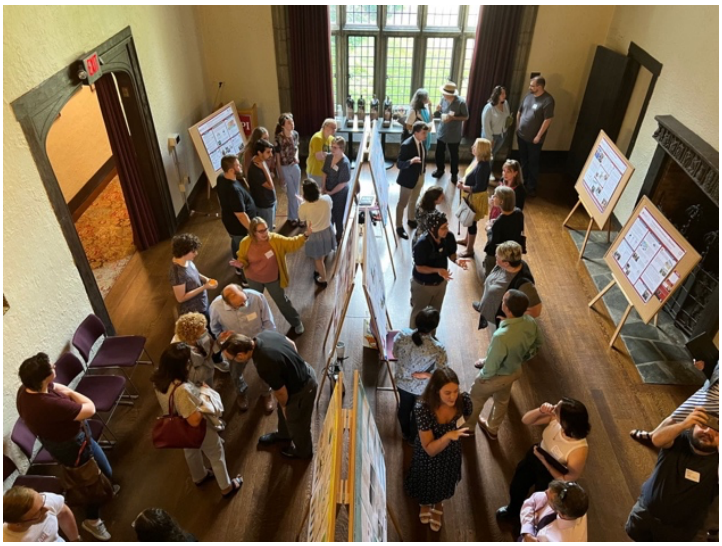


Figure 5. The culmination of the RET summer is a Poster Symposium.

Teacher Professional Development & Lesson Plans

RET participants attend a weekly ½-day professional development (PD) session (Table 3) to translate their research experience into a classroom lesson plan that aligns to state standards, as well as evidence-backed curriculum design and teaching strategies. The "Integrated STEM" lessons are inspired by the RET research projects on Engineering for People and the Planet (i.e., UN SDGs), and the lessons will help develop student skills in the Engineering Design Process (EDP), critical thinking, and creative problem solving.[15] The lesson plans address the all-too-often

student comments of *Why are we learning this?* and *What use is this for?* The UN Sustainable Development Goals provide context to bridge the apparent disconnect between focused STEM research and abstract science and math concepts to the "real world" problems that young students care about. [16]

Figure 6. Weekly teacher PD sessions are interactive and include the Engineering Design Process and developing Integrated STEM lesson inspired by their research.

The lesson plans are drafted by the end of the summer and piloted in classrooms the following academic year. With the focus on doing authentic research during the summer, the teachers felt creating a lesson plan of high-quality by the end of summer was stressful and not possible. True to the "engineering design process," the teachers revise their lesson draft plan based on the classroom implementation experience and feedback from the cohort during academic year. The finalized lessons are then presented at the STEM Education Center's Annual Spring event (Figure 7) and uploaded to be freely accessible on the RET website and other digital repositories of Teacher Resources. Once the lessons are fully developed and tested in the classroom, teachers will be encouraged and supported to submit to TeachEngineering.org.

Figure 7. Teachers present their research and final lesson plan to a broad audience of PK-20+ educators (and the next RET cohort) during the STEM Education Center's Spring event.

Table 3 lists the Professional Development and Support Sessions that are run by the STEM Education Center's Associate Director for Professional Development. She also meets with the RET participants in individual consulting sessions or "office hours" to support the lesson plan development.

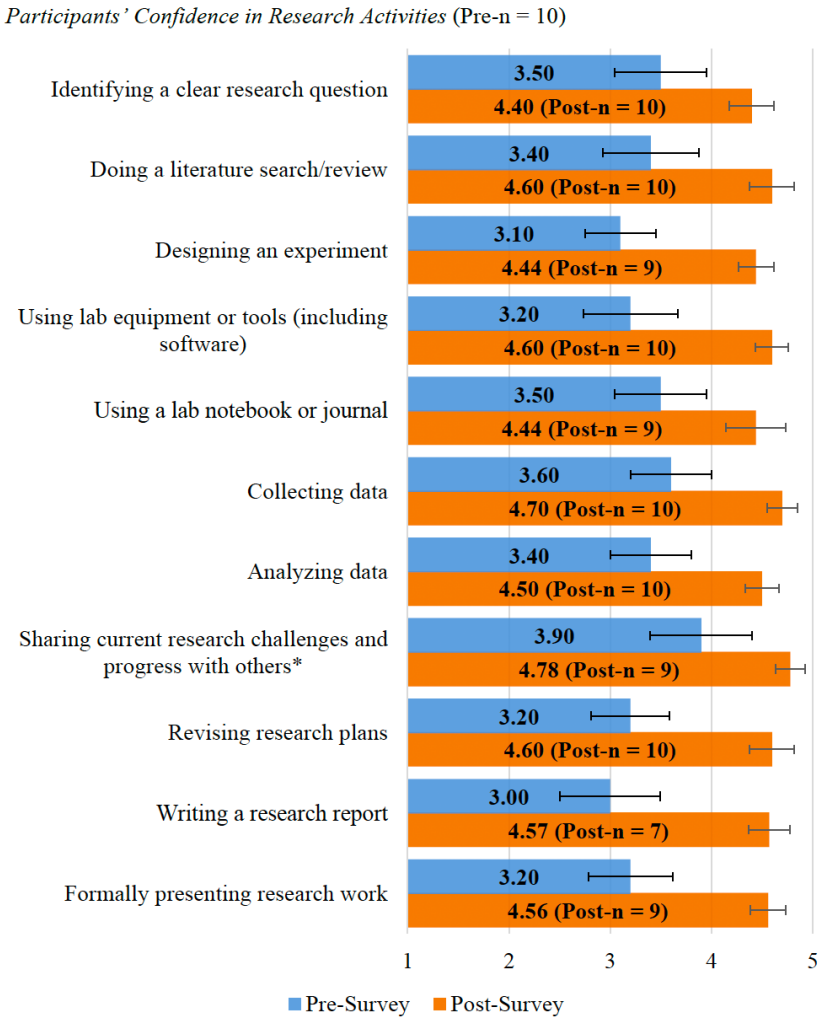
Table 3. Professional Development and Support Session Topics

Week	*Topic*	*Skills*
1	Integrated STEM	• *Unpack high quality STEM and how it relates to People & Planet (e.g., UN SDGs)* • *Review the lesson expectations and timeline, the components of a High-Quality STEM Rubric, and make connections to current practices*
2	The Engineering Design Process	• *Explore the problem-solving process* • *Make connections among Project Based Learning, problem solving and the UNSDGs*
3	NGSS & State Standards	• *Identify key NGSS/MA State Standards that tie directly to research* • *Break down standards into content and skill-based objectives for the lesson* • *Introduce lesson template*
4	Real World Problems	• *Introduce meaningful learning* • *Identify real world problems that connect to research, UNSDGs and standards*
5	Performance Assessment	• *Identify key components to high quality assessment of student learning* • *Create an appropriate performance assessment that aligns with lesson objectives*
6	STEM Equity and Inclusion	• *Identify strategies that make learning more accessible and inclusive to all students (academic level, socio-economic status, race, gender, etc.)* • *Incorporate these strategies into the lesson being developed*
Fall	Careers & STEM Literacy	• *Demonstrate how the skills developed through the research and the lesson will support all students in STEM and non-STEM fields* • *Connect current research & lesson to future careers for our students*
Winter	Lesson Share-out & Presentation Planning	• *Share successes and challenges of lesson implementation, get feedback from colleagues, and make improvements on their lessons* • *Share plans for the Spring RET Presentation*
Spring	RET Presentation	• *Present research and lesson to an audience of educators* • *Finalize lesson plans to be shared on websites*

Program Evaluation

Formative assessment is conducted throughout the summer on various aspects of the RET through surveys and regular check-ins with the teachers. Two graduate students are hired part-time to act as RET program assistants, and they help the teachers and RET staff with whatever is needed. They do weekly individual check-ins with the teachers to see how things are going and they work with the RET staff to quickly address any issues. At the end of the summer, focus groups were conducted by an external evaluator for both the teacher participants and the research mentors.

Comparisons of pre- and post-survey results about the 2023 cohort of RET participants' confidence in doing research increased after the summer on all eleven items (Figure 8).



Note. *This item is a double-barreled question.

Figure 8. Pre- and Post-survey results about confidence with different research activities.

The RET participants shared that they are bringing in the "real world" relevance to their students with an integrated STEM lens (e.g., climate change and UN SDGs) and that they refer back to their

own lab experiences (e.g., importance of measuring chemicals accurately). The research experience has made several positive impacts on the teacher participants, as well as their students. When the teachers display their research posters at their school, they report that their students ask questions and conversations are sparked. In addition, connections made during the summer with WPI research mentors and the industry panelist are being utilized.

For evaluation of the RET program, pre- and post-surveys measured the teacher's self-reported ability, confidence, understanding, and frequency of use of the Engineering Design Process (EDP), Integrated STEM, and the UN Sustainable Development Goals. Table 4 presents a range of statements for the teachers to selected about their knowledge of the concept, confidence level, and ability to implement the three defined learning objectives of the UN SDGs, EDP, and Integrated STEM. The range on one end is at the beginning stages ("I am unsure or unfamiliar with the concept.") to the other end of being a leader ("I know the concept, I have implemented it in my lessons, and could teach others how to implement it."). In between are various nuanced possibilities of the participant's knowledge and utilization of the concepts. The data in Table 4 shows a shift in responses from the beginning stages with the pre-survey towards responses at the teacher leader stages with the post-survey.

Table 4.

Participants' Knowledge & Utilization of Concepts (n = 10)

Statements	Integrated STEM		Engineering Design Process (EDP)		UN Sustainable Development Goals	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
a. I am unsure or unfamiliar with the concept.*	20%	-	30%	-	60%	-
b. I know the concept, and don't know how to implement it in my lessons.*	10%	-	10%	-	20%	-
c. I know the concept, yet don't have the confidence to implement it in my lessons.	20%	-	10%	-	10%	10%
d. I know the concept, and haven't had the opportunity to implement it in my lessons.*	20%	20%	30%	30%	10%	20%
e. I know the concept, I have implemented it in my lessons, and could use more support.*	20%	40%	60%	20%	20%	10%
f. I know the concept, I have implemented it in my lessons, and could teach others how to implement it.*	10%	50%	10%	60%	-	50%

Note. Participants could select multiple statements. * These items are double barreled questions.

The teachers also self-report that their lesson plans are more "integrated."[6] The real-world contexts of the research projects provide extensive opportunities for teachers to present "Integrated STEM" and engage their students in meaningful problem solving using the engineering design process.

The authentic research experience also fosters teacher dispositions towards inquiry-driven learning and doing science and engineering from internal motivation versus cookbook experiments.

Both teachers and mentors report that the RET Site program was well planned and executed. The teachers developed close bonds and connections, learned a lot from each other, had meaningful research experiences, and developed a sense of community. The research mentors reported that the teachers provided useful research contributions, were enthusiastic about the research, had genuine lab experiences, developed professional skills, and built good community connections. Areas for improvement include clear expectations for everyone, reducing steep learning curves, and consistency of mentoring across the labs.

With each year of the RET Site, we take feedback from the participants, research mentors, and project evaluator to make improvements. Thus far, we have received very positive comments and feel that we've fostered a supportive STEM educator community.

"This experience changed my life. I made new connections with wonderful people, worked in a terrific lab setting, and reignited my love for science that will be shared with students."
- RET participant, summer 2023

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