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Development of a precollege engineering outreach program during the COVID pandemic

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Introduction

Precollege STEM (Science, Technology, Engineering and Mathematics) outreach activities have been a common practice to help high school students gain diverse perspectives of STEM university education and career paths [1] – [3].

This paper describes the development of a new engineering outreach program, Engineering 11, by the School of Engineering, University of British Columbia, Okanagan (UBCO) through collaboration with the Central Okanagan School District (SD 23). UBCO Engineering 11 consists of several modules covering a wide range of engineering disciplines and subjects, such as civil, environmental, mechanical, biomedical and electrical engineering, and engineering ethics, aiming to provide senior high school students an opportunity to explore the many disciplines of engineering and career pathways. The course is designed to be taught collaboratively by a physics teacher of SD 23 and faculty and graduate students from UBCO School of Engineering. Since the spring of 2020, the course has been offered to two cohorts of grades 11 and 12 students in Kelowna Senior Secondary (KSS) in two consecutive years, in the format of in-person and online teaching (in response to the COVID pandemic). Both pre- and post- surveys have been conducted to the cohorts to assess the impact of the program on their attitudes towards engineering and their choices of university majors.

This paper presents the curriculum development and delivery model (prior to and during the COVID pandemic) of this outreach initiative. The survey results demonstrate that, in general, many students have gained a better understanding of engineering through this program and are more excited about engineering careers. The survey results also reveals the challenges of maintaining a high momentum of the program due to the restrictions from the COVID pandemic.

UBCO Engineering 11: curriculum development and delivery model

UBCO School of Engineering offers a variety of STEM outreach programs for students in elementary and secondary schools, such as engineering summer programs, Geering-up, and dual credit program, aiming to foster students' interest in STEM, in particular, engineering.
UBCO Engineering 11 is a new initiative developed in 2020 between UBCO School of Engineering and SD 23. It is a credit course falling under the category of Applied Design, Skills and Technologies of BC's curriculum [4]. By taking the course, students will not only earn high school credits, but more importantly, will have an opportunity to learn and explore the many disciplines of engineering, as well as, engineering professions. The main objectives of this initiative are (1) to inspire and attract a wide spectrum of highly motivated high school students to the engineering field; (2) to promote UBCO School of Engineering among students in SD 23.

UBCO Engineering 11 is offered to students in grades 11 and 12 during the spring term. It consists of multiple modules to help students understand how different engineering concepts,

tools and technologies are applied in problem solving and/or design process. The course is designed to incorporate many hands-on, lab-oriented activities to engage students and spark their curiosities on engineering principles and applications, such as, in the fields of construction, infrastructure, water treatment, built environment, energy, product design and manufacture, biomedical and telecommunications. Table 1 presents the main topics of the course modules and approximate instruction hours for each module. The actual timetable and sequence of the modules vary year by year depending on the high school class schedule.

Since 2019 consultation and development phase, this initiative has received a strong support from both UBCO School of Engineering and SD 23. In February 2020, UBCO Engineering 11 was offered to the first cohort of grades 11/12 students from KSS, one of the largest senior secondary schools in the central Okanagan region, British Columbia. More than 20 instructors were involved including UBCO faculty, postgraduate students, technicians, staff and one physics teacher from KSS. The course was originally planned to be delivered in-person in KSS as follows:

- UBCO faculty and postgraduate students teach their preferred modules, with the postgraduate students mainly assisting with hands-on or lab activities.
- UBCO technicians are responsible for safety workshop, machine shop demos, and setting up labs conducted at UBCO.
- UBCO staff hold the admission and scholarship session and provides support on coordination if needed.
- KSS physics teacher develops and conducts the assessments during the flex classes. He is also responsible for coordination within KSS and all tools and materials needed for in-class or lab activities in KSS.

In addition to all the modules listed in Table 1, a one-day event, Engineering Symposium, was planned to be held at UBCO at the end of June 2020 for the first cohort of students to present their course projects and/or learnings to fellow students, parents, teachers, and school district staffs. During the event, students and parents would tour engineering labs and participate in lunch discussions with current undergraduate and graduate students.

In February 2020 before the COVID shutdown, UBCO Engineering 11 was delivered as planned very successfully, as commented in the unsolicited feedback from the KSS physics teacher. Students completed 5 modules, including construction material, structure, SolidWorks, healthy buildings, and sensors and radars. They did different hands-on activities in-class and had the opportunity to complete the experiments on concrete boat at UBCO civil high-head lab.

> *"I cannot express strongly enough how well the Engineering 11 class is going! Students have been fully engaged and enthusiastic about every element so far, and I have had numerous students from outside the class (whom I don't even know) express a regret at not having enrolled." – KSS physics teacher, March 2020 (before COVID)*

After the Spring break in 2020, all the remaining modules were delivered online and the remaining UBCO lab visits and Engineering Symposium were cancelled following the public health's COVID rules. The planned hands-on activities were either cancelled or replaced with videos when it is possible. During April - June 2021, UBCO Engineering 11 was offered to the second cohort of grades 11/12 students from KSS primarily in the online mode. No UBCO lab visits were possible for the second cohort due to COVID.

Table 1: UBCO Engineering 11 course modules

Module		Instruction hours	Instructor(s)	Labs or in-class hands-on activities	
				KSS	UBCO
Course introduction		5	KSS physics teacher		
Civil engineering	Intro to civil engineering; Construction materials	7.5	UBCO faculty, assisted by graduate students and technicians	In-class	UBCO high head lab
	Structure engineering	5	UBCO faculty, assisted by graduate students	In-class	
	Sustainable infrastructure	2.5	UBCO graduate students		
Environmental engineering	Water quality & treatment	5	UBCO faculty	In-class	
	Microbiome & healthy built environment	7.5	UBCO graduate students	In-class	
Mechanical engineering	Fluids & thermodynamics	5	UBCO faculty	In-class	
	Renewable energy	5	UBCO faculty	In-class	
	CAD/CAM & SolidWorks	10	UBCO faculty	In-class	
	Safety workshop; Machine shop demos: CNC and water jet cutting	2.5	UBCO technicians, assisted by graduate students		UBCO machine shop
Biomedical engineering	Intro to biomedical engineering; Heart valves	5	UBCO graduate students	In-class	
Electrical engineering	Intro to electrical engineering; Sensors and radars	7.5	UBCO faculty, assisted by graduate students	In-class and labs	
Engineering ethics		5	UBCO faculty		
Engineering admission, scholarship, and student clubs		1.5	UBCO staff and student representatives		
Flex classes		~ 40	KSS Physics teacher		

Research method and results

The purpose of this research is to understand students' learning experience in UBCO Engineering 11, and whether and to what extend the course has on their attitude towards engineering and the outcome of the outreach program. The research consists of two surveys, administered by UBC-hosted version of Qualtrics. The first survey (pre-Engineering 11 survey), conducted at the start of the course, gathers information on students' attitude towards engineering prior to taking UBCO Engineering 11. The exit survey (post-Engineering 11), conducted at the end of the course, gathers information on students' overall learning experience, as well as, their attitude towards engineering after taking the course. Both surveys are anonymous and voluntary. This research was approved by UBCO Behavioural Research Ethics Board and SD 23, and both parental consent and student assent were obtained.

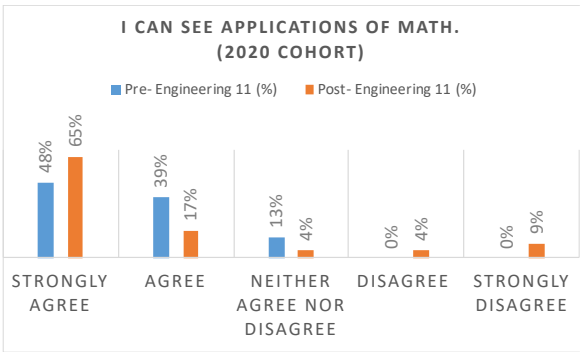
The surveys were distributed to both cohorts in 2020 and 2021. Table 2 shows the class size of each cohort and the number of participants in the surveys. Only students participated in both pre- and post- surveys are included in the table. The participation rate was excellent in 2020, but dropped noticeably in 2021, very likely due to the COVID related stress experienced by the students and their families.

Table 2: Class size and number of survey participants

Year	Class size			Number of students participated in both pre- and post- surveys (participation %)
	Total	Male	Female (female %)	
2020 cohort	24	23	1 (4.2%)	23 (95.8%)
2021 cohort	26	21	5 (19.2%)	14 (53.6%)

The surveys use Likert-scale questions about students' plans on courses (i.e., math, physics and chemistry), post-secondary education, and future career to probe their attitudes towards engineering. Figures 1-5 compare the survey results for both cohorts before and after taking UBCO Engineering 11.

It is very clear that, by taking UBCO Engineering 11, both 2020 and 2021 cohorts can better see applications of math and sciences (Figure 1). For the 2020 cohort, this positive impact may explain the increased percent of students planning to take advanced math, physics and chemistry (Figure 2, a-c), planning to study engineering in post-secondary (Figure 3, a-b), and considering careers using math and sciences (Figure 4, a-b). For the 2021 cohort, the results are mixed; although most students appreciated the applications of math and sciences after they took UBCO Engineering 11, three students changed their mind on taking advanced math, physics and chemistry (Figure 2, d-f). Without further information, it is hard to tell if this shift was correlated to their experience in Engineering 11 or due to any external factors. As the responses from the 2020 cohort are very positive; and the major difference between the 2020 and 2021 offerings is the hand-on components, it is hypothesized that lack of hands-on opportunities in the 2021 offering might make the advanced subjects appear to be too challenging for some students. Nevertheless, for the 2021 cohort, the surveys show an increased percent of students planning to go to post-secondary schools, in particular, study engineering (Figure 3, c-d). The percent of students who will consider careers using math and sciences (strongly agree) has also increased noticeably (Figure 4, c-d).



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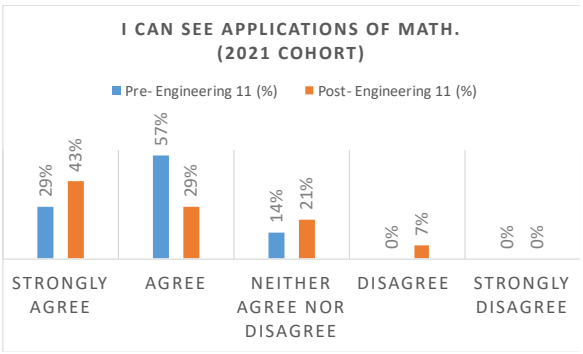

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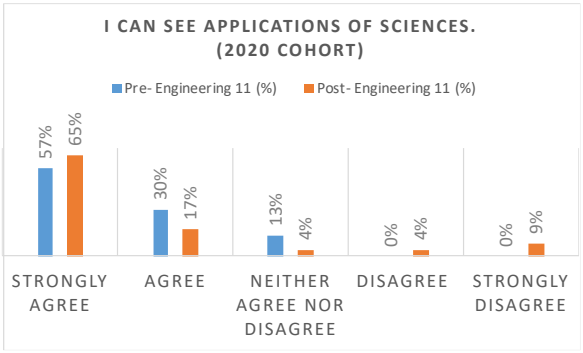

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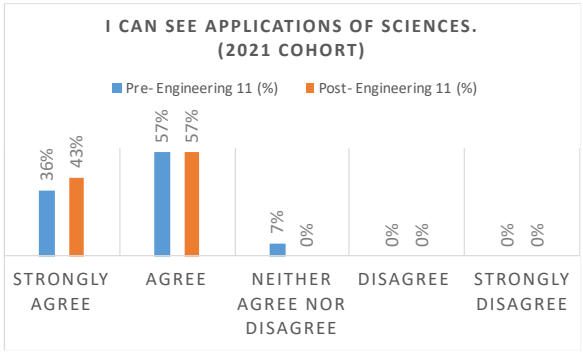

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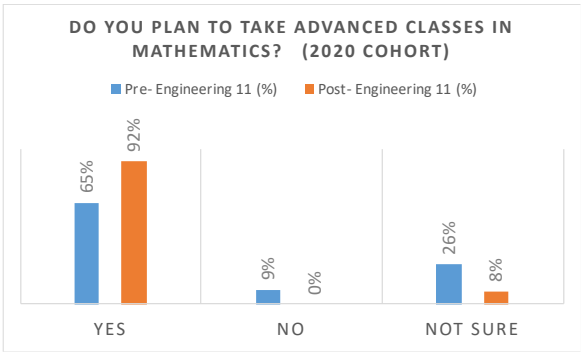
Figure 1 Students' ability to see applications of math and sciences. (a)-(b) for 2020 cohort, and (c)-(d) for 2021 cohort.



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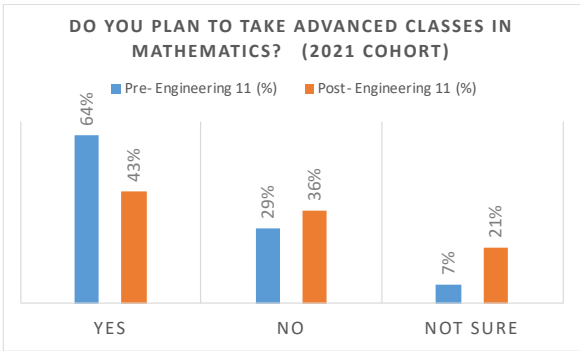

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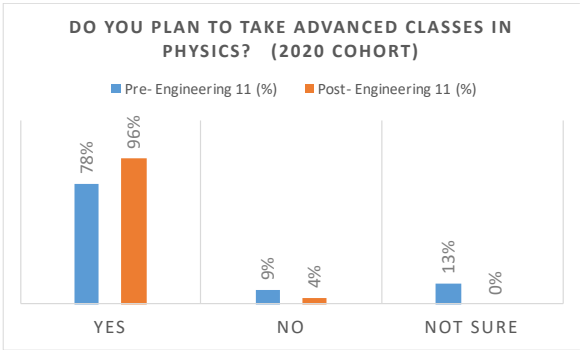

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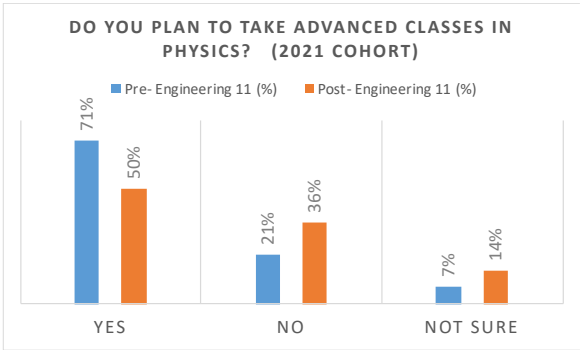

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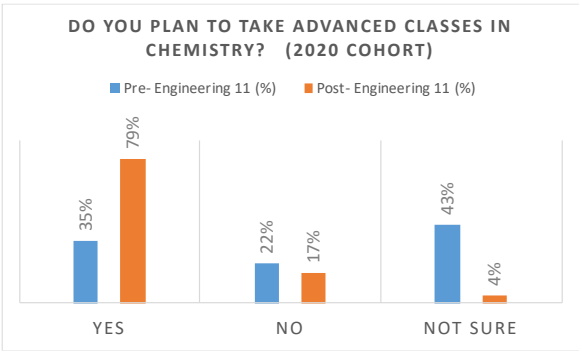

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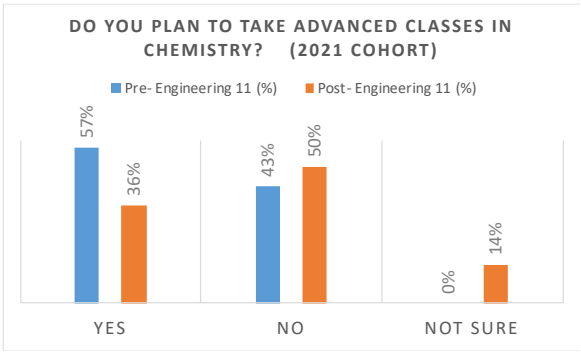

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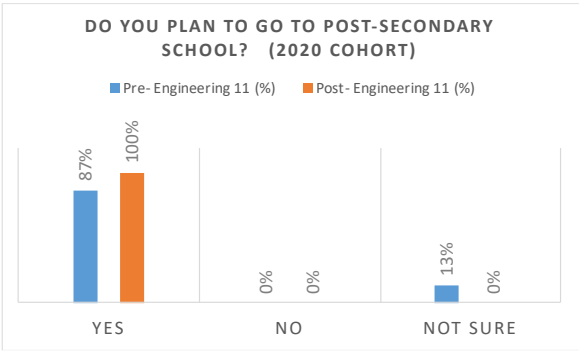
Figure 2 Students' plan on taking advanced math, physics and chemistry. (a)-(c) for 2020 cohort, and (d)-(f) for 2021 cohort.



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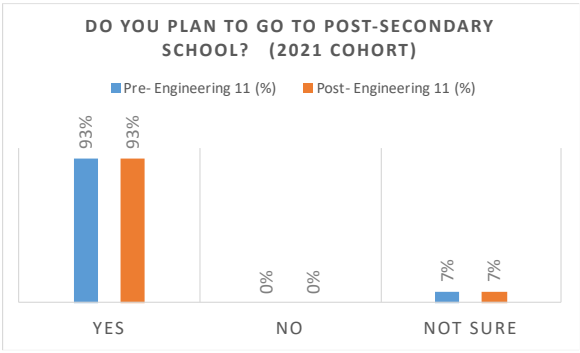

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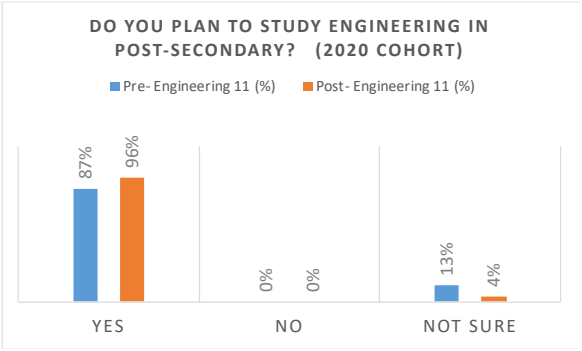

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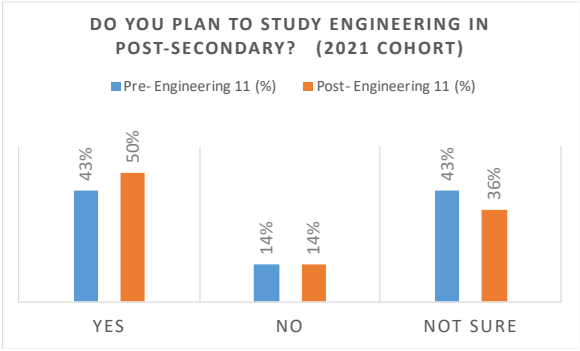

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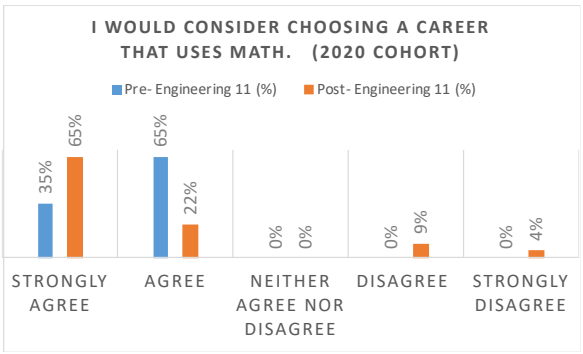
Figure 3 Students' plan on post-secondary education. (a)-(b) for 2020 cohort, and (c)-(d) for 2021 cohort.



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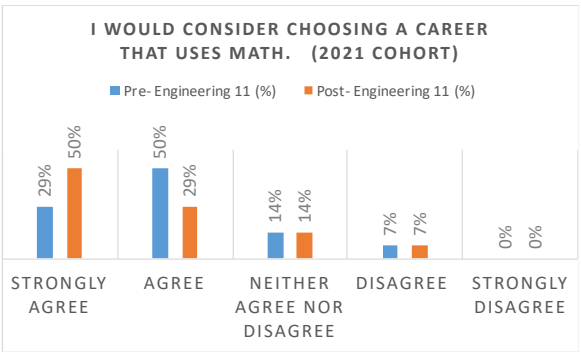

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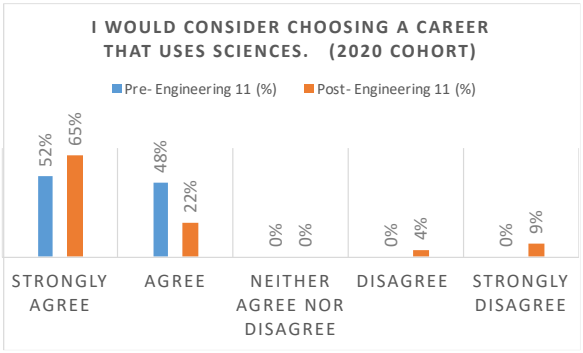

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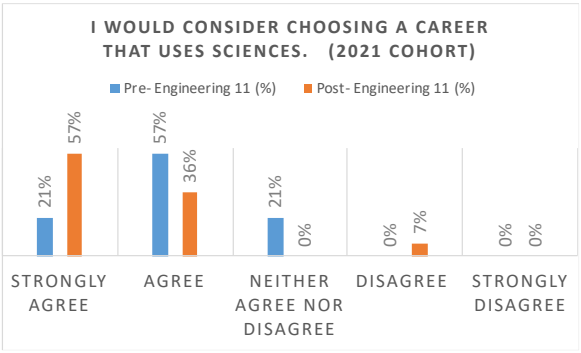

(d)

Figure 4 Students' plan on future career. (a)-(b) for 2020 cohort, and (c)-(d) for 2021 cohort.

The exit survey includes three Likert-scale questions on whether UBCO Engineering 11 is informative and aspires students to develop careers in engineering. Figure 5 shows the results for both cohorts. The majority of students in both cohorts acknowledge that they have learned more information about engineering as a post-secondary degree and as a profession after taking the course. Eighty-seven percent (87%) of the 2020 cohort and 54% of the 2021 cohort become more interested in developing an engineering career in the future. By comparing the 2020 and 2021 results, it seems that the program receives more positive response from the 2020 cohort than from the 2021 cohort. One possible reason is that the 2021 course was offered entirely online and didn't have any lab tours due to COVID. As a result, student engagement was greatly compromised. This observation was confirmed by analyzing student comments related to UBCO labs and online teaching (after COVID) in the open-ended questions.

> *"I think that once schooling is no longer online that having more labs or hands on projects would greatly help the experience. but the course itself was quite useful and gives me confidence that i am on the right career path." – Student in 2020 cohort*

> *"The highlight of this engineering course for me was when we got to build the concrete boats at the UBCO campus." – Student in 2020 cohort*

> *"My highlight was probably the 'indoor microbiome' experiment we did where we swabbed areas for bacteria." – Student in 2020 cohort*

"I wish for more in person lectures, but I realize zoom meetings were the best we could do. More activities would also help me stay more engaged and curious." – Student in 2021 cohort

"The zoom meetings were very informational and all the professors were very good at the presentation aspect. But personally, I would say it was very difficult, staying focused for long periods of time through zoom. More hands-on group projects would have been great as well. I feel like the class wasn't as united and engaged because of the lack of hands-on work." – Student in 2021 cohort

In the exit survey, students were asked about their overall experience in this course. Most comments are very positive, showing their appreciation for the opportunity to interact with UBCO engineering faculty and students, to learn different engineering disciplines, and to conduct all hands-on activities (that they did before COVID). The majority of students, i.e., 100% of the 2020 cohort and 89% of the 2021 cohort, indicate that they would recommend the course to other students. It is interesting to note that the number of female students registered in the course has increased from 1 in 2020 to 5 in 2021 (Table 2). Although the absolute number of female students in 2021 is still very small, the increase in percentage is noticeable, possibly due to the success and word-of-mouth of the 2020 cohort. In addition, we carefully select and involve excellent female graduate students (as teaching assistants) in the program to help change the common perception of engineering as a male-dominant career. It is hoped that this outreach program not only aspire all students, but also help attract more female students in engineering in the future.

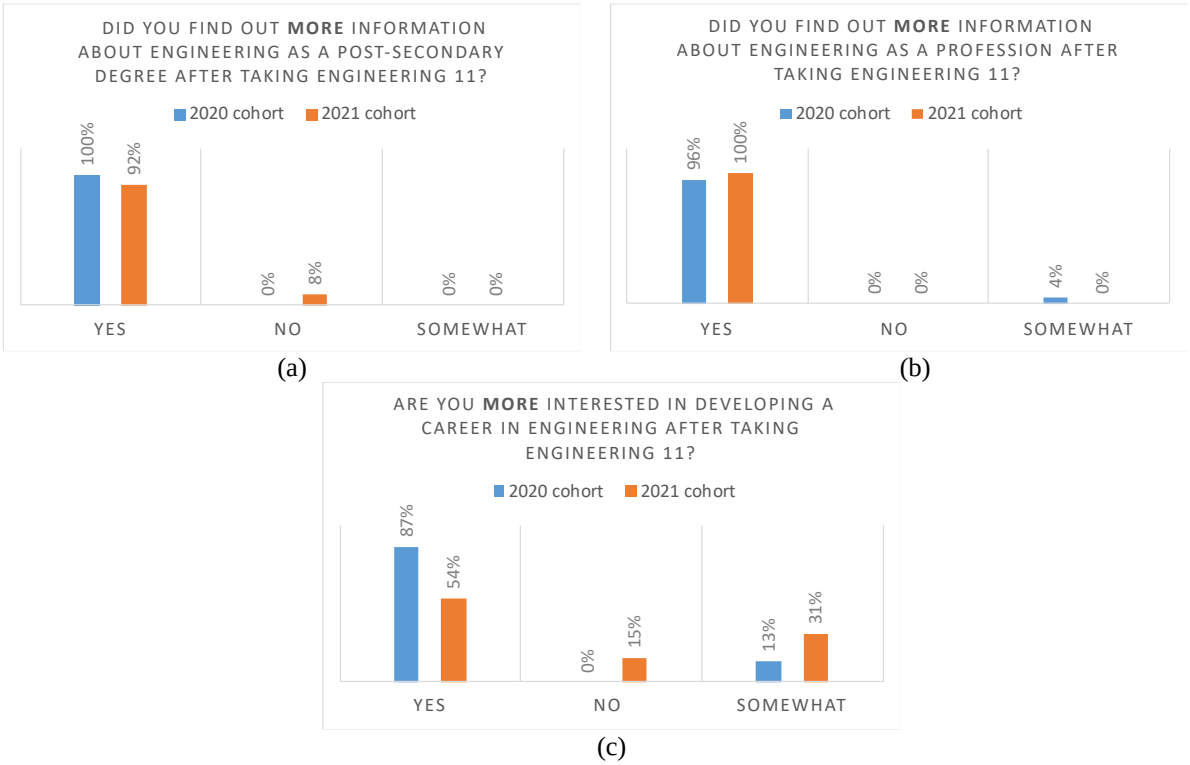

Figure 5 Impact of taking Engineering 11 on students' knowledge and interest on engineering

Concluding remarks

A new outreach initiative, UBCO Engineering 11, was developed and delivered before and during the COVID pandemic to two cohorts of grades 11/12 students in SD 23. Overall, the initiative has received very positive feedback from both students and the high school teacher despite the interruption of COVID. Most students appreciate the course content and organisation, the interactions with UBCO professors, and the opportunity to conduct labs at UBCO. Through this course, they have not only learned engineering disciplinary concepts, but more importantly the engineering profession. Many students become interested in engineering after taking the course. By comparing the responses from the 2020 and 2021 cohorts, it is clear that hands-on activities are a significant component in engaging students, in particular, youth. However, due to COVID, there exits logistic and safety challenges to incorporate many lab/campus tours and hands-on activities. Looking forward, a resumption of in-person teaching, lab/campus visits and hands-on activities might be possible as schools and the society as a whole keep developing strategies to cope with COVID. Moreover, the future work will include developing more creative class strategies to engage students.

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