DESIGNING A MOBILE MAKERSPACE: A STRATEGY FOR INCREASING DIVERSITY THROUGH K-12 ENGINEERING OUTREACH

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Abstract — Makerspaces, physical spaces that provide access to fabrication tools, technologies, and resources, are potentially changing the way educators envision teaching and learning. The purpose of this poster is to illustrate how an engineering design process is being used to help guide Connections Engineering Outreach to design, build, implement, and evaluate a mobile makerspace. One of the objectives of the mobile makerspace is to provide outreach workshops to underrepresented and underserviced groups in an attempt to increasing the diversity in Science, Technology, Engineering, and Mathematics (STEM). Since January 2018, the mobile makerspace has delivered workshops to approximately 2000 students in Grades 3-8. Preliminary results from an online survey indicate that the workshops provided high levels of student engagement and opportunities to learn about STEM. Interview results also suggest that the workshops are helping build the capacity of educators towards using makerspace technology. This project is yet to complete one full cycle of the engineering design process and will be conducting on-going program evaluations.

Keywords: Makerspace; Diversity; K-12 STEM Outreach, Education, Engineering

1. INTRODUCTION

Connections Engineering Outreach (CEO) of the Faculty of Engineering and Applied Science at Queen’s University is a K-12 engineering education outreach organization. CEO’s mission statement is to educate, inspire, and raise the profile of engineering and other Science, Technology, Engineering, and Mathematics (STEM) careers among pre-university students, educators, parents, and the public. Specifically, CEO’s three main objectives are to:

1) Provide experiential opportunities for pre-university students to learn about STEM, with an additional focus on increasing diversity within the engineering profession;
2) Develop and share engineering education tasks that align with the Ontario K-12 curriculum;
3) Provide support and professional development opportunities for educators looking to integrate engineering and 21st century competencies into their teaching practice.

As interest around the utilization of STEM outreach organizations and the involvement they can have towards student learning increases, a key challenge is fostering a relationship between STEM education research/knowledge and the educators who are looking for ways to utilize it. One recent topic of discussion in education is on makerspaces, in which schools and educators are looking to design, implement, and utilize them within their school. Makerspaces, physical spaces that provide access to fabrication tools, technologies, and resources, are potentially changing the way educators envision teaching and learning. To align with its three objectives, CEO used the makerspace literature and an engineering design process to design and build a mobile makerspace to support local schools and educators.

1.1 Motivation for this paper

The motivation for this paper was supported by the knowledge mobilization strategies used by the researcher who is also the engineering outreach lead within CEO at the Faculty of Engineering and Applied Science at Queen’s University. By sharing information about the process of designing, implementing, and evaluating a mobile makerspace within the constraints of a publically funded university, outreach organizations who are considering following CEO’s delivery model and designing their own makerspace, will have a framework or foundation to build on. Additional motivation was to showcase how an engineering design process was used to help solve the complex problem of a mobile makerspace.

1.2 Significance of the paper

Within academia, this paper may contribute towards education within the broader field of STEM education.
goals of the project are to specifically provide increased opportunities to underrepresented youth. It will also contribute towards the body of literature surrounding makerspaces and the link to developing 21st century competencies. Beyond academia, this study may be used to inform the practice of STEM outreach organizations towards developing a mobile makerspace to increase their target audience, which may also have an influence on K-12 teachers responsible for teaching STEM subjects.

2. ENGINEERING DESIGN PROCESS

The purpose of this poster is to illustrate how the steps within an engineering design process that is suitable for the K-12 education system (shown in Figure 1) was used to guide CEO’s mobile makerspace project.

2.1 Defining the problem

According to a recent document published by the Ministry of Education in Ontario, there is a call for the education system to emphasize and develop 21st century competencies through changes in curriculum and pedagogical practices [1]. One goal of these changes is to prepare students to solve messy, complex problems associated with living in a competitive, globally connected, and technologically intensive world.

The makerspace movement contends making — an active process of building, designing, and innovating with tools and materials to produce shareable artifacts [2]. Makerspaces are expanding globally and are being incorporated into community centers, public libraries, post-secondary institutions, and recently into K-12 schools. The emerging literature on makerspaces suggests that they provide opportunities for students to foster ‘21st century’ competencies such as critical thinking, communication, collaboration, and creativity [2]. Another potential advantage is the intersection between student engagement, STEM subjects, and other multi-discipline areas such as literacy and numeracy.

One of the main problems that a school and their senior administrators may face when considering the implementation of a makerspace has to do with its functionality and use. In addition, many schools experience constraints such as available resources, space, funding, and the capacity of its educators [3]. As makerspace discussions are happening in K-12 schools in close geographical proximity to Queen’s University, Connections Engineering Outreach (CEO) was faced with the problem of determining strategies towards minimizing the constraints for schools to experience a makerspace while providing rich STEM education learning opportunities for their students. The full details of the initial makerspace project proposal, which includes a logic model and consultations with stakeholders, will not be discussed in this paper. Instead, the paper/poster focuses on how the engineering design process was used after the initial decision to design a mobile makerspace that could travel to schools to deliver STEM outreach workshops.

2.2 Identify constraints

Table 1 contains a list of the main constraints and the guiding questions that helped shape each step throughout the design of the mobile makerspace project. Responses to these questions will be presented in a detailed report at a later point in time.

<table>
<thead>
<tr>
<th>Possible Constraint</th>
<th>Guiding questions</th>
</tr>
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<tbody>
<tr>
<td>Funding</td>
<td>What is the overall capital cost of project? What are the operating costs to keep the project running?</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Where is the funding coming from? Is this a revenue-generating project? Is the project financially feasible?</td>
</tr>
<tr>
<td>Staffing</td>
<td>Who is going to deliver the workshops? What educational background or training is needed?</td>
</tr>
<tr>
<td>Timeline</td>
<td>How soon can the project be in operation? What is the lifespan?</td>
</tr>
<tr>
<td>Resource Development</td>
<td>Do you have the capacity to develop the necessary resources? What is the focus of the resources? Where is the best place to start?</td>
</tr>
<tr>
<td>Alignment with outreach objectives</td>
<td>How does this project align with the objectives of outreach? What are the advantages and disadvantages?</td>
</tr>
<tr>
<td>Size and scope of vehicle</td>
<td>How big of a vehicle is needed for the project? What specific regulations or need to be followed?</td>
</tr>
</tbody>
</table>
2.3 Brainstorm

As a first step towards idea generation, CEO used a post-it-note exercise to brainstorm different ideas towards the delivery model. Two approaches, which were supported by literature on mobile makerspaces, emerged from this brainstorming activity. The first was to drive a large vehicle (i.e. minivan or cube van) that contained makerspace technology out to a school and unload the technology into the classroom to deliver the workshops. This model is similar to that used by the STEM outreach organization at the Faculty of Engineering and Applied Science at the University of Ottawa (Figure 2).

A second model was to use a larger vehicle (i.e. bus or a truck and trailer combination) that can contain the makerspace technology, travel to schools and the students physically complete the outreach workshop inside this space (Figure 3).

2.4 Selecting a solution

After completing an evaluation on the two different types of delivery model, CEO opted to customize a 24-foot trailer into a mobile makerspace classroom called the Tech ‘n’ Tinker (TNT) Trailer. The TNT Trailer, which is towed by a new 2018 truck leased by the university, can physically travel to schools and communities to engage and deliver engineering design and makerspace workshops to youth. With this model, it also aligns with the objectives of CEO to focus on increasing the awareness and diversity of STEM fields to underrepresented youth as the workshops can travel to communities who do not traditionally receive STEM outreach opportunities. The final design of TNT Trailer as well as some of makerspace technology is shown in Figure 4.
2.5 Prototype

Through a respectful and collaborative community approach to program delivery, the TNT Trailer works with targeted partnering schools in an attempt to increase diversity in STEM fields. Target schools are identified by the school boards and include those where Indigenous student enrolment is higher than the regional average, remote/rural schools, and schools in low-socio-economic neighbourhoods.

While at the schools, CEO will work with the educators of the various grades to select and co-teach the workshops that are suitable for their current abilities. The workshops have direct links to the Ontario STEM curriculum documents, links to literacy and numeracy, 21st century competencies, all while using the makerspace educational technology. One example of a workshop is to design a wearable technology (i.e. watch, wristband, footwear, etc.) that has a built in microcontroller (called the micro:bit) that can count the steps someone takes when walking by using the built in sensors. This workshop has a link to the Grade 7 and 8 ‘Understanding Structures and Mechanisms’ and the ‘Understanding life cycles’ units in Science. The final prototype of the completed TNT Trailer is shown below in Figure 5.

![Figure 5: Tech 'n' Tinker Trailer Prototype](image)

2.6 Test

The delivery of makerspace and STEM education outreach workshops inside the Tech ‘n’ Tinker trailer officially started in January 2018. Since this time, the TNT has visited approximately 25 schools, working with 3 classes per day (250 instructional minutes per day), and ranging from Grade 3-8. To date, the TNT program has delivered workshops to approximately 2000 students. In April 2018, a post-workshop program evaluation online survey was developed using Qualtrics at Queen’s University and was sent to 25 of the educators whom were in communication with CEO when planning the workshops for their students. The qualitative survey was designed to provide opportunities for educators to comment on the workshops ability to engage students, if they provided an increase in exposure towards STEM fields, contributed towards increasing diversity in STEM, and overall program feedback. The preliminary data collection included nine responses and a few of the results are shown in Table 2.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sample Educator feedback</th>
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<tbody>
<tr>
<td>Student engagement</td>
<td>“completely engaging and educational for our Grade 3 group”</td>
</tr>
<tr>
<td>Exposure to STEM</td>
<td>“great interest in how electricity works [in reference to makerspace technology activity] and coding was a hit. Some students are trying to find ways to earn money to buy DASH [robot] on their own! Students want more time with robots to work on coding”</td>
</tr>
<tr>
<td>Increasing Diversity</td>
<td>“I have more girls that seem interested in Engineering. They commented, “ohhh I didn’t know Engineers would do that!” I also think it opened their eyes to the variety of fields involved in engineering. Some of my kids who struggle with math were involved with the robots in the obstacle course and I was so happy to see them using math but not knowing they were!”</td>
</tr>
<tr>
<td>Overall</td>
<td>“It was just an opportunity that we can't provide for our elementary students because we don't have the money in our budgets for such things”</td>
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In addition to the qualitative survey, program evaluation data was also collected through two structured interviews (one with an administrator and one with a student support lead) at partnering schools to gain further insight as to how the program might have an influence on their school. The interviews were recorded using a voice recorder, transcribed into Microsoft Word, and then analyzed for emerging themes. The first theme that emerged from the interviews was the value brought to the school community. The school administrator described what the TNT outreach workshops have meant to her school by stating: “As you know, in education we’re not given a lot of extra funding to do a lot of these things. What Connections has done and generosity of not charging us
for several of our visits has been outstanding. We’re very 
appreciative because I don’t think I would have been able 
to find the money to pay for that many visits”. When asked 
specifically about if the workshops had any influence on 
increasing the diversity in STEM subjects, she commented:

“I checked in with my two Grade 8 classes and 
I have 56 students who have been heavily 
involved in working with Queen’s for their 
whole school year. A lot of them actually, when 
I was looking to see what they were putting in 
as their electives, were choosing computers. I 
noticed that in the last couple of years that not 
very many girls were choosing the computers. I 
see the difference now. I have one student in 
particular who put computers down as her first 
choice and she told me that if she had not had 
all these rich experiences, that she has had this 
year, she would not have chosen that. She is 
hard evidence right there and I have others as 
well.” – Vice Principal

During the interview with a local educator, he 
described the indirect influence the workshops were having 
on the way educators in the school are thinking about or 
planning to use makerspace technology in their practice. 
“The teachers are appreciative and supportive with the 
expertise of the team to come in and show us as educators 
alongside the students, what we can be doing to enhance 
our learning in that area.” Supporting this claim was the 
administrator who also noticed this influence on the 
teachers by offering “I have teachers who just don’ t have 
the capacity to do it, so watching the Queen’s team come 
here and facilitate all this wonderful learning and 
programming has been outstanding. The teachers have 
learned some new technical skills they can pass to students 
in the classroom. Connections provided that for us and 
teachers were thrilled that Queen’s has been coming over 
here to work with us”. Although these results are from a 
small sample size and are preliminary data, the early trend 
suggests that the makerspace STEM outreach workshops 
are having a positive impact on the students and teachers.

2.7 Iterate and Improve:

Connections Engineering Outreach continuously 
seeks feedback on many components of its programs, 
including staffing, workshop content development, 
educator resources, and relevance to K-12 STEM 
education. With the TNT Trailer program within its first 
year of delivery, CEO is yet to collect enough data to 
support a complete program evaluation that will inform the 
ext iteration of improvements. This on-going process 
towards collaborative approaches to evaluation will inform 
the continuous engineering design cycle. CEO will look to 
communicate with others in an attempt to mobilize the 
knowledge on how the project was designed, implemented, 
and then improved at Queen’s University.

3.0 CONCLUSION

The conclusions for this study are ongoing.

4.0 ACKNOWLEDGEMENTS

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