Growth from the STEM: Exploring an International Model of Apprenticeship for Outreach Programs (Work in Progress)

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Introduction

This Work in Progress paper describes a unique, international collaboration between universities in Canada and the United States. We explore the development of a STEM (science, technology, engineering and math) outreach program for K-12 students in the US, through alliance with an existing outreach organization based in Canada. We share this experience to begin to construct a model of collaboration that might be replicated across organizations and institutions to drive the success of similar programs. This paper will focus primarily on the pieces of this collaboration and begin to situate the experience of the student-instructor in STEM outreach as an important, but largely unexplored, area of pedagogical interest.

Undergraduate engineering students from the State University of New York at Binghamton spent summers with *the Engineering Outreach* Office at the University of Toronto to gain insight and experience into the processes and operations of a long-standing outreach program. Upon returning to their home institution, the students deployed this knowledge by developing and delivering curriculum locally. We outline the progress to date and discuss the elements of this 'apprenticeship model' aimed at developing new outreach programs focused on STEM literacy and engagement. Logistics associated with the undergraduate student exchange are also discussed. We present a model that ultimately serves the strengths of the participating institutions and the needs of their communities. This work in progress paper will seek to answer the following research questions:

- What are the characteristics of this collaboration?
- What experiences do undergraduate students have in this role? Are they pedagogically significant?
- What is the nature of STEM in this program?

Theoretical Framework

To situate our work in the broader context, we explore the literature related to STEM outreach programs and experiential learning. The impact of a perceived lack of interest in STEM fields may be felt on both sides of the Canada-United States border. In Canada, concerns for the pace of innovation substantiate the need for STEM, where there is advocacy for "curricula that better integrate science and technology knowledge with a broader set of business, entrepreneurship and commercialization skills that nurture creativity, intelligent risk taking, and ambition" [1]. Similarly, in the United States, STEM jobs are predicted to grow almost twice as fast as any other profession, with over 1 million jobs by 2018 in STEM fields, but with only 16% of degrees anticipated to be awarded in STEM specializations [1]. While similar in some ways, we anticipate that the approach to STEM education may have notable differences between Canada and the US. Part of our vision is to explore these differences and identify strengths in each

country's approach. We believe our model of multi-country mentorship can be applied to other settings as well; where program development (i.e. an established program mentoring a new program) and international STEM education research can occur simultaneously.

The reported impact of outreach programs exists not only on the improvement of the science content knowledge of teachers and students, but also on the "spirit of teaching science" [3] in schools. The need for these shifts can be attributed to concerns of attrition of students in STEM fields, which can present as high as one-half after the first year [2]. Ultimately, the motivation for this work transcends disciplinary and national borders to situate on the needs of the pre-college or pre-university student and the congruence of early interventions toward attracting children and youth into STEM fields, and toward confronting challenges that impede access to achievement in STEM. Investigations of STEM learning advocate for the increased collaboration between and across the traditional and non-traditional spaces for education [3] to better serve students: toward enriching content learned in school classrooms, toward supporting student transition from one stage of education to the next, toward cultivating confidence and competence in STEM fields, and toward supporting informed decisions regarding study and career choices.

Considerable STEM outreach work is completed through the involvement of undergraduate student-instructors who develop and deliver content in this setting. We approached our collaboration by employing an apprenticeship model to inform student training and experience. This model draws on experiential approaches to teaching and learning. Kolb [4] defined learning as "the process whereby knowledge is created through the transformation of experience" and advanced four key phases in this cycle of learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation [5]. Cognitive apprenticeship models aim to "enculturate [learners] into authentic practices through activity and social interaction" [9]. Brandt, Farmer and Buckmaster [7] offer an apprenticeship model that includes modeling, approximating, fading, self-directed learning, and generalizing. Fink's [8] taxonomy considers important situational factors and proposes six elements for significant learning: foundational knowledge, application, integration, human dimension, caring, and learning how to learn. We draw on these models to deconstruct the elements of this collaboration as part of a 'meaningful outreach apprenticeship' framework.

Collaboration: Key Experiences, Elements and Approaches

Undergraduate students were hired as instructors to work with both universities in this apprenticeship model. In 2016 and 2017, four students from SUNY Binghamton spent their summers at the University of Toronto where they gained insight and experience into how a well-established workshop/camp outreach program operates. They developed and delivered workshops and camp programming with the goal of bringing this knowledge home. In Canada, the instructors welcomed over 200 students to community-based camps and led over a dozen workshops, reaching over 300 children and youth. Since their return to the US, these

undergraduate students have been assisting in the creation of a new STEM outreach and education program for K-5 students. A community outreach center at SUNY Binghamton facilitated the formation of a partnership with a local elementary school district in Windsor, NY. STEM workshops in the areas of material science, biodiversity, and structural engineering were delivered to over 300 K-2 students. In the Summer of 2017, one week of workshops were provided to over 100 K-5 students attending a summer camp program.

The logistics were co-determined by the participating institutions and were based on the planned, annual activities of the experienced outreach organization. The experiences of the US student cohort mirrored the activities (on a modified timeline) that participating Canadian students endured. For this project, we worked within a qualitative research paradigm to explore the elements of the collaboration. Data collection thus far for the project was conducted through two methods: document analysis and open-ended survey. Document analysis examined the physical artifacts [9] from the Canadian and US outreach groups, including agenda, program schedules, manuals, curriculum documents, and training materials. Documents were assessed thematically and inductively to suggest the following over-arching themes of student experience as outlined in Table 1, which may be considered as the characteristic elements of this apprenticeship experience.

Table 1: Meaningful Outreach Apprenticeship Model Elements

On-campus Residency	Student-instructors were provided on-campus housing at the University of Toronto allowing them to live and learn on-site.
Pre-Service Training	Student-instructors were provided training similar to *Engineering Outreach* student-instructors in Canada, and were introduced to relevant topics in facilitation strategies, classroom management, developing learning outcomes, and health and safety skills.
Program Delivery - Workshops	Undergraduate student-instructors led 1-3 hour interactive STEM activity sessions in local schools for grade 3-8 students; the number of workshop delivered varied for team members (2-10).
Team Retreat	As part of an all-team retreat at the University of Toronto, undergraduate student-instructors participated in a 3-day outdoor retreat for additional training on camp procedures and emergency protocols.
Curriculum Development	Student-instructors developed all camp content and refined this with program lead guidance.
Job Shadowing/ Program Planning	Student-instructors were responsible for a number of elements of workshop and camp program planning, including submitting activities for safety approval, planning for and obtaining program materials and equipment, processing camp registrations and camp setup.

Program Delivery - Camp	Undergraduate student-instructors led interactive STEM activity sessions in camp settings for grade 1-10 students; the number of camp activities differed for team members (2-10) as well as their focused age-range. Camp was delivered on-campus at the University of Toronto in Year 1. In Year 2, camp was delivered in 4 different community sites (schools and community centres) in Canada and in 1 community-based camp in the US.
Reflection and Evaluation	Student-instructors reviewed program content and iterated on activities throughout the summer to inform future use of curriculum. Instructors contributed to an overall program report and completed pre-post experience surveys to review their perspectives on key program considerations.

In both Canada and the US, as part of *Pre-Service Training* and *Program Delivery – Workshops* components, instructors were introduced to a selection of hands-on activities linked to elementary school curriculum, including bridge-building, slime-making, rocket-launching, car design, and DNA extraction. From this base of exemplars, instructors created and delivered content that was based on academic and personal interest during *Curriculum Development*. Of these experience elements, minor differences were observed between the Canadian and US outreach efforts during *Program Delivery – Camp*. Table 2 outlines these differences.

Table 2: Differences in Program Delivery – Camp

	Canada	**US**
Daily camp sessions	Typically 2 hours in length, 2-3 sessions/day	45-minutes, 6 sessions/day
Lead facilitator	Undergraduate student	Certified teacher
Classroom size	Up to 24	12-18 average
Location	On-campus and public schools	Public school

Students completed a pre- and post- experience survey. These were completed as the very first (prior to any training or program delivery) and very last (after all work had been completed) deliverables in their experience. The open-ended survey consisted of 14 questions, and has been administered for two student cohorts (4 students). Student responses to questions were analyzed for emergent themes, and despite some inconsistencies, results overall suggest that students are reflecting on and deriving meaning from their experience (Table 3).

Table 3: Selected open-ended survey questions and response themes

Question	**Response - Pre**	**Response - Post**
What is STEM? How do you define STEM?	Definition of	Definition of; purpose of
Please describe the engineering design process.	Definition of/not clear	Definition of; list
Please describe the process of scientific inquiry.	Definition of;	Definition of; purpose of
Please describe the role of an instructor in a science and engineering outreach program	Role;	Role; purpose of

What do you think are some of the reasons a University/College might offer a science and engineering or STEM outreach program?	Recruitment; knowledge	Knowledge; opportunity

Interpretations and Implications

We believe that this experience presents as a pedagogically important experience for students. Student-instructors move through the elements of the collaboration, as might be expected of an individual moving through an apprenticeship experience [10], and considers elements of a significant learning experience [11]. Ensuring students have opportunities for concrete and abstract experiences and for reflection and experimentation [6] are also inherent to this setting. Initial interpretations of this experience suggest that the elements of this collaboration map to models of experiential learning in novel ways. Table 4 depicts our initial interpretation of these elements.

Table 4: Collaboration Elements and Experiential Learning Models

Collaboration elements	**Fink (2003)**	**Brandt, Farmer and Buckmaster (1993)**
Residency and training	Foundational knowledge	Modeling
Workshop delivery	Application	Approximating
Curriculum development	Integration	Fading
Camp delivery	Human dimension	Self-directed learning
Reflection and evaluation	Caring	Generalizing
Implementation	Learning how to learn	

The undergraduate engineering students are in a position to translate knowledge, skills and attitudes gained through their own program of study and life experiences, into the creation of an engaging experience for children and youth through a personal act of knowledge translation and meaning-making. We look forward to analyzing this collaboration in greater depth to clarify this exciting area. Future work will explore the role of this experience on student recruitment and retention in engineering programs, and the academic performance and career trajectories for participating students. Through further analysis, we hope that these pieces serve to inform how we describe the characteristics and purposes of the outreach program and STEM, particularly as it is understood by the program instructor, to provide insight into the nature of this collaboration and STEM education as a whole.

This work was supported in part by the National Science Foundation (Award #1554038).

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