TLEF Project – Final Report

Report Completion Date: (2023/11/21)

1. PROJECT OVERVIEW

1.1. General Information

Project Title:	An integrated experiential and problem-based approach to introductory materials engineering		
Principal Investigator:	Gabrielle Lam		
Report Submitted By:	Gabrielle Lam		
Project Initiation Date:	September 1, 2020	**Project Completion Date:**	May 30, 2023
Project Type:	☒ Large Transformation ☐ Small Innovation ☐ UDL Fellows Program ☐ Hybrid and Multi-access Course Redesign Project ☐ Other: [please specify]		

1.2. Project Focus Areas – *Please select all the areas that describe your project.*

☒Resource development (e.g., learning materials, media)

☒ Infrastructure development (e.g., management tools, repositories, learning spaces)

☒ Pedagogies for student learning and/or engagement (e.g., active learning)

☐ Innovative assessments (e.g., two-stage exams, student peer-assessment)

☐ Teaching roles and training (e.g., teaching practice development, TA roles)

☐ Curriculum (e.g., program development/implementation, learning communities)

☐ Student experience outside the classroom (e.g., wellbeing, social inclusion)

☐ Experiential and work-integrated learning (e.g., co-op, community service learning)

☐ Indigenous-focused curricula and ways of knowing

☐ Diversity and inclusion in teaching and learning contexts

☒ Open educational resources

☐ Other: [please specify]

1.3. Final Project Summary – *What did you do/change with this project? Explain how the project contributed toward the enhancement of teaching and learning for UBC students.*

Engineering Materials (APSC 278) and Engineering Materials Laboratory (APSC 279) are two service courses taken by students from eight engineering disciplines, reaching roughly 500 engineering students annually. However, its traditional delivery format and lack of formative assessments have negatively impacted student engagement and learning, as reflected from individual consultations with students and past course instructors. In this work, the course structures and resources were redesigned to better integrate conceptual knowledge and experiential learning in the laboratory. To this end, new virtual laboratory tools and a 150-question problem bank were developed, with the goal of enhancing student development of high-order learning skills, including critical reflection of limitations and errors in experimental procedures and results.

In addition to enhancing student learning, a new training structure and accompanying training resources were developed to improve the quality of teaching in a large laboratory instructional team. Previously, past students and course instructors observed large variations in teaching quality between instructional team members. Because these individuals interface closely with students, they can greatly impact students' engagement and learning from experiential opportunities. The newly implemented training structure incorporated thorough discussion of strategies to engage students and to facilitate meaningful discussions; these were also embedded within relevant training resources. The new training structure also involved mentorship opportunities between returning and new instructional team members, to further enhance quality of teaching.

Finally, this work sought to better engage students from a wide variety of backgrounds and educational disciplines. According to discussions with past course instructors and students, student engagement in both Engineering Materials (APSC 278) and Engineering Materials Laboratory (APSC 279) was very poor, presumably due to a lack of appreciation for the relevance of materials engineering to students' educational path and future careers. A suite of expert interviews was created in collaboration with professional engineers, industry members, and community members to showcase the relevance of materials engineering to everyday life, and its intersection with various engineering disciplines. Importantly, the expert interviews were crafted to demonstrate the engineers' reflections on the value of their engineering work, and their potential impacts on society and the environment.

With the development of new course structures, student-focused and instructional team-focused resources, this project aims to have ongoing impacts on student development of high-order learning skills, student engagement, and quality of instruction of laboratory instructional team members.

1.4. Team Members – *Please fill in the following table and include **students**, undergraduate and/or graduate, who participated in your project.*

Name	Title/Affiliation	Responsibilities/Roles
Mohammadali Shahsavari	PhD candidate, Senior teaching assistant, University of British Columbia	Assisted with the design and implementation of new laboratory curriculum
Mohammad Reza Karimi	PhD candidate, Senior teaching assistant, University of British Columbia	Assisted with the design and implementation of new laboratory curriculum and open-source problem bank
Shuheng Li	PhD candidate, Senior teaching assistant, University of British Columbia	Assisted with the development of the open-source problem bank
Mohammadyousef Azimi	PhD candidate, Senior teaching assistant, University of British Columbia	Assisted with the design and implementation of new laboratory curriculum
Daniel Hawker	MASc candidate, Graduate academic assistant, University of British Columbia	Assisted with the development of case study videos
Nisa Sadaah	PhD candidate, Graduate academic assistant, University of British Columbia	Assisted with the development of the open-source problem bank
Pegah Pourabdallah	PhD candidate, Graduate academic assistant, University of British Columbia	Assisted with the development of the open-source problem bank
Betty Cai	BASc candidate, Undergraduate academic assistant, University of British Columbia	Assisted with developing interactive online laboratory tools and case study video
Rohan Parakh	BASc candidate, Undergraduate academic assistant, University of British Columbia	Assisted with developing interactive online laboratory tools and case study video
Yeedo Chun	BASc candidate, Undergraduate academic assistant, University of British Columbia	Assisted with developing interactive online laboratory tools and open-educational problem bank
Emma Dodyk	BASc candidate, Undergraduate academic assistant, University of British Columbia	Assisted with developing interactive online laboratory tools

1.5. Courses Reached – *Please fill in the following table with* ***past*** *and* ***current*** *courses (e.g., HIST 101, 2017/2018) that have been reached by your project, including courses not included in your original proposal (you may adapt this section to the context of your project as necessary).*

Course	Academic Year
APSC 278	2022W1
APSC 279	2022W1
APSC 278	2022W2
APSC 279	2022W2
APSC 278	2023W1
APSC 279	2023W1

2. OUTPUTS AND/OR PRODUCTS

2.1. *Please* ***list*** *project outputs and/or products (e.g., resources, infrastructure, new courses/programs). Indicate a URL, if applicable.*

Output(s)/Product(s):	URL (if applicable):
Suite of expert interviews (5 full-length videos, 5 preview videos, and 1 introductory video)	https://www.youtube.com/playlist?list=PLBNmz-BfXJ4CU7ECpwO0GWPE4PMZu_vRf
Interactive pre-laboratory modules (5 total)	--
WeBWorK problem bank (159 questions)	--
Laboratory instructor training manuals (5 total)	--
Laboratory training videos (4 total)	https://www.youtube.com/playlist?list=PLBNmz-BfXJ4C1MRIPJ6KK0PmkPvBYpS3X
360° videos of laboratory space (2 total)	Instructor version: https://my.matterport.com/show/?m=jSPkXkLv1bp Student version: https://my.matterport.com/show/?m=oC3Tyz3bJs4
Student communications management system (43 linked Qualtrics forms)	--

2.2. Item(s) Not Met – *Please list intended project outputs and/or products that were not completed and the reason(s) for this.*

Item(s) Not Met:	Reason:
Open education problem bank	The WeBWorK problem bank (159 questions) has been submitted to GitHub for review. Given that each question has been reviewed by multiple project team members (3 total), implemented in courses over two terms and tested by students, we expect that minimal revisions will be needed for publication in the open education platform. However, we are still awaiting a response from reviewers (submitted for review May 2023).

3. PROJECT IMPACT

3.1. Project Impact Areas – *Please select all the areas where your project made an impact.*

☒ Student learning and knowledge

☒ Student engagement and attitudes

☒ Instructional team-satisfaction

☐ Teaching practices

☐ Student wellbeing, social inclusion

☐ Awareness and capacity around strategic areas (Indigenous, equity and diversity)

☐ Unit operations and processes

☐ Other: [please specify]

3.2. Please provide details on each of the impact areas you selected in 3.1. – *For example, explain in which ways your teaching practices changed; how student wellbeing was impacted; how students wellbeing benefited from your project, etc.*

In this work, new course structures, learning resources, and training resources were developed to better integrate experiential learning in two service courses, Engineering Materials (APSC 278) and Engineering Materials Laboratory (APSC 279). One of the important goals of this project was to enhance student development of high-order learning skills, such as critical evaluation of experimental limitations and results. New virtual tools were developed to support student learning. Importantly, these virtual tools provided immediate student feedback while requiring minimal instructional resources, which is an important aspect for the sustainment of this project in the context of large courses (over 200 students per term). As discussed later, student performance on high-order thinking assessment points indicated a good ability to evaluate experimental limitations, and to extrapolate implications of experimental errors.

Another key goal of this work was to improve student engagement, in part by enhancing the quality of teaching of instructional team members. In addition to implementing a new training structure, which utilizes mentorship of new instructional team members by returning instructional team members, a variety of training resources were developed to emphasize pedagogical approaches to engaging students and facilitating discussions. Returning and new instructional team members were surveyed, and given the opportunity to reflect on their experiences in the laboratories. Based on survey results, which are discussed later, instructional team members perceived that training resources supported and/or improved their quality of teaching, which led to good student engagement and critical evaluation of experimental limitations. Importantly, returning instructional team members noted an improvement in both student engagement during laboratory sessions, and instructional team member engagement during training sessions, compared to that before the implementation of the new course structure and resources.

A final goal of this project was to improve student attitudes towards learning materials engineering, through demonstrating the relevance and value of materials engineering to everyday life and different engineering disciplines. Traditionally, student engagement in the course was very poor, presumably due to a lack of appreciation for learning materials engineering. To this end, a suite of expert interviews were developed, and student attitudes were gauged through questionnaires. From 397 students responses, results suggested that an overwhelming majority of students perceived materials engineering to be important or very important to their future careers. Moreover, a majority of students reported that the suite of expert interviews enhanced their understanding of the role of the engineer, the meaning of "responsible" engineering, and the impacts of engineering on society and the environment. Interestingly, although to a lesser degree, a proportion of students reported that the suite of expert interviews contributed to a change in their personal and/or professional goals for the future.

3.3. How do you know that the impacts listed in 3.1/3.2 occurred? – *Describe how you evaluated changes/impacts (e.g., collected survey data, conducted focus groups/interviews, learning analytics, etc.) and what was learned about your project from the evaluation. You are encouraged to include graphical representations of data and/or scenarios or quotes to represent and illustrate key themes.*

Impacts on Student Learning and Knowledge

To evaluate student development of high-order thinking skills student performance on specific laboratory assignment questions were analyzed. These questions were designed specifically to assess students' ability to evaluate limitations in experimental methods, extrapolate the implications of experimental errors, and reason the causes of unexpected experimental outcomes. Student performance on each of these questions was determined for two academic terms, and summarized in Figure 1 below. Certain high-order thinking questions, such as Lab 1 Q21 and Lab 5 Q21, are associated with lower student performance than other questions. However, on average, mean student scores are above 80%, which suggests that there is good understanding of experimental limitations and their implications. This is commensurate with qualitative observations from instructional team members, as discussed later.

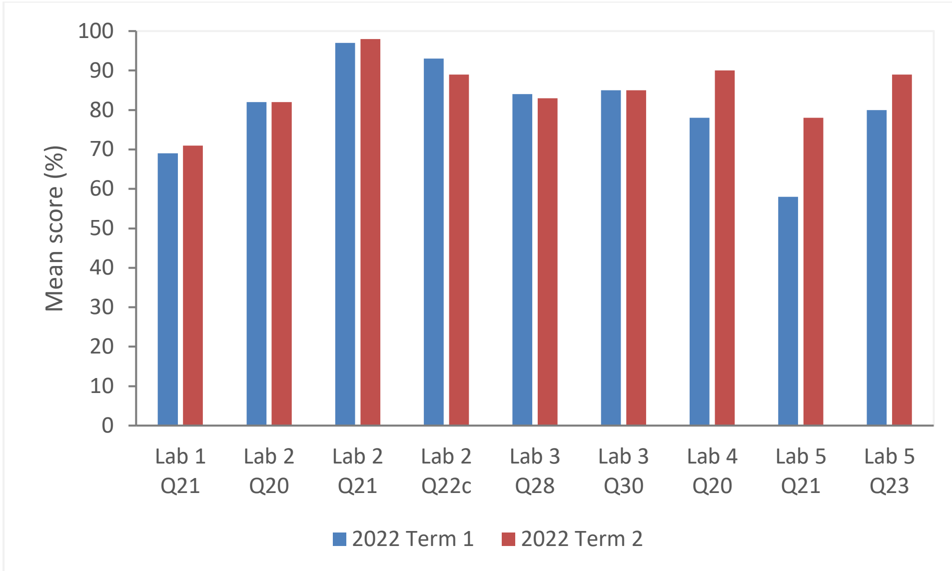


Figure 1. Student performance (mean scores) on questions assessing high-order thinking skills, including evaluation of experimental limitations, errors, and their implications on outcomes.

Additionally, the problem bank was implemented in 2022W and made available to students as additional practice (non-graded). Results from data tracking in the WeBWorK platform revealed that students did, in fact, use the questions as practice. The average number of attempts was greater than 2 for most problem sets, suggesting that students used the immediate feedback from the platform in problem solving to reach the correct solution. The average number of attempts for questions in each course topic is summarized in Figure 2 below.

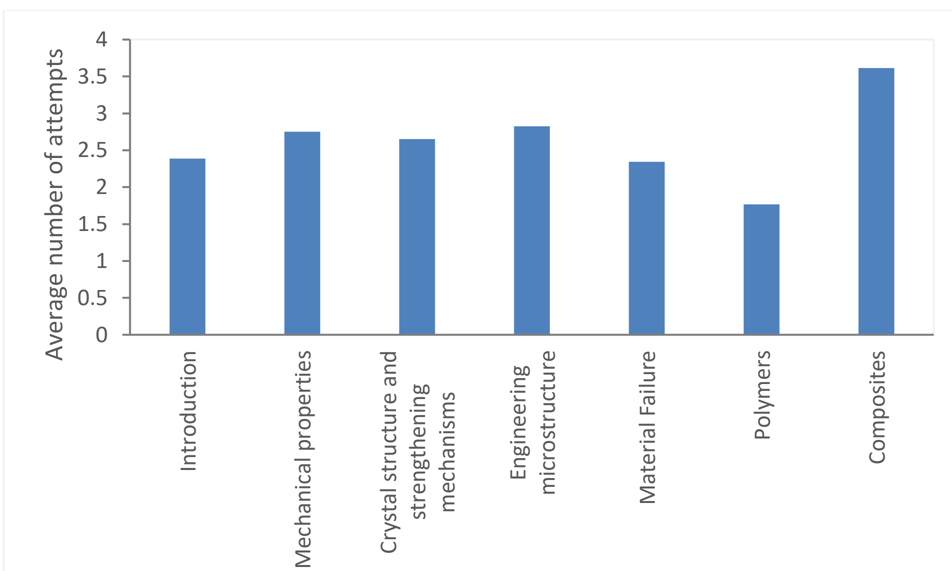


Figure 2. Average number of attempts for WeBWorK questions according to course topic.

Impacts on Student Engagement and the Instructional Team

To evaluate the impact of the laboratory student-centered and instructor-centered training resources, including instructor manuals, training videos, and student pre-laboratory modules, questionnaires were administered to instructional team members, including teaching assistants and laboratory instructors. Feedback was sought from a total of 6 individuals, 2 of whom had been previously involved in the course before and after the implementation of new teaching and learning resources, and 4 others who were new to the instructional team.

Of the returning instructional team members surveyed, both had been involved in Engineering Materials Laboratory (APSC 279) for a total of 10 course offerings. Importantly, these members had led laboratory sessions prior to *and* after implementation of the new course structure, training methods, and training resources. According to these returning instructional team members, students exhibited a good level of preparedness for the laboratory, and a good level of understanding of experimental errors and limitations. Students' level of engagement in the laboratories was rated as good (1 of 2 individuals) or high (1 of 2 individuals). Of note, the returning instructional team members observed that students' level of preparedness was greatly improved, compared to that before the implementation of the new course structure, learning and training resources. Similarly, they perceived students' level of understanding of experimental errors and limitations, and their level of engagement in laboratories to have improved – or greatly improved – relative to the traditional course structure. This is exemplified in the following qualitative reflections from the two returning instructional team members:

"Many students showed genuine enthusiasm for the subject matter. Their interest in understanding the mechanical properties of materials, such as tensile strength, impact resistance, and hardness, was quite evident. This is encouraging as it indicates a strong foundation for future learning… They actively engaged with their peers, sharing ideas and collectively problem-solving… A noticeable number of students were proactive in asking questions and seeking additional clarification. Their inquisitiveness demonstrates a commitment to understanding the subject deeply."

"Compared to before, students come to the lab much more prepared and have a better idea of how the lab will proceed. This has greatly improved compared to before these modifications as then very few students were actually going through pre-labs which were not interactive/engaging."

Similarly, feedback from new instructional team members revealed that students arrived at the lab session well prepared (3 of 4 individuals) or very well prepared (1 of 4 individuals). Moreover, new instructional team members generally perceived that students exhibited good understanding of experimental errors and limitations (3 of 4 individuals; 1 of 4 reported neither good nor poor levels of understanding). However, their evaluations of student engagement levels were more varied, with one reporting very high levels of engagement, two reporting good engagement, and another reporting moderate levels of engagement. This variation may reflect expected variabilities between different lab sections.

In terms of impacts on the instructional team, instructional team members perceived themselves to be well engaged in the training sessions (5 of 6 individuals reported high levels of engagement; 1 of 6 individuals reported good engagement). Moreover, they perceived other instructional team members to be generally engaged during training sessions (3 of 6 individuals reported high levels of engagement; 2 of 6 individuals reported good engagement; 1 of 6 individuals reported poor engagement). One new instructor writes:

"…as a new sessional instructor to this course, the newly developed teaching resources are very informative and detailed. They cover the safety issues carefully and provide guidance for both teaching team and students. The interaction between the instructors/TAs and students is very high. These resources allow students to have prior understanding on how to operate the procedures and cover background information which help the teaching team and students to perform the tests smoothly and address the lab matters accurately… All these factors improve the quality of teaching and develop my personal teaching skills as well… For my own teaching, I am very excited to develop and enrich my teaching experience through adapting this style of teaching."

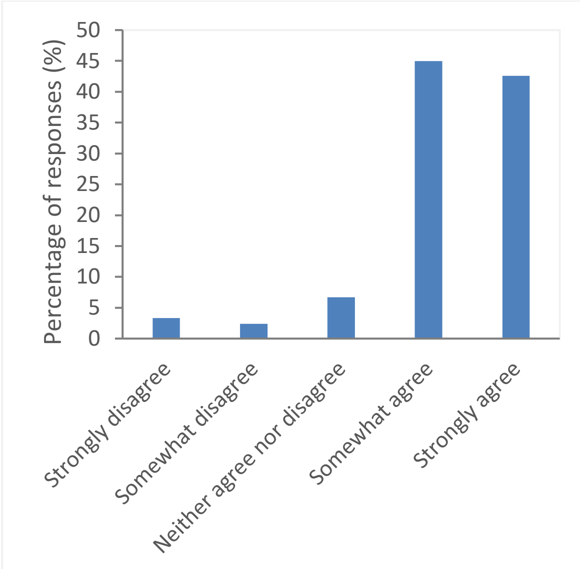
According to a returning instructional team member:

"The redesigned course format has encouraged innovative experimentation, allowing me to explore new approaches to teaching mechanical properties of materials. The flexibility in experiment design has empowered me to create more engaging and relevant hands-on experiences for students, which in turn has improved their understanding of the subject matter."

"The newly developed teaching resources and training format have led to substantial improvements in the teaching quality of new TAs and lab instructors. These improvements are evident in their increased familiarity with course content, the use of effective pedagogical strategies, mentorship opportunities, enhanced confidence, feedback mechanisms, communication skills, and a greater focus on safety. These positive changes collectively contribute to a more effective and engaging learning experience for students in the laboratory sessions."

<u>Impacts on Student Attitudes</u>

To evaluate student attitudes towards materials engineering, students completed a reflection exercise at the end of the course. The reflection exercise was administered in two course offerings of the 2021/2022 academic year, during which the expert interview videos and laboratory learning resources were first implemented. Figure 3 below summarizes students' level of agreement with the following statement: "An understanding of materials engineering is important to my future practice as an engineer in my discipline". A total of 209 responses and 188 responses were obtained in Terms 1 and 2, respectively. In both instances the large majority of students agreed or strongly agreed (89% in Term 1, 78% in Term 2) with the importance and relevance of learning materials engineering concepts to their future careers.



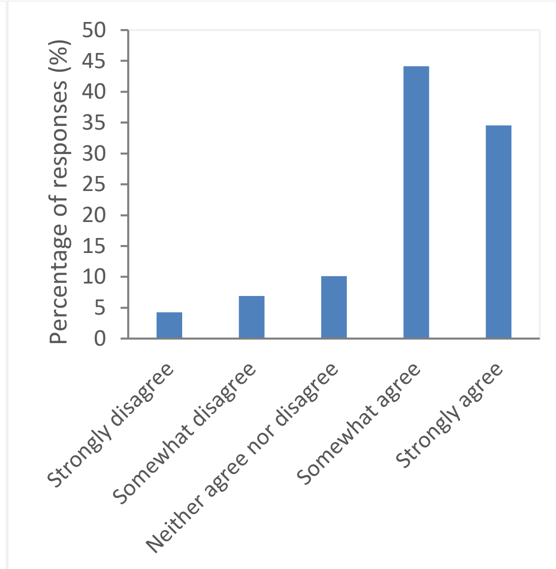
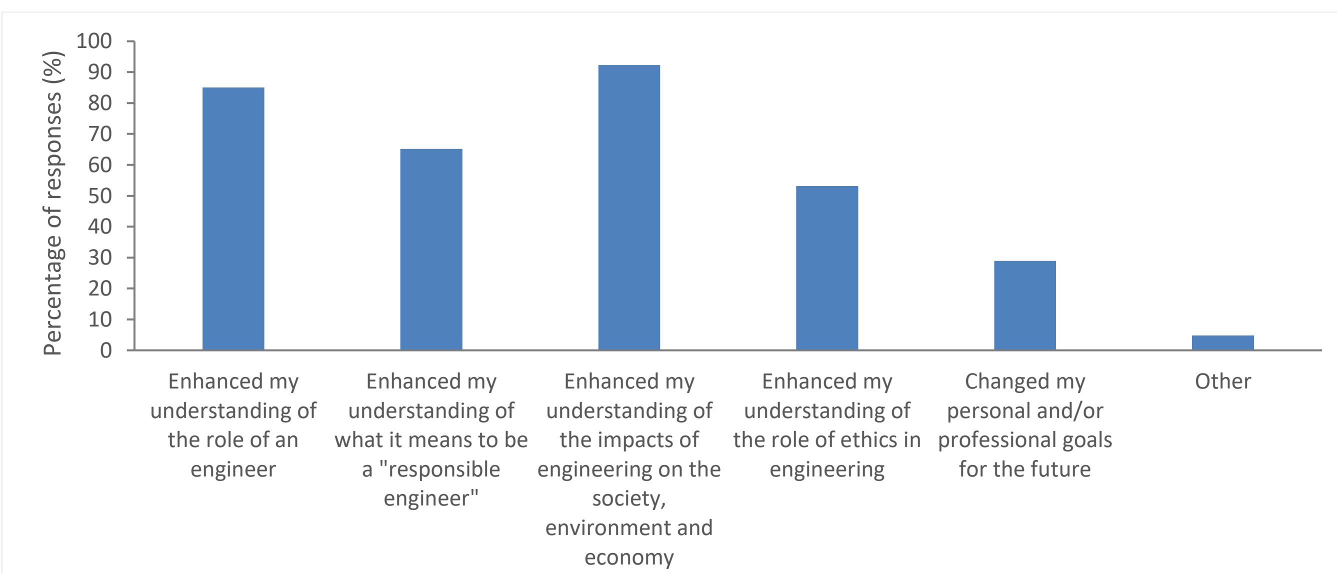


Figure 3. Students' level of agreement with the statement "An understanding of materials engineering is important to my future practice as an engineer in my discipline". Results from surveys administered in APSC 278 2022W1 (left, 209 responses) and 2022W2 (right, 188 responses) are shown.

Additionally, students reflected upon the impact of the expert interviews. In a multiple response question, they were asked to select all options that applied. A total of 207 responses and 176 responses were collected in Terms 1 and 2, respectively. The results revealed that the expert interviews had a positive impact on students' understanding of the role of an engineer, what it means to be a responsible engineer, and the impacts of engineering on the society, environment and economy. Interestingly, the expert interviews also contributed to a changed view of students' personal and/or professional goals for the future, although to a lesser extent than other response options (29% and 25% of responses in Terms 1 and 2, respectively). Of the respondents who selected "Other", most pointed to the impacts of the expert interviews on their awareness of other career paths and other engineering disciplines.



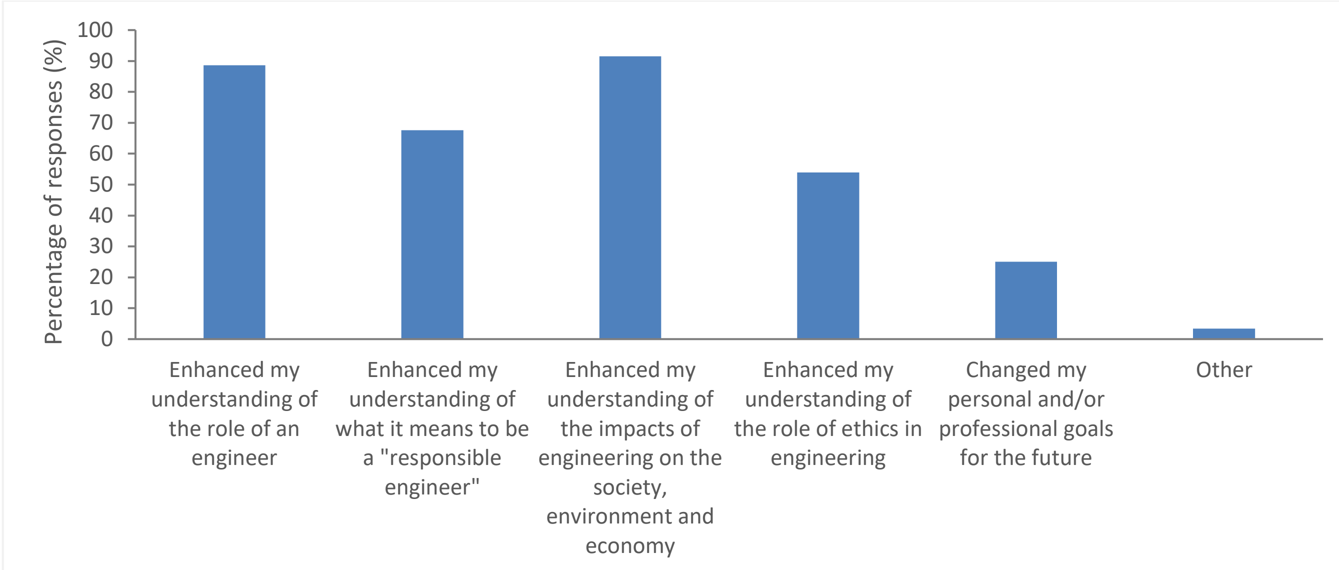


Figure 4. Student perceptions of the impact of the suite of expert interviews, in response to the prompt "The expert interview videos (select all that apply):". Results from surveys administered in APSC 278 2022W1 (top, 207 responses) and 2022W2 (bottom, 176 responses) are shown.

4. **TEACHING PRACTICES** – *Please indicate if **your** teaching practices or those of **others** have changed as a result of your project. If so, in what ways. Do you see these changes as sustainable over time? Why or why not?*

An important goal of this work was to enhance the quality of teaching in a large instructional team of teaching assistants and laboratory instructors. This, in turn, was expected to positively impact student learning and engagement in experiential opportunities. As discussed in the previous section, feedback from new and returning instructional team members alike suggested that this was achieved during the 2022W course offerings, and was largely attributed to the newly implemented training structure and resources. These improvements are expected to be sustained over time, because the learning and training resources were specifically designed to contain guidance about strategies to engage students and to facilitate discussions. This way, changes in course coordinator roles and/or changes in composition of instructional team members will have minimal effects on quality of training and teaching. Additionally, supplementary training tools, such as 360° laboratory maps and videos, were developed to support new and returning instructional team members.

A key barrier to maintaining excellent teaching practices was the resource-intensive nature of coordinating large classes. As the course instructor for the past several terms, I noticed that I dedicated significant time to communicating with students and teaching assistants regarding student issues, absences, and special accommodations. To address these issues and to ensure that good teaching practices could be sustained over time, a communication system was developed to manage student requests, track attendance, and to respond to queries or concerns in a large class. This system was developed to support any individual who coordinates these courses in the future.

5. **PROJECT SUSTAINMENT** – *Please describe the sustainment strategy for the project components. How will this be sustained and potentially expanded (e.g., over the next five years). What challenges do you foresee for project sustainment?*

To ensure that the project components can be sustained into the future, detailed manuals were developed to provide guidance for instructional team members and future course instructors alike. For example, instructional laboratory manuals were specifically designed to include notes about teaching strategies and suggestions for facilitating meaningful group discussions. Manuals were also developed to support the use of the student communications management system, to ensure that any new course coordinator would have sufficient information and resources to implement it in the future. Moreover, all virtual tools, including student learning resources, problem banks, and expert interview videos, have been made available in a Canvas course or on publicly available platforms. These resources will also be shared with the department administering both service courses.

One challenge to project sustainment is expansion of class sizes. This was already observed in previous years, and demanded significant teaching resources to manage student queries and requests. With the development of automatically graded assessments, which also provide immediate feedback to students, I expect that project components will support any expansion in class size. Moreover, the student communication system was specifically developed to reduce the amount of teaching resources and time required to manage student requests, absences, and queries. It was also designed with the intention of supporting future expansion of the course. Ultimately, the greatest challenge to sustainment of project components is related to the willingness of future course instructor(s) and level of departmental support to continue implementing this new course structure and supporting resources.

6. **DISSEMINATION** – *Please provide a list of scholarly activities (e.g., publications, presentations, invited talks, etc.) in which you or anyone from your team have shared information regarding this project. Be sure to include author names, presentation title, date, and presentation forum (e.g., journal, conference name, event). These will be included on the TLEF scholarly output page.*

D. Hawker, **G. Lam** (2022). Expert interviews: shifting student attitudes towards social responsibility and the role of the engineer. *American Society for Engineering Education Zone IV Conference (ASEE Zone IV 2022).*