Expanding Access to Engineering: A Compilation of Chemical Engineering Outreach Programs and Resources

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Dr. Bilgin's research focuses on engineering education, particularly in fostering professional identity among engineering students and integrating data science into the chemical engineering curriculum. She has received multiple awards for her contributions to teaching and mentoring, including the ASEE Ray Fahien Award and the UIC COE Harold Simon Award. Dr. Bilgin is also actively involved in professional service, currently serving as the Director of the Chemical Engineering Division for ASEE and participating in various initiatives to improve engineering education and student success.

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Introduction

Broadening participation in engineering necessitates sustained, localized, age-appropriate initiatives for both students and educators that also encourage participation and engagement. Within chemical engineering, outreach takes many forms: hands-on workshops for elementary students, immersive summer camps for middle and high school students, teacher professional development, curriculum development, and undergraduate-led outreach activities. While these efforts are often developed independently to address local needs, they share common goals of broadening participation and helping students see themselves as being successful in pursuing STEM careers.

Over the last academic year, members of the Chemical Engineering Division have met regularly to share outreach initiatives, reflect on successes and challenges, and exchange strategies for sustaining impactful programs. These conversations revealed both the diversity of outreach programs currently in use and the common design principles that make them successful. This paper emerged from those discussions and serves as a compilation of outreach efforts that span a wide range of audiences, time scales, and institutional contexts.

Rather than presenting a single outreach model, this work brings together multiple programs hosted by the authors at their home institutions and communities. Collectively, these programs provide illustrative examples of approaches to scaling, adapting, and sustaining chemical engineering outreach, and are considered in the context of established evidence-based practices in engineering education, including prior literature on student engagement, self-efficacy, and design-based learning. Where possible, connections are drawn between program elements and these frameworks, while also identifying areas for continued assessment and more rigorous evaluation. As summarized in Table 1, the featured programs include short-duration, low-cost workshops for elementary students; multi-track, student-centered summer programs for grades 4–12; middle/high school enrichment academy; high school summer camp; low-barrier teacher-facing initiatives; NSF-funded engineering curriculum development and teacher professional development; and a required undergraduate outreach project embedded within the chemical engineering curriculum. For each program, we describe the guiding philosophy, core structure, representative activities, and observed outcomes.

The goal of this compilation is twofold. First, it provides concrete examples of outreach programs that have been implemented, refined, and sustained over time. Second, it serves as a practical resource for departments and faculty seeking to adopt or adapt outreach activities to fit their own contexts. By documenting these efforts side by side, this work highlights not only the structure and implementation of these programs, but also the extent to which they are grounded in evidence-informed approaches. In doing so, it identifies shared best practices that may inform the development and refinement of future outreach efforts across the chemical engineering community. In addition, assessment and evaluation tools provide a strong foundation for outreach programs. Specifically, some recent ASEE presentations and publications have reinforced the importance of rigorous, theory-informed assessment strategies in engineering outreach. Rodriguez-Devora et al. [1] demonstrates how engineering identity frameworks can be used to evaluate shifts in students' self-perceptions as engineers, while Tran et al. [2] emphasize mixed-methods methodologies that combine surveys, qualitative interviews, and demographic analyses to assess impact on historically marginalized populations. Knight et al. [3] further illustrate formative assessment approaches in rural K–12 contexts that triangulate identity measures with observational data. Complementing these frameworks, Zhou [4] provides longitudinal evidence of sustained program impact over time in a pre-college STEM outreach initiative, highlighting the value of multi-year tracking. Travaglini [5] outlines structured evaluation practices for community college engineering outreach, emphasizing alignment between program goals, measurable outcomes, and systematic data collection. Collectively, these studies underscore the need to align outreach objectives with survey instruments (with prior validity evidence in a context similar to this application), employ triangulated data sources, and incorporate longitudinal and continuous improvement mechanisms to substantiate claims of meaningful and sustained impact.

Table 1. Summary of Featured Outreach Programs

Program	Target Audience	Duration / Format	Core Focus	Key Features
Complex Fluid Toys Workshop	Grades 3–5	Three-hour workshop (adaptable)	Introduction to chemical engineering through materials	Hands-on toy making (slime, orbeez™, oobleck), formulation concepts, low-cost materials, adaptable learning targets
Multi-Track Summer Outreach Program	Grades 4–12	Three tracks, 1-week for each track, full-day summer program	Engineering identity development and engagement	Age-specific tracks, project-based learning, real-world context, interdisciplinary exposure
Summer Enrichment Academy Course	High School	1-week, half-day course	Introductory chemical engineering concepts	Low-cost entry, lab tours, core ChE topics, growing enrollment, measurable matriculation impact
High School Chemical Engineering Summer Camp	Rising 11th–12th graders	4-day, full-day camp	Hands-on engineering exploration	Reusable and transportable activities, safety-focused design, scalable demonstrations
Teacher-Facing Outreach	K–12 Teachers, 6-12 Students, & Undergrads	One-day events & campus visits	Relationship building and classroom support	Low-barrier Professional Development, parallel student/teacher programming, near-peer outreach
Engineering Design Curriculum & Professional Development	Secondary Students & Teachers	Classroom modules ~2-4 weeks (adaptable)	Engineering design in core STEM classes	NGSS-aligned design challenges, low-cost materials, teacher PD, assessment tools; adaptable to first/second year design courses
Undergraduate Outreach Project	K-12 Students and CHE undergraduates	Semester- long course project	Communication & outreach training	Problem-based learning, ABET alignment, large-scale student impact

It is our intent to provide all of the outreach program materials, activities and resources on a faculty accessible website for chemical engineering departments to use and adapt as they develop their outreach initiatives.

Complex Fluid Toys

Is slime a liquid or a solid? What about orbeez™? In this workshop we will explore the world of complex fluids, which are materials that aren't quite solids, but aren't quite liquids either! We'll learn all about the chemistry that makes these types of materials squishy and gooey, along with how chemical engineers use these materials to make products we use every day.

"Complex Fluid Toys" is a three-hour outreach workshop for students in grades 3–5 that introduces foundational concepts in soft materials and complex fluids through hands-on, inquiry-based activities. The workshop targets four core competencies: distinguishing between science and engineering, recognizing and defining complex fluids in everyday contexts, explaining behaviors such as cross-linking and shear thickening, and describing how chemical engineers formulate products.

Each competency is paired with an aligned assessment approach consistent with evidence-based practices in engineering education. Brief pre/post prompts are used to capture shifts in content understanding and interest in STEM. During the activities, structured observation protocols document student engagement, use of disciplinary language, and evidence of concept application. In addition, student-generated artifacts (e.g., slime and bouncy ball formulations) serve as performance-based evidence of understanding, particularly in connecting material composition to observed properties.

Students engage with these concepts through three activities: synthesizing Orbeez™, formulating slime and a bouncy ball from similar ingredients to explore cross-linking behavior, and interacting with oobleck to investigate shear thickening. Each activity is intentionally designed to elicit observable evidence of student thinking aligned with the targeted competencies. Initial implementations indicate strong engagement and emerging conceptual understanding; ongoing iterations are focused on strengthening systematic data collection and analysis to evaluate impact more rigorously.

The workshop is modular and adaptable across age groups, with corresponding adjustments to both content emphasis and assessment strategies. The following sections will describe each of the activities in detail and give suggestions for how the activity can be adapted for a wider age range.

Polymer crosslinking: Making orbeez™

Water beads, commonly called "orbeez™" are a water-absorbing polymer bead that are often used for tactile play, sensory experiences, and in arts and crafts. Store purchased orbeez™ are typically made from sodium polyacrylate "seeds" that are placed in water and "grow" through the process of absorption. Instead of sodium polyacrylate, our orbeez™ is made by adding 5 wt% sodium alginate solution with a drop of food coloring into a 2 wt% calcium chloride bath in a process similar to that outlined by the SMILE program at Oregon State University [6]. The cross-linking reaction of sodium alginate by the calcium ions forms a squishy hydrogel with a similar texture as orbeez™. Students are provided spoons, syringes, and pipettes and encouraged to make different sized and shaped orbeez™.

At the third-grade level the concepts of crosslinking chemical reactions and simple diffusion of the calcium ion into the orbeez™ are discussed. The activity can be adapted for higher level learners where discussions about the diffusion of the food coloring can be tracked with UV-vis and modeled over time. This in turn can be discussed in terms of drug delivery concepts.

Formulation Engineering: Slime vs Bouncy Balls

The second complex toy activity is a challenge posed by the fictional *Materialz of Ze Future Corporation.* Their CEO, Ima Boss, has hired the students to create two new product lines that can be used in the latest "Tik-Tok™" challenge: 1.) A bouncy ball capable of bouncing UP a flight of three stairs and 2.) Slime that is gooey enough to flow DOWN a flight of three stairs. The real challenge is that they must use the same ingredients for both products: white or clear school glue, borax solution, water, cornstarch, and food coloring. Students are given a basic formulation that doesn't meet either of the specs and they have to figure out how to change the formulation to get their desired product properties. At the end of the session, we test the products (with the course staff filming for Tik-Tok of course) and see which product Ima Boss will choose. The chemical reaction between glue and the borax solution is a cross-linking reaction, which is built upon the first orbeez™ activity.

At the third-grade level, the concepts of formulations are heavily emphasized and connected to chemical engineering. We talk at length about how a formulation is both the ingredients and the processing steps used to make products, using examples like different types of soap (dish, laundry, shampoo, etc.) and baking (cookies, cake, bread, etc.). The activity can be adjusted for more advanced learners by adding elements of cost and environmental impact. Different ingredients can be labeled as "biodegradable" or "organic" with different cost points. Students then have the added challenging of determining the cost of the product and the trade-offs of traditional vs an "eco-friendly" option.

Ooblek

The last activity of the workshop is oobleck, a non-newtonian sheer thickening fluid made of cornstarch and water, named after the classic Dr. Seuss Book "Bartholomew and the Oobleck." In the story, the King is angry with regular weather like rain, snow, and fog, and calls on magicians to make a new kind of precipitation, a green goop called oobleck. In the class, we talk about the dilatant, or shear thickening, nature of oobleck and how it is caused by the difference in size and shape of the water and cornstarch particles. Under low force conditions, the particles are able to slide past each other and the oobleck flows like a liquid. Under high force conditioning, the cornstarch particles become jammed together causing the mixture to become hard like a solid.

Oobleck is made with equal parts water and corn starch. The amount of cornstarch made for the workshop depends on the season. When the class is taught in the winter, a large bowl of oobleck is prepared prior to class and each student gets a small cup they can play with at their seat. In the summer, a small swimming pool (2.5ft wide by 5ft long and 0.5 ft tall) of oobleck is prepared and students can take turns running across the oobleck surface without shoes or socks. Students can also play with the oobleck with their hands. The pool should be placed on a grassy surface with enough space that students will not run into any obstacles. The cornstarch can be very slippery on grass, so a canvas tarp is placed on the ground under the pool, extending about 1ft in every direction. The pool is lined with a medium duty plastic tarp to ease with cleanup. It takes approximately 200lbs of cornstarch to fill the pool and must be prepared prior to the start of class. The oobleck is prepared in small batches by hand in 5-gallon buckets. It typically takes 2-5 volunteers one hour to prepare. At the conclusion of the class, the outreach volunteers often send an email out to the department students, faculty, and staff, letting them play with the oobleck pool through lunch before cleaning up. The oobleck can be disposed of in 5-gallon buckets with tight fitting lids in the trash.

Guiding Principles

When running this workshop, the instructors are guided by five fundamental principles:

1. We want students to be able to see themselves as chemical engineers in the future.
2. We want students to work together in groups. The workshop should be interactive and require active participation from the attendees. While technical concepts are taught, we try to explain them while students are working with the materials, rather than lecturing.
3. We want the students to be excited about what they are learning. We don't expect students to leave the class with enlightened technical knowledge. If they can describe one new idea, we call it a win!
4. We want students to connect what they are learning to things they see and use every day. We pull as many examples as we can of products students use at home or in school. We want ChemE to be close to their lives.
5. We want ChemE to be fun and not scary. So often society focuses on how "hard" engineering is and how "smart" you have to be to do it. We don't let that vocab enter our outreach classes!

Multi-Track, Student-Centered Chemical Engineering Outreach

Many K–12 engineering outreach initiatives are designed as intensive summer camps or enrichment programs that aim to spark early interest in STEM and broaden participation in engineering. When thoughtfully structured, such programs can play a critical role in shaping students' perceptions of engineering [1], building confidence [2], and fostering a sense of belonging [3]—particularly for students who may not have previously considered engineering as a viable pathway.

In response to this need, the Department of Chemical Engineering at University of Illinois Chicago developed a three-week summer outreach program serving students in grades 4–12. The program was intentionally designed as a student-centered, immersive experience that introduces participants to chemical engineering through hands-on, real-world activities while emphasizing the societal relevance of engineering work. Rather than focusing solely on content delivery, the program prioritizes engagement, collaboration, and identity development, recognizing that early exposure and positive experiences are critical to long-term persistence in engineering.

To ensure developmental appropriateness and maximize impact, the program is organized into three age-specific tracks: rising 4th–6th graders, rising 7th–9th graders, and rising 10th–12th graders. Each track follows a shared set of learning goals while offering activities tailored to students' cognitive and experiential levels. Participants rotate through multiple engineering disciplines—including chemical, biomedical, civil, mechanical, industrial engineering, and computer science—allowing them to explore the breadth of engineering applications and better understand how disciplines intersect in solving real-world problems.

Program Structure and Implementation

The camp operates as a full-day, in-person program hosted on a university campus, with structured morning and afternoon sessions. Morning sessions introduce the engineering discipline of the day and establish foundational concepts through interactive discussions led by faculty and graduate students. Afternoon sessions emphasize project-based learning, where students work in teams on design challenges that require creativity, experimentation, and problem-solving. This structure reinforces engineering as an active, collaborative process rather than a purely theoretical endeavor.

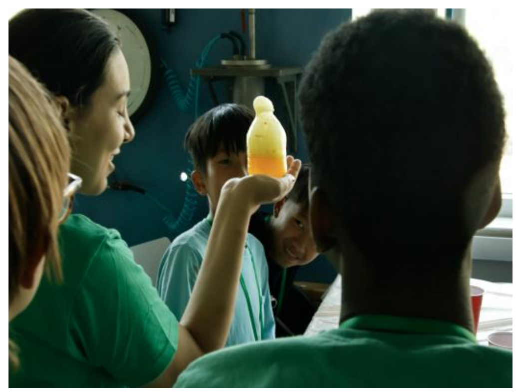

Figure 1. *Multi-track student-centered chemical engineering outreach activity engaging students in hands-on, interactive learning experiences.*

Across all tracks, students participate in four to five activities per day, each lasting between 30 minutes and 1.5 hours. Activities are intentionally varied to capture diverse interests and learning styles while highlighting different facets of chemical engineering. Examples include plant-based ice cream formulation, DNA extraction, elastomer design, bottle rocket propulsion, pH indicator development, and pharmaceutical product design. These activities connect engineering principles to familiar contexts such as food, health, sustainability, and consumer products, helping students see engineering as relevant to everyday life.

A signature activity, the *Plant-Based Ice Cream Challenge*, illustrates the program's pedagogical approach. Students are introduced to the growing demand for plant-based food products and explore how ingredient selection and processing conditions influence texture, taste, and stability. Working in teams, participants modify a base recipe, predict outcomes, and test their formulations, engaging with chemical engineering concepts such as emulsions, crystallization, mixing, and batch processing. The activity culminates in team presentations and informal evaluation, reinforcing communication skills and reflective thinking alongside technical understanding.

Accessibility and Learning Environment

Equity and access are central considerations in the program's design. Approximately half of the participants receive need-based scholarships, with priority given to students from underrepresented backgrounds and those eligible for free or reduced lunch programs. This financial support lowers participation barriers and broadens access to high-quality engineering experiences.

The learning environment is intentionally structured to be supportive and inclusive. Low student-to-staff ratios are maintained through the involvement of faculty, graduate students, and undergraduate mentors, all of whom receive training prior to the program. This mentoring structure allows students to ask questions freely, receive individualized feedback, and interact with role models at different stages of the engineering pathway.

Scope of Activities and Educational Goals

Collectively, the program's activities are designed to achieve three primary goals:

(1) increase student interest in chemical engineering,
(2) build confidence in engaging with engineering tasks, and
(3) help students develop an emerging sense of engineering identity.

Rather than emphasizing mastery of specific technical content, the program focuses on how engineers think, collaborate, and solve problems. By engaging students in iterative design, experimentation, and reflection, the program aims to demystify engineering and position it as an accessible field for students with diverse talents and interests.

This multi-track, activity-rich outreach model demonstrates how immersive summer programs can support early engineering identity development while remaining adaptable to different age groups. The program's structure, variety of hands-on activities, and emphasis on real-world relevance provide a replicable framework for institutions seeking to engage K–12 students in chemical engineering and related fields.

Summer Enrichment Academy

The summer program at University of Maryland Baltimore County is an annual program for high school and middle school students interested in learning about a wide variety of fields, including music, coding, and engineering. The program primarily offers half-day (3-hour) courses, with some full-day (6-hour) courses from Monday to Friday. This is a day program and is intended to reach a broader community. The program cost is intentionally quite low, ranging from \$200 - \$300, with an increase to \$374 in the current year. There are numerous early-bird discounts and scholarships as well. Some partnerships also exist with other programs supporting underrepresented groups. A need was identified to introduce chemical engineering to high school students. The aim was to facilitate an uptick in student interest in chemical engineering while reducing negative perceptions of the field, such as the view that it is a "polluting" major. The hands-on introductory chemical engineering course was first launched during the summer of 2022 and is offered in late July. Enrollment has been growing, starting with 18 students and reaching 28 in summer 2025. Some of the topics covered during the week are as follows:

- Reactions and Kinetics
- Electrochemistry
- Fluid flow
- Separations
- Research Lab tours

***Figure 2**. Students at University B performing the bath bomb experiment.*

Sample Activity

One of the popular hands-on activities at the summer chemical engineering course is making bath bombs. Bath bombs are a popular commercial product using simple ingredients. The primary components are baking soda, citric acid, Epsom salt, and cornstarch, with optional ingredients such as essential oils for scent and moisturizing oils like almond, coconut, jojoba oil, etc. They can customize the bath bombs by adding food coloring, molding them into various shapes, and adding various fillers like flower petals, glitter, etc. The core reaction is an acid-base reaction between citric acid and sodium bicarbonate, with products being sodium citrate, carbon dioxide, and water. The carbon dioxide released by a bath bomb produces the trademark effervescence at the water's surface. The students also test the formed bath bombs and examine the gas release. Ideas about unit operations, scale-up, and safety are discussed as well. They also get to take a couple of bath bombs home as a souvenir. The material cost for this activity is less than $100 total for all participants.

Reception and feedback

The student feedback for the introductory chemical engineering course has been positive, with students finding the various experiments engaging. This is also evidenced by the increase in course enrollment. The students have indicated an increase in career awareness by virtue of knowing about multiple job options and various things chemical engineers do. Students like the lab tours as they give them the opportunity to see the work done and the broad application of chemical engineering. A separate ASEE 2026 paper by one of the authors explores the course's impact using a structured survey [7].

Direct Impact

Since the main goal of the outreach efforts has been to increase enrollment in chemical engineering programs, it is worth noting some enrollment results from the course. We have tracked the enrollment in University of Maryland Baltimore County’s chemical engineering program as a result of this course. Since the second year, we had at least one student join the department of chemical engineering with about 1-3 being admitted each year. While this may not seem like a lot, it is a significant return on investment for our small department. Anecdotally, another student has joined another chemical engineering program at another university. This year we have an undergraduate working in a research lab who joined due to the course and is interested in enrolling at the university.

Chemical Engineering High School Summer Camp

Outreach coordinators for the Department of Chemical and Biomolecular Engineering at North Carolina State University plan and evaluate potential activities by prioritizing the following attributes:

- **Reusable** – Activities using supplies that can be reused for several events or years minimize cost and are more favorably viewed by funding sources.
- **Transportable** – Outreach events may occur in buildings other than the Chemical Engineering Building or even off-campus, so ease of transport can determine which activities are practical.
- **Minimize risk** – Activities may be led by undergraduate students, and outreach events may include younger students, so addressing and minimizing safety concerns allows broader participation for both our activity leaders and the targeted audience.
- **Provide an engineering experience** – Activities that allow students to explore different properties or test theories help participants feel like engineers and inspire scientific exploration.

Outreach for the department has historically focused on two types of events: (1) tabling events (like the college open house or science/college fairs) that target a variety of ages, and (2) a weeklong summer camp for rising 11th and 12th grade students. A thorough discussion of the camp's history, logistics, and activities is available in reference [8].

Activities at tabling events are often led by undergraduate ambassadors who may see hundreds of people at a single event. This requires that demonstrations be quick and repeatable. Summer camp activities have the advantage of time; camp participants spend the four full days (9 AM to 4 PM) engaged in activities, so although tabling event activities are also used at the camp, the activities are extended to allow longer or more varied experiments.

For example, thermoelectric coolers have been utilized at both tabling events and during the camp. The coolers are relatively inexpensive (at the time of writing, a set of 10 were available for less than $30) and reusable. Batteries can be used to power the cooler such that one side of the cooler becomes hot while the other side gets cold. Different sized batteries were tested to determine the battery that generates the desired heating/cooling effect without causing the temperatures to be uncomfortable to touch. For the selected coolers, AA batteries provided a subtle effect and were used for demonstrations; 9V batteries were also available to produce a stronger effect but were only used when there was direct supervision as the temperature can become uncomfortably hot. The coolers and batteries are easy to transport, quick to demonstrate, and reusable. The activity has minimal risk when an appropriate battery is selected (to keep temperatures within a safe range) and when following safety protocols for batteries/electronics. Participants were encouraged to test what happens when the wires in contact with the batteries are swapped (consequently causing the hot and cold sides of the cooler to switch). This activity is quick, repeatable, and prompts discussions on the role of chemical engineering in the development of materials, semiconductors, and energy.

This activity is extendable for events like the summer camp by using thermoelectric coolers to produce electricity. Just like engine cycles use a temperature difference to generate work, a temperature difference applied to the coolers can generate electricity to power a small LED light. Participants set up a circuit with the LED light and several coolers (the generated electricity is additive, so more coolers provide more power to the LED). A temperature difference is applied to each cooler using ice packs for the cold side and reusable hand warmers for the hot side. Participants can measure their electricity production with a voltmeter and observe the LED as it lights up. They can further test their setup by adding/removing coolers to see the effect on the brightness of the LED and the voltmeter reading. This experiment demonstrates temperature's relationship to usable energy (like electricity); activity leaders can then relate this to engine cycles and demonstrate another example using a small Stirling engine to again highlight how engineers use temperature differences to generate power.

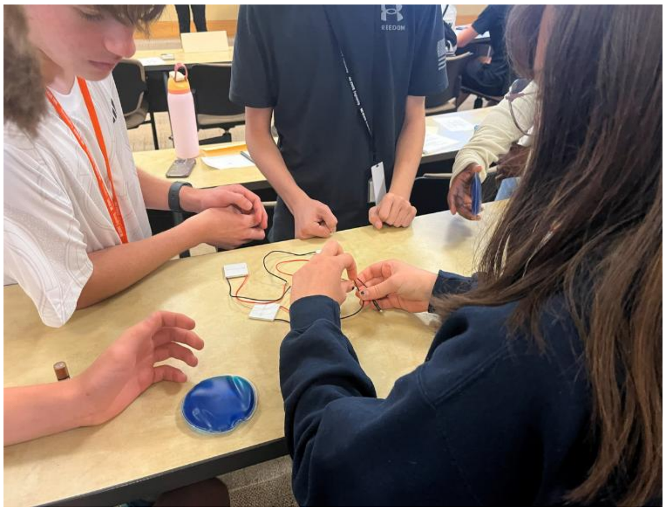

Figure 3*: Students connecting an LED to several thermo-electric coolers in series during the 2025 summer camp.*

Small Scale, Teacher-Facing Outreach

Many engineering outreach efforts for K–12 educators take the form of multi-day conferences, long-term curriculum partnerships, or summer research experiences for teachers (RETs). While these programs can be impactful, they often require a substantial time commitment that is difficult for teachers to accommodate alongside existing instructional, administrative, and extracurricular responsibilities. As a result, participation is frequently limited to a small subset of educators who already have flexibility or institutional support to engage in extended programming [9-10].

In contrast, the Chemical Engineering Department at Trine University has intentionally emphasized small-scale, short-duration outreach activities designed to be accessible, practical, and relationship-driven. These efforts prioritize one-day events, campus visits, and low-barrier interactions that allow teachers to engage without long-term commitments. This approach recognizes secondary education teachers as key partners in STEM recruitment and advising, given their direct and sustained influence on students who are beginning to consider postsecondary pathways [11-13]. By lowering participation barriers, these initiatives aim to broaden engagement, establish initial connections, and create opportunities for continued interaction over time.

Small, targeted outreach activities provide several benefits for both educators and the university. They allow teachers to gather concrete classroom resources, gain exposure to engineering applications relevant to their curricula, and develop personal connections with faculty and programs they can reference when advising students. For the department, these activities support sustained relationship-building with regional schools and increase awareness of engineering pathways among both teachers and students . Within this framework, the Trine University McKetta Department of Chemical and Bioprocess Engineering Department pursues four primary areas of engagement.

Professional Development and Teacher Networking. The department contributes to *Storm into Summer*, a free, one-day conference for K–12 educators hosted by Trine University's Franks School of Education. The conference includes sessions led by experienced public and private school educators, administrators, and faculty. Topics from the 2025 event included artificial intelligence in STEM education, project-based learning, career pathways, and student engagement. Educators also had opportunities to learn about university resources and earned professional growth points applicable to teaching license renewal. Chemical engineering faculty sessions focused on designing engineering-based classroom problems, touring the food engineering laboratory, and discussing the role of chemical engineering in everyday products and processes. The inaugural 2025 conference hosted nearly 300 educators and is planned to continue in 2026.

Figure 4*: Storm into Summer teachers participating in a workshop about the role of chemical engineering in separations and the chemistry and engineering behind ice cream.*

Student-Focused Campus Experience with Parallel Teacher Engagement. Through *Impact Your Future: Careers in Engineering & Science*, the departments of Biomedical Engineering, Chemical Engineering, Chemistry, and Biology invite advanced placement, dual credit, and honors high school chemistry or biology classes to campus for an immersive visit. Now in its fourth year, the program has hosted approximately 350 students from nine schools. Student visitors select two, 60-minute sessions from a list of activities that emphasize applications of chemistry and biology within engineering and science degree pathways. At the same time, participating teachers engage in parallel sessions that include peer and faculty networking, lab tours, discussions on teaching with limited resources, assessment strategies, and the use of artificial intelligence in the classroom.

Figure 5*: AP and Dual Credit Chemistry and Biology teachers sharing best practices over coffee and learning about engineering makerspace design opportunities.*

At the end of the visit, students and teachers were asked to complete a short survey. In addition, student registrants were tracked through the university's admissions platform. Following their visit, 60% of students reported they would consider an engineering-related career, and 36% indicated they planned to return to campus independently.

Figure 6 presents matriculation outcomes for event participants, grouped by incoming class cohort. Across cohorts, the figure highlights a consistent increase in participation, application rates, and the proportion of applicants selecting STEM-related majors. The program has demonstrated continued growth in the number of students reached, as well as in application and enrollment counts. Among students who applied, an increasing proportion selected STEM-related majors (science, mathematics, engineering, or computer science). These results remain preliminary, as many attendees from the 2025 and 2026 events are still in the college decision-making process.

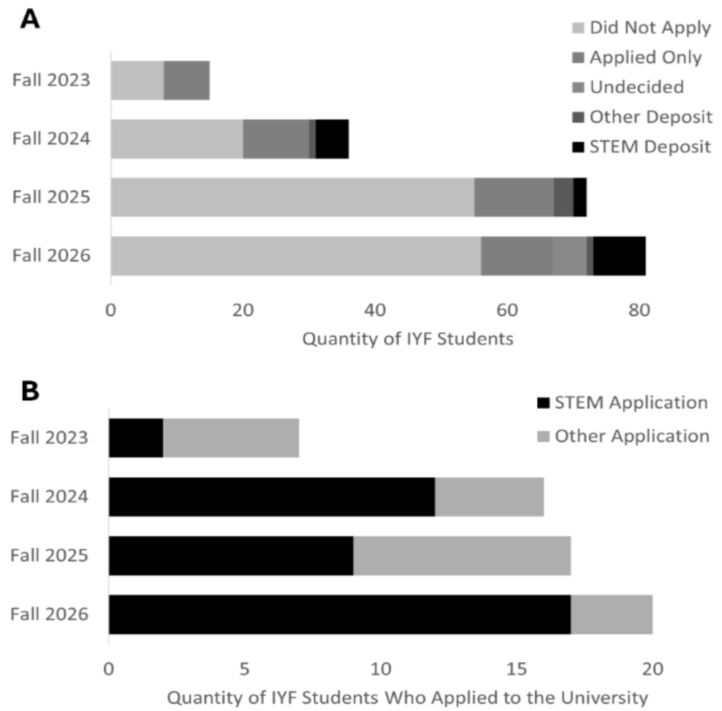

***Figure 6**: Matriculation outcomes for students participating in the Impact Your Future (IYF) outreach event, organized by incoming class cohort (Fall 2023–Fall 2026). (A) Application and enrollment (deposit) status following event participation. (B) Intended major among applicants, comparing STEM and non-STEM fields. Results indicate increasing participation over time, along with growth in both application volume and STEM program interest. Data for Fall 2025 and Fall 2026 cohorts remain preliminary.*

Near-Peer Outreach to High Schools. As part of the chemical engineering curriculum, second-year students complete a high school outreach assignment that requires them to return to their former schools and present to advanced mathematics, chemistry, or physics classes. These presentations focus on the nature of chemical engineering, distinctions between engineering and pure science, and career opportunities associated with the discipline. Students are required to design an interactive component and to complete a practice presentation with faculty feedback prior to visiting the high school. This approach provides high school students with relatable, near-peer perspectives while also strengthening ties between the department and local teachers [17]. Students often return home during fall or holiday breaks, allowing a broader geographical reach. In addition, teachers seem more receptive to having their former high-achieving students return to the classroom.

In a follow-up survey for teachers to summarize key takeaways, many reported understanding more about the differences between chemical engineering and chemistry and the variety of occupations available. Other comments included:

"I will try to have kids come speak every year because my students had good questions about college, majors, and the different careers that can come out of the differing fields of study"

"I usually shun guest speakers as a bit of a "wasted day" where we could be tackling learning and doing STEM but instead are just hearing about it. However, hearing a former student's experiences and enthusiasm brought hope, perspective, and enthusiasm to my students that I am looking forward to see carry on (at least for a few days) in my classroom."

***Figure** 7: Combining Chemical & Environmental engineering, high school students design their own activated carbon filtration system.*

Recognition and Appreciation of Teachers. Since 2009, the department has presented an annual Outstanding High School Teacher Award to recognize educators who have inspired students to pursue STEM fields. Teachers are nominated by members of the senior chemical engineering class. The selected teacher receives a cash award and plaque during a department dinner attended by faculty and the nominating student. Teachers who are not selected still receive handwritten thank-you notes from students, often including updates on their college experiences and future plans, reinforcing ongoing connections beyond the award itself.

These teacher-facing strategies can also work synergistically. For example, one educator first hosted a near-peer outreach visit from a current student, was later recognized by that student through the Outstanding Teacher Award, subsequently brought a new group of students to the on-campus outreach event, and ultimately encouraged colleagues to participate in the teacher conference. Together, these initiatives reflect a deliberate strategy to support teachers through accessible, meaningful engagement while building sustainable relationships that benefit students, educators, and the broader STEM pipeline.

An Alternative Undergraduate Outreach Program

Engineering education prepares students not only with technical knowledge, but also with the ability to communicate complex ideas to diverse audiences and work effectively in teams. With this in mind, a required undergraduate outreach project [18] was developed to address these objectives, but also to provide exposure to engineering concepts and career opportunities to K-12 students. This project requires undergraduates to participate in problem-based learning (determine what they are going to teach and how they will teach) via demonstrations, hands-on activities, while challenging them to present technical materials to an audience with little technical knowledge.

***Figure 8**: Lemon battery used to light a LED*

Undergraduate students work in teams to design and deliver an outreach presentation in a local K–12 classroom or program. Presentation topics are selected by the teams but must be aligned with what the K-12 students are currently learning (so that the outreach presentation supplements their learning and is not an isolated activity). Each outreach project includes a short introductory presentation, hands-on demonstrations or activities, and interactive elements designed to actively engage the K-12 students. Teams also provide "leave-behind" materials to support continued learning and career exploration.

The project is intentionally structured as a semester-long, problem-based learning experience with multiple milestones, including topic development, meetings with faculty and K–12 teachers, classroom site visits, and a required practice presentation. The practice presentation is a critical component, frequently revealing misconceptions that may not surface in traditional exams or written assignments. These misconceptions are subsequently addressed in course instruction.

Assessment is a central element of the project. Undergraduate teams design and administer pre- and post-surveys to evaluate the effectiveness of their outreach, analyze results using basic statistical methods, and submit a critical self-assessment reflecting on project efficacy, teamwork, and communication. Faculty evaluation, peer observation, and feedback from K–12 teachers further inform assessment. The project also aligns with ABET Criterion Three: Student Outcome number three [19] by providing students with experience communicating effectively to a *range* (nontechnical) of audiences. This project started in 1999 at University of Maryland Baltimore County and has continued at the University of Pittsburgh, and to date, the program has engaged over 1,300 undergraduate chemical engineering students and more than 12,500 K–12 students.

High School Curriculum Development and Teacher Professional Development

Through NSF IMD (Instructional Materials Development) and DRK–12 (Discovery Research PreK–12) projects, the *INSPIRES* curriculum [20] was developed to provide real-world, low-cost engineering design experiences for secondary STEM classrooms. The curriculum consists of four NGSS-aligned modules that use real-world engineering challenges and inquiry-based learning strategies to engage students, increase scientific and technological literacy, and develop key STEM practices essential for success in engineering and science disciplines. Each project also included teacher professional development, allowing teachers to practice implementing the *INSPIRES* curriculum with Upward Bound students while strengthening their pedagogical content knowledge and confidence in teaching engineering.

Each *INSPIRES* module is organized around an overarching, open-ended engineering design challenge grounded in a real-world problem. Design challenges include quantitative criteria and constraints that require students to evaluate tradeoffs and make informed design decisions as they move through the engineering design process. Challenges are structured to be completed within two to four weeks of class time, while remaining sufficiently open-ended to support creativity and multiple viable solutions.

Comprehensive instructional materials support classroom implementation. Each module includes detailed lesson plans, student handouts and worksheets, and suggested pedagogical strategies for facilitating hands-on and inquiry-based activities. Classroom display materials—such as an Engineering Design Loop and module-specific design targets—are provided to make the design process explicit and visible to students. Professionally produced videos introduce the real-world context, societal relevance, and related engineering career pathways for each challenge.

STEM content is integrated with mathematical modeling and hands-on activities that allow students to explore how changes in design parameters affect system performance. These quantitative tools help students connect scientific principles to engineering decisions. Assessment materials include end-of-unit tests to measure learning gains, as well as scoring guides for evaluating both individual and team performance on design tasks. The curriculum is intentionally designed as a low-cost solution, relying primarily on common science laboratory supplies and readily available materials.

An example module is *Engineering in Healthcare*, which focuses on the design of a hemodialysis system. Students are introduced to the challenge featuring a teenage girl with kidney failure who undergoes hemodialysis on a regular basis. The video describes her treatment, introduces her doctor, and explains the function of a modern hemodialysis machine. Student teams are given the challenge to design, build, test and refine a system that mimics attributes and functions of a hemodialysis system including the removal of a minimum of 2.5 mg of “waste” from simulated “blood.” Design teams are challenged to maximize efficiency while minimizing system costs. Using collaborative strategies such as Think–Pair–Share, students identify criteria and constraints, develop and justify design decisions, and iterate on prototypes.

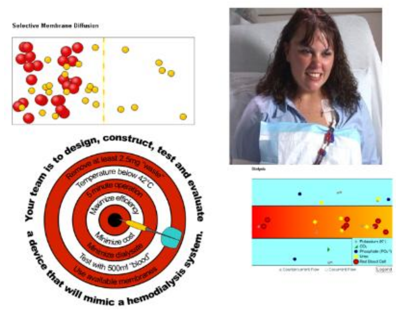

***Figure 9**: Engineering in Health-care module advertisement*

To support the final design, students engage in scaffolded mini-design challenges and inquiry-based investigations that introduce key concepts including diffusion, selective membranes, equilibrium, concentration gradients, and fluid flow. Hands-on activities are paired with mathematical models and visualizations to help students connect observable outcomes with underlying principles. Students document their work in design notebooks, reflect on their learning, and present final designs and analyses in an open forum, reinforcing collaboration, metacognition, and communication.

In addition, the curriculum and design challenges have been used in an NSF BPE program, as well as first year engineering design classes, sophomore level chemical engineering projects and high-school outreach program. To date, the curriculum has been used by over 500 high school teachers with over 10,000 high school and undergraduate students. The assessment of this curriculum in a high-school outreach program has shown that the curriculum enables students to achieve statistically significant learning gains in science and engineering [21].

Best Practices for Sustainable Chemical Engineering Outreach

Across the diverse outreach programs presented in this paper, several consistent best practices emerge. While individual activities and audiences vary, successful programs tend to share common principles that support engagement, accessibility, and long-term impact.

- **Meet participants where they are –** Effective outreach aligns activities with students' developmental levels, prior knowledge, and lived experiences. Programs that connect engineering concepts to familiar contexts—such as food, toys, consumer products or healthcare—help participants see engineering as relevant and approachable.
- **Prioritize hands-on, inquiry-driven experiences –** Across all age groups, activities that emphasize making, testing, and iterating consistently foster deeper engagement. Open-ended challenges with clear criteria and constraints allow participants to experience how engineers think and solve problems, rather than simply following instructions.
- **Lower barriers to participation –** Programs that minimize cost, time commitment, and logistical complexity reach broader audiences. Low-cost materials, short-duration formats, need-based scholarships, and transportable activities all contribute to increased access for students and educators who might otherwise be excluded.
- **Invest in people and relationships –** Outreach is sustainable when it is relationship driven. Near-peer mentoring, teacher partnerships, undergraduate involvement, and repeated engagement over time help build trust, reinforce engineering pathways, and extend program impact beyond a single event.
- **Design for adaptability and reuse –** Activities that can be scaled, extended, or modified for different audiences allow programs to grow without requiring complete redevelopment. Reusable materials and modular designs support long-term sustainability and ease adoption by other institutions.
- **Assess and reflect intentionally –** Incorporating reflection, feedback, and assessment—whether through surveys, discussions, or formal evaluation—provides critical insight into program effectiveness. This data informs continuous improvement and helps articulate impact to stakeholders and funding sources.

Taken together, the outreach efforts presented here demonstrate that expanding access to chemical engineering does not rely on a single model or format. Instead, it requires a portfolio of complementary programs that collectively support awareness, engagement, identity development, and persistence. By sharing these examples and best practices, this paper (and the access to these shared materials, activities and resources) aims to support chemical engineering faculty, departments and students when designing outreach initiatives that are inclusive, effective, and sustainable.