2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #52519

Bringing Emerging Engineering Technology into Classrooms Through a Transdisciplinary RET Program (Evaluation)

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Abstract
Emerging engineering technologies such as cellular agriculture (CellAg) and tissue engineering are becoming increasingly important for addressing societal issues, including sustainability, food systems, and ethics, yet they are largely absent from secondary STEM classes. Further, teachers often lack access to authentic research experiences and the curricular resources required to integrate such cutting-edge technologies into their classrooms. This work-in-progress paper outlines a transdisciplinary Research Experiences for Teachers (RET) program that aims to close this gap by engaging high school teachers in CellAg and tissue engineering research while also facilitating collaborative curriculum co-design. The six-week summer RET brought together high school teachers from biology, physics, engineering, and environmental science for laboratory-based tissue engineering activities, digital manufacturing, and related organized talks. Teachers created curricular modules relevant to their disciplinary settings, grounded in engineering design and prototyping, and tested chosen activities with middle and high school students at a community-based workshop. In this paper, we share our work in progress based on our (teacher) written retrospectives, curricular artifacts, and field notes from the pilot workshop implementation of the first year of the three-year program. We detail (1) the types of curricular modules we created, including low-cost engineering tools like DIY Instron machines and scaffold-based investigations; (2) the opportunities and challenges that we encountered when adapting emerging technologies for non-laboratory learning environments; and (3) our reflections on student engagement that we observed during the pilot workshop. During the pilot workshops, we observed high levels of student engagement and inquiry, but also noted time, tempo, material, and logistical difficulties. This work can provide practical insights for in-service teacher-oriented program designers and STEM teachers who want to present complex, emergent engineering technology using accessible, transdisciplinary approaches.

Keywords: Research Experiences for Teachers (RET); emerging engineering technology; cellular agriculture; secondary STEM education; transdisciplinary curriculum

Motivation

Emerging technologies, such as CellAg and tissue engineering, are revolutionizing food systems, biomedical research, and sustainability practices, yet they are rarely taught in secondary STEM schools. When students come across engineering ideas, they are frequently isolated from social applications, ethical issues, or transdisciplinary problem domains. Prior research indicates that students' interest in engineering grows when learning takes place in real-world situations that stress relevance, agency, and social effect [1], [2]. Teachers, on the other hand, face significant barriers to incorporating emerging engineering technology into their instruction, such as limited training, a lack of appropriate equipment, and uncertainty about how to adapt research practices for classroom settings [3], [4]. Research Experiences for Teachers (RET) programs provide a potential strategy for tackling these difficulties by immersing teachers in actual research while also facilitating curricular translation. In this paper, we focus on teachers' experiences as curriculum designers and translators of emerging engineering research, rather than assessing student performance.

Integrating biotechnology, sustainable engineering, and digital fabrication into secondary education has been found to increase student involvement and interest, especially when linked to real-world social concerns [1], [5]. However, these themes are frequently lacking from the K-12 curriculum due to a lack of teacher preparation and inadequate resources. RET programs have improved teacher confidence, instructional creativity, and the adoption of inquiry-based pedagogies [6], [7]. When RETs include organized curriculum design time and opportunity for reflection, teachers are more likely to apply research findings in the classroom [8]. Cellular agriculture combines biology, materials science, engineering design, ethics, and sustainability, providing a rich setting for transdisciplinary STEM study. For example, scaffold decellularization and mechanical testing give concrete examples for understanding technical restrictions, material attributes, and social repercussions [9].

This work describes a transdisciplinary RET program centered on cellular agriculture and tissue engineering as contexts for engaging teachers and students in core pre-college engineering education practices, including engineering design, materials testing, constraint negotiation, and socio-technical decision making. In this paper, we share the program's framework, the instructional materials we created, and the opportunities and challenges we faced when implementing our curriculum in a one-week summer workshop, which informs our classroom implementation iterations.

Guiding Questions

The following guiding questions inform our work in this paper:

- How and what types of curricular modules were developed after participating in the CellAg-focused RET program?
- What are the opportunities and challenges of adopting burgeoning engineering technologies for teaching and learning implementation?
- What were our learnings from implementing the program in a one-week summer workshop in an informal setting?

Program Orientation and Pedagogical Commitments

The RET was developed on the principles of cross-disciplinary STEM learning, inquiry-based education, and teacher autonomy. These commitments informed program structures such as collaborative co-design, hands-on research immersion, and space for teacher agency. These values served as a guide for program design rather than as a formal analytical framework for retrospective data analysis. While previous research on RET programs has consistently found positive shifts in teacher confidence and instructional practice, less attention has been paid to how teachers translate research-intensive engineering technology into feasible pre-college learning experiences—particularly the curricular design decisions, constraints, and adaptations required when the topic lacks established K-12 pathways [8], [10]. In this paper, we document teacher curriculum design processes and early implementation experiences in a CellAg-focused RET, in line with the broader professional development literature, which emphasizes active, coherent, teacher-centered learning designs [11], [12].

RET Program Context and Design
The RET was held at a university in the northeastern United States and implemented in collaboration with academic and industry partners. The program brought together engineers, biologists, and educators. The participating professors were from physics, biology, engineering, and environmental science backgrounds. The program aimed to help teachers connect CellAg and tissue engineering research to high school STEM contexts, as well as design adaptive, standards-aligned curricular modules while utilizing the engineering design process and prototyping techniques. Integrating sustainability and ethics, utilizing engineering tools with low barriers and high ceilings.

Teachers participated in laboratory-based tissue engineering activities (such as scaffold decellularization and mechanical testing), digital fabrication workshops (3D printing, Tinkercad, and Micro:bit), and organized conversations about sustainability and food justice (Figure 1). Weekly co-design meetings aided curriculum development and peer review.

Figure 1. High school STEM teachers engaged in hands-on research and curriculum design during the RET. (Identifiable information for teachers was redacted for peer review, but is visible in the final version since all the teachers are authors on the paper)

Implementation and Testing in a Community Workshop
In summer 2025, we hosted a community workshop with middle and high school students to test and iterate upon curricular activities we designed based on our research experiences (Figure 2). These activities included DIY Instron machines, glucose extraction from biomass, and investigations into material qualities relevant to food texture and sustainability.

Figure 2. Students participating in teacher-designed engineering activities during a pilot workshop.

Below, we share details of our program, curriculum development, and learnings from our summer workshop. These findings reflect the teacher's perspectives and observed implementation dynamics, rather than formal evaluations of student learning outcomes.

Participants

The participants included middle and high school students engaged in a community-wide summer program at a museum in the same Northeastern town as their local public school system. The students were recruited for a workshop spanning multiple weeks, including other science, engineering, and technology workshops focused on food production, physical computing, and prototyping. The CellAg activities took place in one of the weeks in August, where a pre-lunch and post-lunch session was held every working day, with different students engaging in the mornings and afternoons. Between 15 and 20 students attended each of the morning and afternoon sessions.

Evidence and Sources

Our evidence for this evaluation paper includes teacher-written retrospectives from after the workshop implementation, teacher and research reflections, curriculum artifacts developed, and observation and programmatic notes. It is important to note that, unlike a traditional model in which the research team publishes work evaluating teachers' experiences, this paper is jointly authored by the teachers and the research team. For this paper, we analyzed our retrospectives and observation notes using an inductive thematic method, identifying patterns directly from the data rather than through predefined coding categories. We also reviewed curriculum artifacts and reflection/discussion notes to identify recurring patterns.

Findings: Research Experiences, Curriculum Design, and Early Implementation

Below, we share some of our findings aligned with the guiding questions we outlined above. We group these findings by inductive themes to share our experiences of conducting research to inform curriculum in a burgeoning field in engineering, creating research-informed lessons, and our experiences of teaching and facilitating teaching in the summer program.

Experiences with Research Immersion

In the retrospectives, we described the research immersion as radically different from standard professional development. Rather than receiving pre-packaged educational materials, our experiences were guided by authentic engineering and biotechnology techniques in active research, including scaffold decellularization, mechanical testing, iterative prototyping, and data analysis. Several of us felt that dealing directly with research uncertainty, such as troubleshooting failed experiments or adjusting methods, changed our perspective of engineering as a dynamic, iterative process rather than a rigid series of processes. This experience influenced how we are likely to explain engineering techniques to students, notably in terms of failure, modification, and decision-making under limits. For those of us from non-biological fields (such as physics and engineering), we sometimes felt out of our comfort zones when first introduced to cellular agriculture principles, since the field is heavily rooted in biology. However, collaborative work with colleagues from different disciplines supported uncovering disciplinary entry points that were relevant to different teaching contexts.

Research to Curriculum Connections

All teachers created curriculum items that aimed to bring RET research experiences into high school or informal learning settings. The curricular units developed differed in disciplinary concentration but were grounded in the engineering field of CellAg.
First, we prioritized low-barrier, high-ceiling designs, purposefully converting laboratory-based research into exercises that students could complete with limited classroom resources. Examples include building DIY mechanical testing instruments from found materials, simplifying scaffold research to emphasize material features, and modeling exercises using digital fabrication tools. Second, all of our units linked CellAg engineering to societal and ethical considerations, most notably food systems, sustainability, and public health. We attempted to present engineering issues as real-world concerns, such as analyzing alternate protein sources or investigating material durability in food production, rather than abstract technical exercises.
Third, we aimed to incorporate student autonomy and open-ended inquiry into our curriculum designs, rather than assigning a single "correct" answer. Many of our exercises were designed to encourage students to test concepts, compare findings, and explore tradeoffs. For us, this is a purposeful shift away from single-protocol lab-based experiences toward exploratory engineering experiences.

Opportunities and Challenges

While we believe CellAg to be an exciting engineering technology and way to engage students in STEM, it is important to be realistic about both classroom implementation and current uncertainties of the field.

Opportunities. We noticed a high level of student engagement in the summer implementation, especially when students could make, control, or test actual objects. Hands-on construction and testing activities were particularly interesting for younger learners, whilst older students

expressed interest in conversations about ethics, sustainability, and food fairness.
Adopting cutting-edge emerging technologies in our classroom practices can positively impact student engagement. We also noticed that some students who were not as engaged in the activities at first were drawn into activities when we presented the activities in terms of societal significance.

Challenges. We also experienced certain challenges. A majority of us felt that we did not have enough time to test our activities. It takes time to combine hands-on exploration, conceptual explanation, and reflection within a short time, especially in informal workshop settings where we did not know the students beforehand.

We also sometimes struggled with clarity and pace. Students often needed additional scaffolding to comprehend complex processes or connect tasks to broader engineering topics. Also, since we were implementing research-inspired activities outside of laboratory settings, we also encountered practical issues, including safety, material preparation, and classroom management. However, these issues are more programmatic constraints than insurmountable obstacles, and we have already considered specific adjustments and adaptations for subsequent iterations.

Learnings from summer implementation

Our engagements with students at the informal community workshops offered early insights into our RET-inspired curricular activities. Our activities engaged students in collaborative problem-solving and the testing of designs. We observed that younger students responded better to hands-on construction and testing exercises, whereas older students engaged more fully in abstract debates about sustainability and ethics. The students also appeared to experience moments of uncertainty around some of the low-cost experimental setups, and we attempted to respond to such moments by calling in their peers and providing direct support when needed, in hopes of preventing disengagement. We found these insights to be useful in revising our curriculum structure and pace before implementation in our formal classrooms.

Discussion

The results of this evaluation paper provide insights into how RET programs may help teachers translate new engineering technologies and research into learning experiences that are accessible and engaging. Importantly, while student engagement is mentioned as an observable consequence of pilot implementation, this paper does not attempt to assess student learning or effect. Rather, student participation is considered an early signal of how teacher-designed, RET-informed activities work in practice.

Our paper's focus has not been on student learning but on teacher professional development, curriculum design, and the organization of RET programs. These observations from the first year of our three-year project are helpful as we design the next iteration of our experiences and can potentially support research-to-practice translation at RET or similar sites as well. In particular, we would like to highlight the following aspects from our

RETs as Design Spaces for Engineering Translation

The RET program served as both a research immersion and a design environment, where we conducted research in a cutting-edge field while creating curricula to engage students in both informal and formal settings. We had the opportunity to experience uncertainty, iteration, and limitation firsthand when conducting authentic research. This outcome is consistent with previous research that underscores the significance of authentic engineering approaches in teacher education

[13]. Our retrospectives show that an essential affordance of research immersion is in helping teachers see engineering as a process that their students, even with limited resources, can engage with in authentic hands-on ways [14].

Curriculum Design as a Site of Teacher Agency

Our findings and experiences demonstrate significant ownership and contextual flexibility, suggesting that organized co-design time is an essential component of RET programs. Rather than using externally designed curricula, teachers drew on their disciplinary expertise and students' understanding to create learning experiences that were authentic to their surroundings. This agency appears especially relevant when dealing with emergent technologies that lack defined K-12 curriculum pathways.

The Role of Informal Pilot Spaces

The community workshop acted as an effective bridge between research immersion and classroom application. The pilot implementation enabled us to identify pacing concerns, clarify instructions, and evaluate student engagement patterns without the constraints of formal classroom evaluation. Thus, including informal pilot spaces into RET program design may encourage more considered and confident classroom integration, especially when working with complicated or new technology.

Balancing Ambition and Feasibility in Emerging Technology Education

It is still challenging to integrate engineering topics under active research into teaching while navigating real-world classroom expectations and constraints. Though, rather than perceiving these conflicts as flaws, we approached them as design problems that required iterative improvement. This further emphasizes the viewpoint that engineering education is intrinsically iterative and context-sensitive, reflecting the nature of engineering work itself.

Limitations and Future Directions

Curriculum modules were only piloted in a community workshop and are currently being implemented in teachers' classrooms. We are meeting over several Saturday sessions to discuss and provide support for these implementations. We have already met in November and December. Future research may focus on the systematic classroom implementation of these curricular modules across participating teachers' schools, including an examination of how students interact with and learn from these activities over time, as well as how teachers adjust the curriculum to formal classroom constraints. This paper demonstrates how immersive research experiences and collaborative curriculum design can help teachers prepare to incorporate emerging engineering technologies into informal and formal STEM teaching. Our retrospectives, experiences, and curriculum design and implementation efforts hopefully yield valuable insights for future RET programs and curriculum development initiatives. By focusing on teacher design work and early implementation findings, this paper offers practical guidance for adapting new engineering technologies and research into pre-college settings.

Acknowledgements

This work was supported by the National Science Foundation (NSF) award EEC 2419249. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The authors would also like to thank the research participants and their families for their engagement.

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