Cultivating High School Leaders through Engineering and Science

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Abstract *- Engineering and leadership go hand in hand for many within the engineering profession and throughout undergraduate studies. Students are challenged to work in teams, self-assign tasks, manage team members, set deadlines and see projects to completion. The Waterloo engineering Catalyst High School Summer Leadership Program (Catalyst) aligns specifically with the engineering knowledge base, problem analysis, investigation, design, lifelong learning and communication outcomes outlined by the Canadian Engineering Accreditation Board (CEAB). Catalyst was developed to link engineering problem solving and design with leadership skills.*

Catalyst students are engaged to develop both soft and hard skills in an effort to display the multitude of connections, benefits and opportunities available to students entering their undergraduate studies. More and more entrepreneurship, design and effective group leadership are all becoming essential traits and skills for students entering the workforce as well for those taking the leap to dream, market, build and succeed with their own ideas or products.

Over the past three years, the summer leadership program has grown through trial, feedback and collaborative brainstorming to offer a four-week program that focuses on leadership skills, design, research exposure and entrepreneurship. Through hands-on design thinking and problem solving projects, entrepreneurial group study and by offering leadership experience in a controlled setting a new type of high school student emerges. One who is prepared, excited and inspired to get involved, try, fail and challenge themselves and their peers to create change and solve problems facing their generation.

Keywords: Outreach, Youth, Secondary Student, High School, Programming, STEM

1. INTRODUCTION AND BACKGROUND

1.1 Discovering the need for High School programming

The Engineering Outreach office at the University of Waterloo began in 1990 with the formation of the Engineering Science Quest (ESQ) summer program, which was designed to educate the elementary aged population about what engineers are, what they do and promote the study of engineering and science to students in the local community. As the ESQ program has grown to accommodate all elementary grades, inquiries about opportunities for high school students have also grown.

Over time, a junior leader volunteer program was created which offered the chance for high school students to volunteer in an ESQ camp room and receive community service hours to apply towards their high school diploma requirements. As the junior leader program developed it became apparent that there was a group of high school students who were eager for more formal leadership training and a deeper exploration of engineering than what was provided by ESQ.

In 2012 the Catalyst Summer Leadership program, a multi-week day camp for youth entering grades 10 or higher was developed with the goal to train incoming volunteers while also providing a continuation of the ESQ camp programs with the ability to focus on larger projects.

1.2 Outreach vs. Recruitment

An important distinction needs to be established between programs as being primarily outreach or recruitment. On the surface the idea of high school outreach being used as a recruitment tool is an easy connection to be drawn. Although recruitment is certainly seeded in the program, the local day-camp structure of the program is less effective from a recruitment standpoint. The small size and focus on local students does not make the Catalyst programan ideal recruitment tool for Waterloo. If the program was larger, and offered an overnight residence program for students from abroad, Catalyst would better meet the interests of recruitment.

The majority of Catalyst Summer Program participants are students who have just completed grade 9 or 10. This particular selection of students are ideal candidates because for many of them, they have not yet made any concrete decisions about what their post-secondary career might look like and are starting to look towards what courses are needed for their post-secondary future. UW's engineering program, reputation and graduate successes are easy to boast about, it is a competitive, highly focused environment and often times can be very intimidating to students still trying to figure out what they are both gifted and interested in. Rather than using the Catalyst program to pitch a recruitment message, the core sentiment of the program is Science Technology Engineering and Math (STEM) education and the importance of disciplined study in each subject throughout a student's high school career and removing assumptions and possible fears about post-secondary education.

1.3 Science, Technology, Engineering and Math Promotion

Though many of the participants for the Catalyst program are already geared towards a post-secondary study of science or engineering, there are a few that need to see the benefits and opportunities gained from the pursuit of STEM subjects at the high school level. The Catalyst program offers opportunities to learn more about the breadth of subjects within science and engineering and experience hands on learning opportunities that highlight many of the skills, attributes, research and goals of engineering study. Not only does it illustrates the possibilities but provides a strong connection between the academic theories learned as an engineering student and the real world application of those theories. Students entering the program are also at a point in their academic career where major changes to their course selection can still be made. A student entering grade 11 can still make academic course changes they will allow them to meet the prerequisites for engineering, while for a grade 12 students a modification of that magnitude, though possible, is much more difficult if they intend to apply and graduate with their cohort. Highlighting the engaging, interesting and noteworthy research, facilities and people to a grade 10 and 11 audience and challenging them with personal leadership development sessions inspires them to align themselves with the admission requirements for an engineering program long before they need to prepare and submit an application.

2. CATALYS SUMMER STEM AND LEADERSHIP PROGRAM

The Catalyst program has evolved from year one to address different topics within the engineering community but largely the program is split into two major themes, entrepreneurship and the business of science and the theme of engineering design and skills. The overarching goal for delivery is to have as much hands-on interactivity as possible. Sessions that follow the hands-on approach allow students to learn much of the theory they need whilst they are problem solving. In the last two years the coordinator and facilitator have looked for more opportunities to infuse and integrate principles of inquiry based learning which allows the students themselves to direct the path of the session. Allowing students to control what they engage with, how and what they get out of that engagement has been a difficult transition because it requires a great deal of trust and confidence in the curiosity and work ethic of each student.

2.1 Exploration of Engineering

Week one of the program has a focus on engineering design skills and the tools needed to make a design a reality. Participants work individually and as part of a group. Alongside tours of labs and research centres on campus. Table 1 provides a sample of hands-on activities and how they tie to engineering disciplines.

Table 1 Sample Engineering Activities

Engineering Discipline	**Activity**
Electrical	Circuit assembly / soldering activity
Manufacturing	3D printing
Design	Building and testing a cardboard boat that will carry at least one team member across the length of school pool
Mechanical	Assembly and exploration of fuel cell car kits
Computer	Arduino programming and construction
Software	Talk and presentation on embedded systems

These activities focus more specifically on the academic and research side of the engineering program at UW and allows for plenty of connections to be made with faculty and research groups on campus. The sessions are sequenced in such a way that core knowledge and skills are introduced and then reinforced throughout the rest of the program.

2.2 Business of Science

The second week expands the focus from engineering skills to incorporate entrepreneurship and business problem solving. Table 2 describes the principles that are being addressed and the way in which the sessions challenge participants to investigate each one.

The business focus is further supported with an off campus visit to the Communitech Hub start-up incubator which also shares space with the Google offices in downtown Kitchener. Seeing these two offices shows real world examples of people who are starting the process or have completed the same steps that students have just finished learning about.

Table 2 Business of Science

Principle	Practice
Ideation	Participants are given constraints within which to work. These constraints might be specific to their client, location, economic market or any other unique need.
Market Research	Participants first poll each other, conduct internet research and then when time allows, move on to asking the public. Being on a university campus is convenient because there are students, staff and faculty readily available to be polled.
Prototyping	Using program owned resources participants are able to design a prototype using 3D printers, SketchUp, CAD programs and physicals materials.
Pitches	In front of an audience of their peers, engineering outreach staff and people from community partners and supporters participants present and pitch their new business idea, explaining what the need is and how they have addressed it.

2.3 Leadership Development

During the development phase of Catalyst, it was felt that many leadership programs focus on skill development but do not give a chance for practice outside the classroom. With this in mind the third pillar of the program was a focus on providing both leadership development and relevant experiences outside of the Catalyst classroom. Table 3 lists the principles addressed and how they may be put into practice.

Table 3 Leadership Development

Principle	Practice
Public Speaking	Participants are taught a standard camp activity of making slime, and are expected to deliver this activity for each week they are in a camp room.
Dealing with the unexpected	Activities throughout the Catalyst camp session with a focus on developing improvisational skills. For example, being given an easy task, but missing key components. This mirrors how in camp environments you may have to make adjustments on the fly.
Reflection	During the weeks leading up to their placement, participants are placed in camp rooms for an hour at a time to observe how the camp room operates. They reconvene as a group and share their observations and reflections of what they learned with other.
Responsibility	Students are put in charge of organizing free time play, leading small camper groups through activities and transitions.
Feedback	At the end of each week of their volunteer experience they are given constructive feedback from supervising staff, a plan if formed on how to act these comments.

By offering leadership experience as a volunteer placement, this allows the Catalyst participant to achieve the mandatory community service hours that are needed for their Ontario Secondary School Diploma.

At this time the practice experience is being offered in ESQ, which replaces the ESQ Junior Leader program. For some the ESQ camps environment is familiar. This familiarity allows them to focus on practicing their leadership skills. For many this is the first time they have had a chance to be in a position of responsibility over people who are not their peers.

2.4 Connection to CEAB Outcomes

While the programs were not designed to meet the CEAB outcomes, the program has unintentionally met many of the outcome topic areas. Specifically the focus on Engineering design skills addresses the design, project management, teamwork and engineering knowledge base outcomes. The business entrepreneurship focus addresses problem analysis, investigation, communication skills and business planning outcomes. Going forward the CEAB

outcome list along with various provincial curriculum documents will be used as a list of learning outcomes to help guide and further direct development of the summer program.

3. CHALLENGES

Promoting the program has been a challenge. The program needs to stand out amongst the many other enrichment, leadership and advanced placement opportunities for high school students, and their desire to work a summer job. The most overt challenge has been enrolment and working towards filling the program every year with students who will benefit the most from the program's offerings by not only their attendance but also their own investment. The small number of participants each year makes it more difficult to create the word of mouth that might help to grow other, larger, programs faster.

There are two methods of promotion currently being used; the first is promoting the program to parents of the ESQ program, and the second to local schools through guidance counsellors and in-school workshops

3.1 Internal program promotion

Promoting Catalyst to families enrolled in the ESQ program has been where the most success has been found. The majority who come from this path are participants who have attended ESQ for multiple years and see the Catalyst program as a means to summer employment at ESQ.

The volunteer placement in the ESQ program also builds on and supports the connection. While giving practical experience to the Catalyst camper, it also exposes the ESQ camper to the Catalyst program.

Despite the large size of the ESQ summer program, the number of youth who would be eligible for Catalyst each year is small. In summer 2014, only 38 participants met the age requirements for Catalyst 2015. In future summers, more effort will be given to intentionally promote the program to the more senior camps with hope their participants will join the program in the next two to three years.

3.2 Communication with schools

School boards understandably limit the amount of direct-flyer based advertising towards their students. As found in ESQ, offering workshops that have a hands-on component with the program promotion as part of the presentation is an effective way to circumvent this barrier. The local secondary school teachers have commented that two factors stand in the way of widespread interest in them booking workshops for their classroom: time and money.

In Ontario, grade 9 and 10 teachers are responsible for covering four major subject areas throughout a course's lifespan: Biology, Chemistry, Earth and Space Science and Physics. Taking the nineteen week term and subtracting exam periods and days off, teachers have roughly three and a half weeks to cover each subject. Due to the rotation structure of high school, teachers only have students in their classrooms for 75 minutes a day, which further constrains the available time. This poses a challenge for workshop delivery and promotion because the window for meaningful program delivery is very small. Workshops need to be designed to supplement the education curriculum and also be flexible to compliment the teaching style/plans of the classroom instructor.

There is a cost to delivering these workshops in terms of time, transportation and consumable materials. High School teachers have a limited budget which is designed to cover replacement of lab supplies, AV repair costs and upgrading of text books. Even when workshops are offered at no-cost, the larger issue of available time remains the limiting factor.

3.3 Maintaining interest once in the program

The Catalyst program currently offers two weeks in a classroom setting, and two weeks of volunteer experience. This two week period allows for large more in-depth projects, but also brings a bigger need to keep interest strong, and to carry over the weekend breaks.

An application process exists for Catalyst, which helps to ensure only those who want to benefit from the program apply. The application asks the student to answer a couple questions expressing what they wish to get out of the program, and also a letter of reference from a teacher. The application process was design to not be a small hurdle to attending.

Once they are on campus, the primary method to ensure interest has been to focus on the amount of hands on engagement that is built into the program and the opportunity to investigate their own interests. Because of this freedom for the participants, the 'buy in' period is greatly reduced and participants are much more likely to contribute meaningfully, reflect and genuinely invest themselves in the sessions. The UW Engineering Outreach office also has the benefit of having plenty of interesting content to show off that has been developed over time.

Integrating new research, lab space, facility tours, faculty or grad student talks and student team projects helps to accentuate the highlights of the possibilities available for engineering students. Catalyst participants get the chance to see lab space and learn about the institutes and facilities at Waterloo in a more in depth and meaningful way than what one might experience during a campus open house or general faculty tour.

The facilitators and coordinators have learned to leverage these opportunities to keep the enthusiasm and excitement going throughout the session. These experiences again, effectively shortens the 'buy in' period for the participants and gets them excited about what is coming next in the schedule

3. DISCUSSION/CONCLUSIONS

During the three years the program has been offered the development and planning has constantly been tweaked in an effort to determine if there is a higher impact schedule that can be assembled or a method to increase the effectiveness of sessions that have carried over from year to year. Through this process of reflection, several notable points have been learned.

First and most importantly the Catalyst program has shown that grade 10 and 11 students can still be pushed to complete the extra work necessary to compete for a spot in a post-secondary engineering program. In the case of the Waterloo Engineering Outreach office, this has been accomplished by focusing on creating a program that is as hands-on and participant driven as possible and connecting with exciting researchers and facilities on campus.

The second realization was that Catalyst program was able to meet the same curriculum goals as a traditional classroom but without the same imposed structure. If anything the environment and opportunity to explore is almost the opposite of a traditional classroom space.

Lastly, the realization that promoting opportunities through school board contacts has been ineffective in actually getting the word out about the program and it is associated benefits. The strongest connections have been formed when we communicated directly with the teachers who provided us early feedback about the workshop program. Going forward, more effort will be made to directly connect with teachers.

As a result of these periods of reflection, assessment and analysis the Catalyst program has evolved to target a particular set of skills that high school students are not able to exercise as frequently, doing so through projects and tasks that they themselves guide. Furthermore the program has been able provide opportunities for high school students to expand their engineering knowledge, develop their business acumen and build confidence in their problem solving and leadership skills. Despite the struggle of building the program's reputation in a saturated market of opportunities aimed at high school students, the program continues to grow and evolve to address the needs and abilities of this audience. Through hands-on engagement and fostering genuine curiosity the Catalyst program will keep providing opportunities for high school youth to challenge themselves and their perception of what they can accomplish.

Acknowledgements

The authors wish to acknowledge the work of the Catalyst staff past and present. In particular we wish to acknowledge the work of Gareth Sharpe who has been the lead activity developer and program facilitator since its inception.