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Engagement in Practice: The GOAL Engineering Kit Initiative

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Engagement in Practice: The University of Maryland's Get Out and Learn (GOAL) Engineering Kit Initiative

Undergraduate engineering education often reinforces an arbitrary sociotechnical divide that attempts to isolate technical skills from their embedded social environments (Cech & Sherick, 2015). Engineering curriculum focuses primarily on developing technical skills, often without consideration of the social (e.g., cultural, political, economic) contexts within these technologies, skills, or training are situated. Service-learning opportunities for engineering students and faculty represent one opportunity set for bridging social and technical knowledge and skills. Furthermore, service-learning courses can foster an engineering culture of practice around STEM education that brings together multiple on and off campus communities in collaboration (Eyler et al., 2001; Jacoby, 2003). In this paper, we discuss the ongoing Get Out and Learn (GOAL) program, an innovative project developed in response to COVID-19 school shutdowns. The GOAL program sought to provide K-12 students with a basic STEM learning activity kit to illustrate the engineering design process. The activity was supplemented by a curriculum that complimented in-class learning and demonstrated simple engineering concepts. Once K-12 students and teachers had used the materials, participants attended (virtually) a culminating event that introduced middle and high school students to the University and connected them with current undergraduate engineering students. In the first two years, 3500 kits have been distributed, primarily through two school district partnerships. Consequently, the program provided important opportunities for knowledge and skill development across overlapping technical and social domains.

In this paper, we articulate the history and objectives of the GOAL program and its evolution. We discuss how the program engaged several communities of practice (undergraduate students, social science and engineering faculty, K-12 teachers and students, external funders) in an emergent, collaborative STEM education exercise. Finally, we note some preliminary outcomes, areas of tension, opportunities for program growth and scale.

GOAL Program Launch and Evolution

In the summer of 2020, UMD's Women in Engineering (WIE) program and the Department of Mechanical Engineering initiated the GOAL program in response to the sudden shift in the K-12 educational environment created by the COVID-19 pandemic. The cancellation of outreach programs, summer camps, and the complete pivot to online/remote instructions greatly reduced access to hands-on STEM curriculum and closed outreach avenues for the university. In particular, faculty and staff were concerned with the impacts of school closures on STEM opportunities for traditionally under-represented groups. This shift had the potential to greatly disrupt the pathway for these groups to be exposed to and engage with STEM education and career pathways.

University faculty quickly brainstormed the central tenants of the GOAL program which include:
Intentional distribution to area public schools with targeted underrepresented groups
Inexpensive physical components and a curriculum that introduces STEM concepts
Access to materials and content in a way that is fun and accessible to all.
Student engagement through independent physical exploration, instructional + group reflection, and design thinking.

From the beginning, the GOAL program was aimed at maintaining pathways to expose under-represented and first-generation students to STEM and eventually pursue advanced education in the field. This entails including populations that wouldn't otherwise be exposed, and engaging audiences that wouldn't otherwise be interested in STEM. The ultimate goal is to directly improve the under-represented applications, and particularly those from neighboring school systems that do not traditionally apply to UMD. There are several sub-requirements in achieving this overall goal. The K-12 students are looking for engaging activities that clearly demonstrate observable and repeatable, physical phenomenon. The activities should include some individual exploration building individual STEM identity.

The program needs to be accessible and robust to a variety of skill sets (insensitive to prerequisite knowledge, nomenclature, or skills), living situations, and require little at-home supervision. At the same time the program needs to have a real and recognizable STEM connection, building technical confidence and STEM identity. The desired program should include a culminating event that would ideally be housed on-campus, exposing the K-12 students to the campus community, and providing information sessions about admission requirements and admissions pathways (including transfer pathways that are accessible and economically efficient). Past outreach efforts indicate that getting first-generation students to step foot on campus means that they are far more likely to apply, so this exposure is critical to the overall program goals. Logistically the program needs to be economically feasible, meaning low-cost physical componentry that is easily manufactured, assembled and quality controlled.

Between Spring 2020 - Spring 2021, the first iteration of the GOAL program was implemented using dragster kits created from cardboard, wooden dowels, glue, and rubber bands. Middle and high school students explored concepts of traction and acceleration dynamics by mapping out the nonlinear relationship between wind-up and distance traveled (the kits were intended to reach traction and/or "wheeling" limits across a variety of surfaces). Individual observations could be collected to collaboratively identify parameters for a final challenge, to get their cars to consistently travel as far as possible over different surfaces.

Adding Undergraduate Education

In Fall, 2021, the GOAL staff partnered with the UMD Science, Technology, and Society Program (STS) to incorporate an undergraduate education component. GOAL became embedded within a multidisciplinary, two course sequence. The undergraduate educational element creates a unique opportunity for project-based learning through responsible do-ing.

The first course was a revised version of an existing STS course entitled *Contemporary Issues in STEM Education.* The course was initially a robotics service-learning opportunity (see Aruch et al., 2018), also disrupted by COVID-19 school closures. The robotics aspect was modified to include the GOAL kits and partnered with the same schools and teachers. In the first course of the sequence, students from various majors collaborate with teachers in the local schools to examine the current kit and protype new kit iterations that are more suitable to the goals of the program. The project work includes aspects of technical design, education, policy, and business.

The course has two components, run in collaboration with partner K-12 classroom teachers. In the first part, students assess the dragster kits looking at the kits from different perspectives that assess their curriculum content, forms of capital (Yosso, 2005), and other dimensions of STEM equity. Every other week, student teams touch base with their partner teacher to discuss their class work and get feedback on how the kits are useful (or not) with students. In the second part of the course, student teams consider future kit designs. Using input from their partner teacher and critical concepts discussed in the course, the teams and teachers develop distinct kit prototypes for future consideration. The hope is that these kit designs can be picked up in the second course and potentially manufactured and distributed in future GOAL activity iterations.

The second course runs Spring 2022 and builds off the first. In this course entitled, *Entrepreneurial Design Realization (EDR),* and is housed in the mechanical engineering department but is open to all majors. In this course small, focused groups of students take on responsible engineering projects and bring them to real-world implementation utilizing strong stakeholder involvement, and social entrepreneurship. This course is still in an early pilot stage and the GOAL program provided a clear developed opportunity for a project. The EDR group will assess the proposals from course 1 and move forward with implementation. With the continual collaboration of the teacher partners, this group will select a final program idea, design, and prototype the kit + curriculum, and plan the culminating event activities. This will be followed up with full-scale manufacturing and quality control plans for the physical componentry. The group will also be tasked with seeking funding and continuing the implementation partnerships with the local school systems.

Collectively, these two courses provide undergraduate students with an opportunity to collaborate across majors and work to address a complex social-technical problem (STEM education). In both courses, university students engage and collaborate with multiple stakeholders (i.e., educators, 6-12 students, engineering corporations, manufacturers, etc.), and apply aspects of the design process including project management, social entrepreneurship, design realization, manufacturing, and communication. Furthermore, the courses encourage undergraduate students to reflect upon their experiences, better understand their university community, and grapple with the significance of diversity, equity, and inclusion in engineering. Similarly, the courses are a vehicle to reinforce and continue partnership opportunities between the University and nearby school districts. Finally, the undergraduate course work in a step in the direction of program sustainability, as it solidifies a process for designing, producing, and implementing the kits to local schools.

Partnering With the K-12 education community: District or Teacher

K-12 school community was keenly interested in participating in the GOAL program. With the shift to virtual learning, schoolteachers and administrators were looking for meaningful, accessible curriculum aligned with the Next Generation Science Standards (NGSS) standards. At the district level (in MD, this at the county), district administrators valued the flexible implementation of the kits that worked in a variety of classes and grade levels. In the first iteration of the GOAL program, the dragster kits provided free, accessible, flexible, and engaging materials aligned with the curriculum.

The main distribution method of the GOAL kits is through partnerships with two systems at the district level. GOAL administrators coordinate the distribution of the materials with the district, who were responsible for allocating the kits to teachers and students. In total, 3000 kits were distributed through two years of implementation from 2020-2021. GOAL staff were also able to coordinate with the one district for virtual culminating events that included a final design competition with the dragsters.

A secondary implementation method of the GOAL kits is by distributing directly to cooperating teachers. One example pathway for this is through course 1 of the undergraduate education effort started in Fall 2021. This K-12 teacher community was built on previous existing relationships. Since 2011, a number of partner schools have been working with STS to implement robotics programs (Aruch et al., 2018). The GOAL model was a logical progression away from in person service-learning opportunities. Schools and teachers had the opportunity to continue collaboration with their university counterparts, engage with university students, provide feedback on relevant content and curriculum, and utilize the kits in their classrooms. As of Fall 2021, ~500 GOAL kits have been distributed directly to the teachers.

In Spring 2022, the two approaches were combined. Reaching out to the district administrators, GOAL staff was introduced to a set of additional partner teachers interested in working with a new group of students participating in the STS Contemporary Issues in STEM Education. The students and teachers are currently engaged in a similar process of GOAL kit evaluation and redesign.

Across all, K-12 partners were excited about the opportunity to cross pollinate K-12 and university STEM students in conversation related to technical knowledge, but also informal conversations related to sports, music, food, and other hobbies or interests. Teachers appreciated the hands-on nature of the projects, particularly in the virtual learning environment. The pivot to classroom teacher support is another bonus that helps within the individualized class environments and ensures the kits are activated by their intended users (K-12 students). Related to the GOAL program motivation and objectives, school partners noted that this university exposure is critically important to attract and motivate K-12 students who may be the first in their families to consider university enrollment.

External Partners and Sponsors

External corporate and foundational partners have also supported the GOAL program. The needs of these entities are varied. For example, state educational grants that seek to directly improve local K-12 STEM education, and as such require some demonstration of impact. Corporate sponsors are always interested in visibility but may also include a variety of nuanced requirements. Some corporate funding is earmarked specifically for outreach at the K-12 level, and desire measurable impact assessments related to STEM recruitment of under-represented populations. Other corporate sponsors are looking for exposure to undergraduates, attracting quality and responsible minded engineers and scientists.

The culminating event is a very visible opportunity to engage the sponsor community. As noted, some sponsors are looking for direct ways to interact with undergraduate students, and some are interested in interaction with K-12. The culminating event provides a method to directly involve sponsors and their employees by way of competition or design judging. The culminating event additionally provides a clear opportunity for sponsor visibility.

GOAL Program Challenges and Opportunities
Over two years, the GOAL team has received important feedback from school administrators, teachers, K-12 and university students about the challenges and opportunities for the GOAL program. Still, there are important practical and logistical challenges for K-12 and university partners as they consider the design, implementation, and evaluation of the GOAL program.

K-12 Challenges and Opportunities
School administrators are open to new programs and collaborations, particularly when those programs are low cost (or free), require little staff time or training, and are affiliated with a well-regarded institution (like a university). In this case, the GOAL kits meet those benchmarks. However, there were several challenges. For one, there are ongoing challenges in communication across institutions as personnel are always changing roles and responsibilities. As a result, working at the district level to distribute the materials at a large scale presented a different set of communication and coordination challenges than working directly with teachers. At the district level, university partners had little input into the distribution and implementation of GOAL activities. Still, there were a great number of kits allocated to students.

On the other hand, working with teachers ensured use of the materials. However, it required ongoing coordination between K-12 teachers, university staff, and undergraduate students. Furthermore, the semester schedule was not always aligned with the K-12 curriculum. Similarly, there was some confusion around expectations for implementation on both the K-12 and university on how kits could be used.

Overall, the teachers were especially interested in collaborating via feedback and the development of the next kits. There is certainly a strong desire to be a part of an effort that has far reaching implementations extending beyond their individual classrooms. Several teachers reached out to the undergraduate course instructors eager to find out when they were meeting with their student teams next.

In an anonymous survey assessment to follow up on K-12 outcomes, results indicated a high positivity in self-reported STEM confidence, the desire for more activities like the kit, and the positive role of the kit toward inspiring further exploration of STEM. The current COVID restrictions do not allow for direct K-12 student interaction but the undergraduate to K-12 connection is a component of high value and is always a desire for any outreach effort. The future direction of the program includes more direct connection with this community by way of an in-person culminating event that brings these students to campus. Tentatively an on-campus event is scheduled for the end of Spring with one partner school system but faces challenges related to COVID and field trip restrictions.

University Challenges and Opportunities
At the university level, there were similar issues of staff turnover and internal administrative tension among roles and responsibilities pertaining to instruction, budgets, and curriculum.
In the GOAL course, the lack of 'in-person' service meant preparing undergraduate students with some skills for contacting external partners, preparing a meeting agenda, recording notes, and managing a schedule. The undergraduate student teams often required a lot of nudging and reminding to contact their assigned teacher partners. To incentivize communication, assignments

were created that acknowledge when students sent a direct message to their teacher partner via email, text, or another form of communication. On the other hand, these were important skills cited by class participants as a benefit of the course. The role of the teachers within the course curriculum was critical to success as they were the only link to the K-12 students using the kits. Students appreciated and acknowledged the course as a rare opportunity to work directly with real world practitioners relevant to course materials. Students noted how challenging curriculum design and lesson planning is for students from diverse backgrounds and skill levels. Moving forward, juggling developing these undergraduate communication skills with keeping the teacher partners engaged is something that needs to be carefully balanced in future iterations.

Logistically speaking, the kits themselves presented several challenges in their financing, materials, and distribution. The first kits were financed and purchased through an external provider. The materials were not built to specifications and needed to be modified for packing and distribution. The GOAL course helped mediate this issue by using students as labor to cut dowels and package kits. Still, for future kits, the cost, standardized parts, and physical size are logistical limitations as we consider the inventory, storage, and distribution of materials.

Shared Challenges and Opportunities

There were several shared perspectives on the goals. Communication and logistics noted above were shared, but there were also shared concerns about materials and curriculum. K-12 and university students all noted that some of the materials were of poor quality, easily broken, or were difficult to assemble. The GOAL kit, if not assembled correctly, did not perform in interesting ways, and the materials were not durable to last through multiple uses. Similarly, there were repetitive or boring aspects of the curriculum that may not be interesting or motivational for a product intended to inspire STEM engagement.

Another significant challenge is program evaluation. For university actors, once the kits leave campus, there is little control of their implementation. For K-12 actors, the evaluation goals are different. One focus of GOAL is to encourage students into STEM activities. While this is important, K-12 teacher motivations are focused on engaging classroom activities, student learning outcomes, and meeting standards. While the two are related the evaluation metrics are different.

Still, university and K-12 partners agreed that the GOAL program has a strong foundation. The program is anchored in a commitment to creating a dynamic and collaborative set of teaching and learning opportunities. The program is built on foundational relationships across institutions within programs (STS, WIE) with proven experience in community engagement and service-learning.

Conclusion

The GOAL began as a university pivot to community engagement in the face of school closures during COVID-19. Like other outreach programs, GOAL is committed to the recruitment of underrepresented students into engineering. From March 2020 - 2021, GOAL kits were distributed at the district level. In August 2021, the GOAL component began to work directly with teachers by integrating in pre-existing undergraduate course work. Today, the program has reached more than 3500 students broadly. Through undergraduate coursework, we've worked in collaboration with about twenty partner teachers and schools. Moving forward, the program plans to leverage these relationships and program activities to build a sustainable interactive set of STEM materials.

While there are challenges with respect to logistics, administration, and communication, K-12 and university participants are aligned in their mission to generate exciting opportunities for STEM engagement, confidence building, and competency.

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