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Get Outside and Learn (GOAL) Engineering Kits

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Vincent P. Nguyen is a Senior Lecturer at the University of Maryland, College Park. He is a founding member of the Environmental and Socially Responsible Engineering (ESRE) group who work to integrate and track conscientious engineering aspects throughout the undergraduate educational experience across the college. His efforts include formally integrating sustainability design requirements into the mechanical engineering capstone projects, introducing non-profit partnerships related to designs for persons with disabilities, and founding the Social/Environmental Design Impact Award. He manages several outreach and diversity efforts including the large-scale Get Out And Learn (GOAL) engineering kit program that reaches thousands of local K-12 students.

Dr. Paige E Smith, University of Maryland College Park

Paige Smith, Ph.D. is the director of the Women in Engineering Program in the A. James Clark School of Engineering at the University of Maryland. She has over 20 years of experience with recruiting and retaining diverse populations in engineering. Under Paige's leadership, the Women in Engineering Program has received many awards for retention and outreach programming. From 2017-2020 she served as the Program Director for Broadening Participation in Engineering in the Engineering Directorate at NSF. While at NSF she also served in a two-year rotation as the Implementation Team co-lead for NSF INCLUDES. Paige is a Past President of the Women in Engineering ProActive Network (WEPAN). Paige earned her Ph.D. and M.S. in industrial and systems engineering and B.S. in engineering science and mechanics from Virginia Tech.

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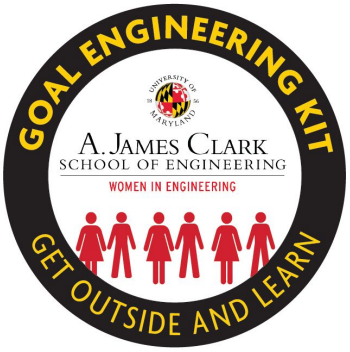


Jen Bishop, Vincent Nguyen, Elisabeth Smela, and Paige Smith

CoNECD 2023 Conference

Equitable K-12 STEM Access and Exposure to Higher Education

- ➔ Engage K-12 students with STEM activities
- ➔ Access to campus and higher education pathways
- ➔ Connect community to University of Maryland

Equity-centered engineering starts with K-12 education. The GOAL Engineering Kits seek to close the opportunity gaps in engineering education by:

1. Supporting a pathway for K-12 students to engage with high quality engineering activities, with a current focus on middle and high school students and especially historically underrepresented and first generation students.

2. Supporting local K-12 educators with integrating engineering activities, including teacher curriculum support and connecting students and teachers to higher education and admission pathways.

3. Empowering undergraduates to engage with their local community and educators, including focusing on incorporating DEI in the design process to create an inclusive activity for all.

The opportunity inequities addressed focus on gender, race, and first-generation disparities in our local communities. Engineers are tasked with addressing many societal issues, and it is vital to improve diversity in engineering so that all perspectives are represented in the solutions. We know that students experience education differently depending on their environment and access to resources. This initiative aims to level the playing field by providing high quality, inclusive engineering activities that can be easily integrated into educational environments.

Geographically, the University of Maryland (UMD) resides in a region rich in diversity. Over all majors, UMD seeks a balance that is representative of the state's population between female and male students, as well as underrepresented minority and non-minority students. However, this balance is not reflected in engineering majors, in which only 27% of students identify as women, and 16% of students are from historically underrepresented racial and ethnic groups. UMD is working to overcome the disparity in our ability to attract underrepresented students from our local communities. A 2021 review by the Washington Post ranked UMD 6th among state flagship institutions in terms of the gap between the percentage of black high school graduates in the state and undergraduate enrollment. This issue is not unique to UMD and is complicated by many factors, including equitable educational access (particularly important for STEM), familiarity with higher education (particularly important for first-generation students), and financial constraints. As an institution, we strive to address these issues to support both our local communities and beyond.

The GOAL Engineering Kit Program was initiated in the summer of 2020 as a partnership between the Women in Engineering (WIE) Program and the Department of Mechanical Engineering at the University of Maryland (UMD). The beginning of the COVID pandemic brought an abrupt shift to online education, which instantly opened a void in K-12 hands-on STEM engagement. The pandemic also brought about a complete shutdown of traditional outreach avenues. This meant a major disruption in the STEM pipelines that disproportionately affected historically underrepresented and first-generation students. GOAL was conceived as a wide-reaching, scalable opportunity to maintain successful pathways for underrepresented groups to become engaged and pursue STEM.

Now in its third year, the program has transitioned to support in-person events and continues to expand to support hands-on learning opportunities for both area K-12 students as well as UMD undergraduate students.

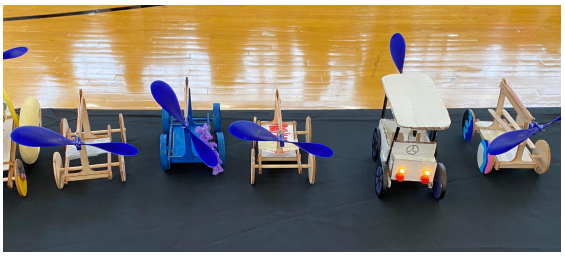
The GOAL program provides participants a hands-on kit that encourages individual exploration and connection to STEM, and the program extends well beyond the low-cost physical components. GOAL includes specific curricula, activities, and design challenges that allow students to engage with foundational STEM concepts. The curricula and explorations have been tied to K-12 Next Generation Science Standards, and GOAL provides teacher support and school system integration. Middle and high school educators gain access to a comprehensive activity with materials and

curriculum to guide their students through exercises designed to introduce foundational concepts and inspire future engineers. Engineering is still an emerging curriculum in many public K-12 schools, and the GOAL program exposes students and teachers to high-quality engineering experiences that involve making and testing solutions. The culminating events add an additional component beyond the physical kits and allow for direct interaction with students for both the challenge competitions and introducing students to engineering education pathways.

Evolution of Kit Design

Version 1-Dragsters

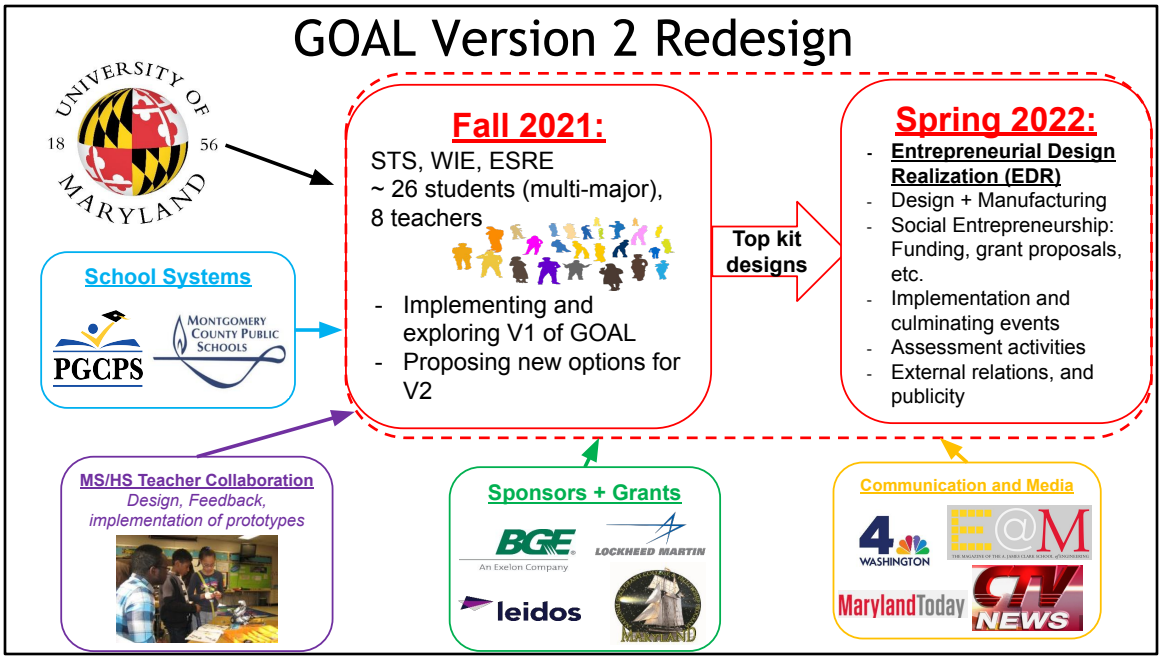
Version 2-PropCarts



Version 1 of the GOAL Kit utilized a purchased Rubber Band Dragster kit with additional curriculum developed by Dr. Nguyen, Mechanical Engineering Professor. Using a prefabricated kit allowed for the program to get up and running quickly. The curriculum was available in English and Spanish.

Version 2 utilizes a PropCart kit that was designed and tested by UMD students and manufactured on campus at Terrapin Works, UMD's additive and subtractive manufacturing makerspaces. To develop this version, the program engaged UMD undergraduate students, K-12 teachers and students in 2021 to collaboratively design and test a new kit through a multi-major service learning course. The new kit, including materials and curriculum, was produced at scale by undergraduates in an Entrepreneurial Design Realization Course. The new PropCart design features exploration of the real world challenge of fuel efficiency.

While the initial version and vision for the program focused on creating a hands-on, screen-free, individual exploration of STEM activity during the pandemic, the program has evolved to place an emphasis back on in-person learning within classrooms and interactions with UMD students, staff, and faculty. The kits are flexible to support both individual outreach kit exploration and in-person collaborative learning.



The GOAL kit design schedule plans to revolve around a 1-2 year cycle for design of new kits and programming, utilizing UMD students for design and testing and on campus resources for manufacturing. This is patterned after the version 2 redesign process.

GOAL Version 3

Do you want to work on a project that makes a real positive impact?

Do you want to work on a product that goes out into the real world?

Design for production, real manufacturing and/or an actual physical implementation, project management, …

ESRE
Environmentally and Socially Responsible Engineering

ENES401: Entrepreneurial Design Realization

UMD undergraduates working on social and environmentally responsible projects that go out into the public domain.

Open to all majors (>90 credits)

Spring 2023 project: GOAL outreach kits

- Over **4000** kits distributed in **3** local school districts
- Major challenge events (~700 participants on campus!)

Design outreach kits and curriculum that introduces first-generation and historically under-represented students to STEM and connects them with **UMD**.

- Work directly with teacher partners to co-develop programming
- Prototype and test
- Work with production and manufacturing at scale
- Manage real-world project logistics, finances, and funding (social entrepreneurship)
- Measure and track impact

If interested in this project email: vince1@umd.edu or smela@umd.edu

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Undergraduate students in this Spring semester's Entrepreneurial Design Realization course are beginning the design cycle for version 3 of the GOAL kit to build out a library of kits. These students will be tasked to reimagine the definition of engineering so that the kit may better attract students who might not engage with more traditional engineering content. We are also collaborating with the Institute for Robust Quantum Simulation at UMD, to develop a kit combining computer science, engineering, and physics to introduce K-12 students to quantum systems.

K-12 Implementation and Impact

This project made me realize that I'm a good problem solver and might be a good engineer.

To date, over 4000 kits have been distributed to middle school (MS) and high school (HS) students in 3 local school districts. A fundamental aspect of the GOAL programming is the inclusion of culminating events wherein multiple classrooms come together for challenges and competitions. These events motivate connectedness to content and offer opportunities for group discussion and collaborative design. These events are used to provide exposure to UMD and engineering and include information sessions regarding pathways for admissions and transfers, better familiarizing the students with higher education. Several culminating events have been conducted, initially beginning with online and hybrid events, and expanding to an energetic 650 student, 4 school, 32 class, in-person competition with Prince George's County Public Schools during Summer 2022 and most recently a 100 student on-campus competition and Maryland Engineering introduction with Montgomery County Public Schools in December 2022.

Working closely with the school systems, the GOAL programming was focused on classes and locations that had significant populations of historically underrepresented and first-generation students. GOAL is actively expanding to additional local school systems, and is even exploring online programming, including an international collaboration with a school in Nigeria.

Assessment

2021/2022 Assessment Data (out of 267/252 responses):

- ➔ 56%/36% identify as women
- ➔ 87%/58% historically underrepresented minorities
- ➔ 46%/49% no identified immediate family that have earned a 4-year institution college degree

We want to hear from you!
Provide feedback and share your results here.

go.umd.edu/GOAL2022

Assessment is currently managed with an IRB approved post activity survey that is shared with the K-12 teachers, students, and parents. The survey captures data, including grade level, gender, race, first generation college student status, first generation engineering status, interest in engineering, challenges to possibly pursuing higher education, engineering exposure, confidence in pursuing engineering, and kit activity feedback. Completion of the survey is highly encouraged, through voluntary participation. The assessment is a work in progress and we are exploring possibilities of partnering with the UMD College of Education to help strengthen the assessment process to ensure that we are meeting the program's goals.

Assessment

2021/2022 Assessment Data (out of 267/252 responses):

- ➔ 47%/73% Did not identify having an engineer in their immediate family
- ➔ 75%/77% Responded that the activity made them interested in learning more about engineering
- ➔ 60%/52% Responded little or no experience with engineering activities outside of classroom
- ➔ 88%/90% Responded some confidence in their ability to complete another engineering-related activity on their own

Assessment

- ➔ Main challenges to achieving career goals: math, need to improve time management and study skills, overcome fear of failure and mistakes, procrastination, & lack of confidence
- ➔ Kit feedback: More kits with different activities & variation in part fit due to tolerance of parts

The assessment also captures what the students feel are the main challenges they will need to overcome to achieve their career goals so that we can help address these challenges as well as gather their feedback on the kit, activities, and culminating event experience.

Integration with Undergraduate Courses

- ➔ Infusing responsible engineering throughout the undergraduate curriculum
- ➔ Opportunities for students to "Do"
- ➔ Incorporating multidisciplinary approaches to solve real problems

GOAL is more than just an outreach program as it also has significant impact potential for undergraduate education at UMD. As of Fall 2021, the design, testing, manufacturing, and implementation of the GOAL program has been integrated into 2 undergraduate courses and a service-learning group. This integration provides undergraduates with the unique experience of bringing a real-world product to the public domain, including stakeholder involvement, end-user testing, mass-manufacturing and assembly. More impactfully, GOAL presents an opportunity for UMD students to actively advance the goal of ensuring equitable educational access, a problem whose impact is directly experienced within students' own local communities (both geographic and professional). Faculty and staff stress the importance of diversity and inclusion in engineering. Students are challenged to think about how their designs can be used to engage K-12 students who might not be familiar with engineering. The GOAL experience grants our undergraduates direct agency in solving an important educational challenge and empowers them to connect with their communities and engage with social challenges.

Co-Development with Community

In addition to the teacher involvement during implementation, **15 local teacher partners were directly involved in the design process**. The undergraduate student classes worked closely with these teacher partners to design and test prototype versions of the kit and curriculum. This stakeholder involvement adds tremendous value to the design of the programming, providing concrete insight into the needs and constraints of existing STEM classrooms. An example outcome of this collaboration was a testing event held during the Spring 2022 semester at which over 60 students were brought to the UMD campus to pilot the newly developed kit and curriculum. The event coincided with the Mechanical Engineering Design Day, further connecting the participants to engineering and undergraduate students at UMD. We plan to hold another testing event for version 3 of the kit once ready.

This process of co-development creates **real agency for these important stakeholders, and establishes genuine connectedness between K-12 educators and UMD**. In this way the GOAL kits are not just a UMD project, but a community product, creating a cohesive education ecosystem.

Partnerships

K-12 Partners

Campus Partners

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K-12 Partners: GOAL is distributed through multiple channels, including school districts, specific teacher partners, and collaboration with other outreach programs. The first major partnership is with UMD's home district of Prince George's County Public Schools (PGCPS). PGCPS implements GOAL as the centerpiece project for their Summer Bridge program for rising 9th graders who are entering HS engineering programs. Each year the GOAL challenge is integrated into their program finale which includes 4 schools and ~700 students. UMD partners closely with administrators and teachers to develop the curriculum. UMD is also responsible for providing design challenge programming and information sessions at the final event.

Montgomery County Public Schools (MCPS), a neighboring district, is the second major partner in the GOAL program. MCPS implementation is during the school year through specific STEM classes at the middle school level. The program is rolled out at locations where there are high populations of historically underrepresented students in STEM, or where the district has observed dramatic drops in STEM interest among underrepresented populations. The GOAL curriculum occurs across multiple classes at different times during the year. There are ongoing efforts to reconstitute these groups for design challenge events toward the end of each semester. MCPS distributes 750-1500 kits per year.

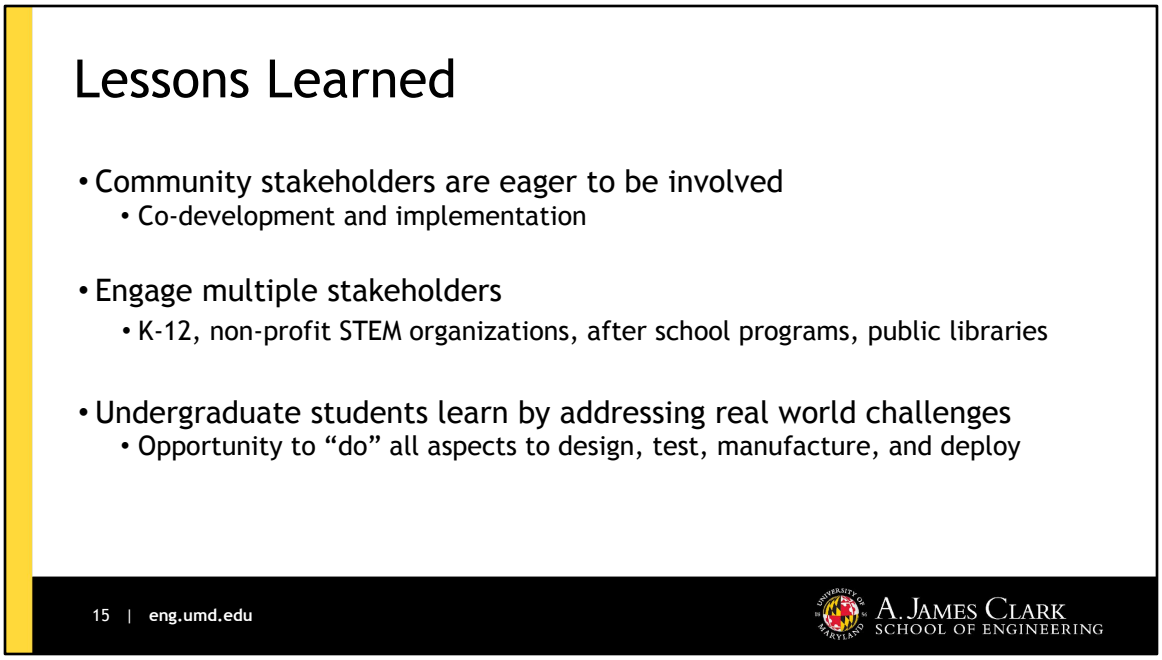
Students from District of Columbia Public Schools have also been a part of the GOAL programming through our relationship with specific teacher partners. The GOAL kits provide stand-alone, ready-to-go, activity packages that can be readily integrated into other outreach efforts, and GOAL kits are often requested for a variety of one-off events. Engineering For US All (e4usa) is another major engineering outreach effort, and GOAL has been utilized as an aspect of the course curriculum in e4usa classrooms. Teachers from all of these groups have participated in the co-development and design of new versions of the GOAL kits. Other area public schools are expressing interest in the GOAL program and we are beginning to explore the expansion of our partnerships to these new school systems.

Campus Partners: The GOAL program originally launched from Women in Engineering (WIE) and the Department of Mechanical Engineering, and all aspects of the program still run through these two main entities, including design, production, finances, partner relations, distribution, and events.

Undergraduate education integration has been spearheaded by the newly formed Environmentally and Socially Responsible Engineering (ESRE) group. ESRE first worked with Science Technology and Society (STS), a College Park Scholars program, to reprogram an STS service learning course toward developing GOAL. ESRE supported this class for two semesters during the pandemic while the historic in-person service activities were not available. ESRE tackled the design, testing, and manufacturing of the 2022 kits as a part of their new “Entrepreneurial Design Realization” course. ESRE also has developed partnerships with the schools of education, business, and public policy, which will be a part of the program's growth.

The Research, Instruction, and Service in Engineering (RISE) student group provides personnel support for many GOAL events. The college’s office of Recruitment and Outreach has provided support through information sessions at events. The Physics Education Research Group is currently planning on financially sponsoring future on-campus GOAL culminating events.

There are several corporate sponsors who have supported the GOAL program via connections established through the Engineering College's Development team. There has also been additional grant support from the Maryland Space Grant Consortium and the Lemelson Foundation.



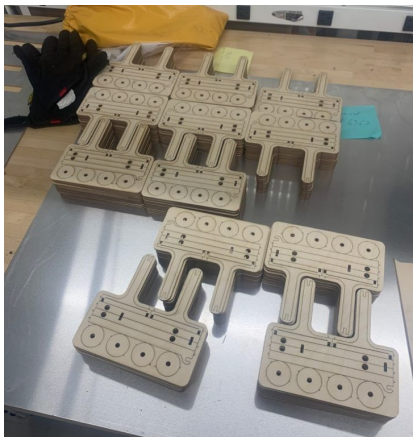
Lessons learned:

Community stakeholders are eager to be involved and co-design and implement the engineering activities. It's important to engage multiple stakeholders, from K-12 teachers, administrators, and students to campus partners, including staff, faculty, and undergraduate and graduate students. We are exploring ways to connect and collaborate with our community non-profit STEM education organizations, after school programs, and public libraries. Stakeholders are much more engaged when invited to be a part of the design, testing and implementation of the program.

The program addresses a vital need to train the next generation of engineers to be ready to address the complex multifaceted challenges facing the world today. In many undergraduate engineering courses, there is often too little time for the students to "do" and engage in a project from ideation, design, prototyping, testing, and small scale manufacturing. Taking a design and prototype to then scale and manufacture at this level, brought to life challenges such as need to consider material consistency, deployment and delivery of the kits, etc. This program gives undergraduate students the chance to move beyond case studies and prototyping to address real world challenges at a small scale.

Challenges

- ➔ Funding to expand and scale
- ➔ Program staffing
- ➔ Improving assessment
- ➔ Inclusive activity design



Limited funding and support hinders institutionalization, with the program continuing to rely on a small number of faculty and staff. The latter also makes the program less effective than it could be, since there are a lot of “moving parts” to be managed.

The majority of the current funding is for direct manufacturing and operational costs. These aspects are attractive to fund but only make up a part of the need for the program. Although costs for physical parts have been covered to date, most of the effort to make this program successful has been voluntary. If the GOAL program is to continue to grow and scale, then program development and workload needs appropriate consideration and support.

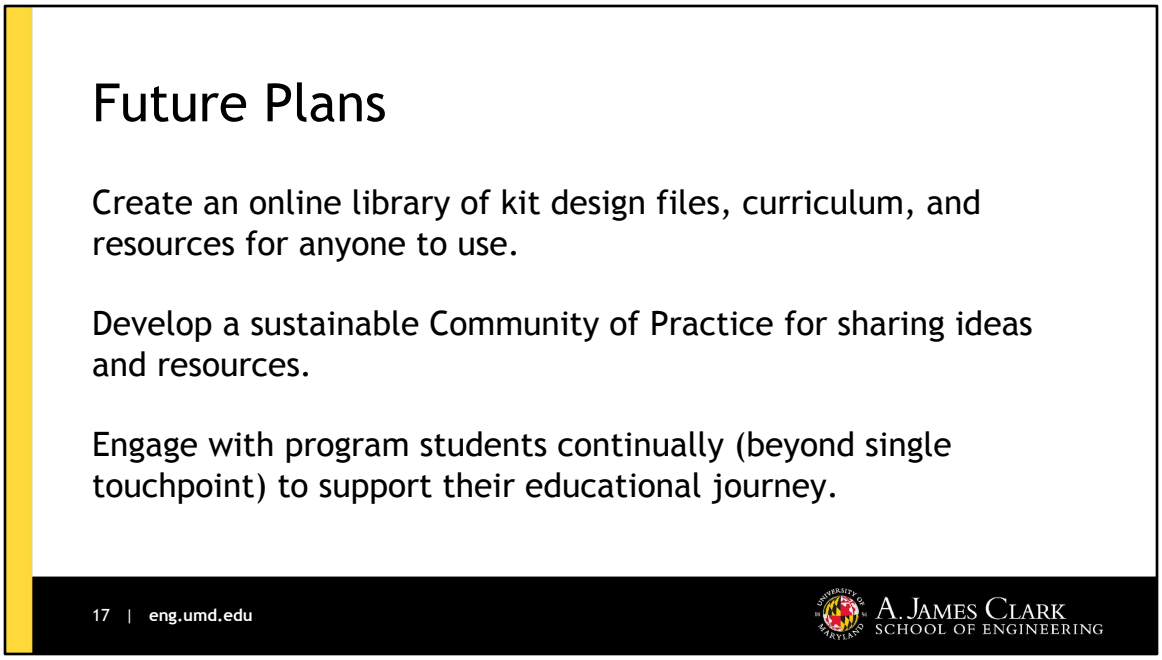
The program continues to seek funding for **program management**, **developmental + design costs**, the **analysis and advancement of assessments**, and the **dissemination of assessment results**. These aspects are traditionally more difficult to fund but are vital to the expansion and continuation of the project.

The undergraduate course is necessary not only for the design, testing, and manufacturing of the GOAL programming, but also for involving undergraduate students and for stakeholder/community agency, two main GOAL program outcomes. To date, the course instructional load has been primarily voluntary, which is unsustainable long-term, and new GOAL programming will be difficult to develop without instructional support.

The program also seeks materials funding to cover design, prototyping, testing, and sample manufacturing as well as support for stakeholder involvement (such as transportation for events and shipping of supplies). Development and testing costs are intrinsic to any physical product that is released at scale, and these activities ensure quality design and participant engagement. The release of low quality components or untested curriculum not only reduces the success but may even undermine program outcomes. Development funding may also be directed toward production costs. For example, bulk material procurement may be necessary for feasibility and planning during the design phase. Early procurement would support some production costs and reduce design-to-production times (critical for the rapid Spring to Summer integration timeline).

Support is also needed for the assessment of program outcomes. The main aim of the GOAL program is to provide a pipeline for historically underrepresented groups to pursue STEM careers (particularly at UMD). Assessments are currently in place to begin to measure these outcomes. Preliminary results include observed increases in an interest in learning more about engineering, increases in excitement about engineering, and general interest in attending UMD. Without proper assessments and the monitoring of these assessments, the GOAL outcomes cannot be properly measured for impact or effectiveness, especially for impact of reaching target audiences. To date, the workload for GOAL has been dominated by the logistics of the program implementation. No personnel time is currently available to dedicate to the assessment of the activities.

Another challenge to address is the design reliance on traditional STEM education activities, such as vehicle-based challenges. Studies have shown that more gender-neutral activities and those that also involve other disciplines, such as art, can be more effective in changing attitudes toward STEM. Therefore, reaching out to other colleges within the university to devise new kits is an exciting opportunity that is being explored.



Future plans for this program include continuing to utilize the undergraduate courses to collaboratively design new kits for the development of an online engineering curriculum library for K-12 educators that will expand the educational reach, focusing on co-design with historically underrepresented groups. This will help other educators replicate the kit themselves so that they can utilize the activity.

Build a sustainable Community of Practice to better support teachers and those implementing the activities as well as provide a shared resources and add-on curriculum repository.

Explore ways to move beyond a single touchpoint to continually engaged these students with engineering throughout their educational journey.

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Thank you & Questions