TLEF Project – Final Report

Report Completion Date: (2020/06/24)

1. PROJECT OVERVIEW

1.1. General Information

Project Title:	Flash Feedback for Second-Year Engineering (FF2E): Personalized Experiential Learning with Instant Feedback Through Shared WeBWorK Resources		
Principal Investigator:	Agnes d'Entremont		
Report Submitted By:	Agnes d'Entremont		
Project Initiation Date:	April 2018	**Project Completion Date:**	May 2020
Project Type:	☐ Large Transformation ☒ Small Innovation ☐ Flexible Learning ☐ 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. Project Summary

Effective practice in solving engineering problems requires timely feedback, allowing students to assess and improve understanding. Large classes (130-180) make timely feedback challenging when using paper-based assignments (weeks), and hours spent marking could otherwise increase instructor-student interaction. Online homework sites exist for engineering, but are typically costly for students.

At the outset of this project there was no open, online homework source for most engineering subjects. Our project created resources that instructors and students at UBC then used to provide fast feedback with no marking or student cost, using the WeBWorK open-source online homework platform. The WeBWorK Open Problem Library (OPL), widely used in UBC Mathematics, contains 35,000+ math problems, but very few engineering problems.

We initially identified 14 second-year engineering course offerings in four departments with overlaps in subject matter. We then added two more courses in an additional department. In our second year, we added two courses (including one major core course) in two additional departments. We planned to create and deploy 700 WeBWorK problems in these courses to guide student practice, with the subsequent posting to the OPL. We completed 870 problems (170 more than anticipated), and translated another 231 problems from other homework systems (total 1049 engineering problems). 711 of these problems are submitted for inclusion in the OPL, and the rest are awaiting final testing in classes. In addition to the 711 new problems submitted, we were able to get 494 previously created problems submitted for inclusion in the OPL, and out of these, we facilitated getting 327 in the OPL proper to date (as well as getting other school's problems into the OPL by creating new engineering taxonomies). In addition, we encouraged and supported others to use WeBWorK, with colleagues teaching third-year heat transfer and fluid mechanics building their own WeBWorK problems.

In total, we have created, converted, and/or published for open use 1543 engineering homework problems, which represents more than a seven-fold increase over the number of engineering problems available in the OPL at the start of this project.

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
Agnes d'Entremont	Sr. Instructor/MECH	• Supervising Dynamics, Solid Mechanics, plus Statics conversion, Materials, and Mining • Dynamics instructor using problems • Participated in OPL admin work
Jonathan Verrett	Instructor/CHBE	• Supervising Fluid Mechanics • Participated in OPL admin work
Negar M. Harandi	Postdoctoral Fellow/ECE	• Supervising Circuits, Electromagnetism and Signals and Systems • Circuits and Electromag. instructor using problems
Gianni Co	Co-op and part-time UAA/MECH	Coding problems, making images, troubleshooting and problem support, problem conversion

Warren Chan Wan Fong	Co-op/ECE	Fixing issues, coding problems, making images, adding year 2 problems with instructors
Tyler Leonzio	Part time UAA/MECH	Troubleshooting and problem support, OPL submission and GitHub posting
Mahsa Khalili	Part-time GAA/MECH	Dynamics problem creation
Masoud Hejazi	Part-time GAA/MECH	Solid Mechanics problem creation
Parisa Samedi	Part-time GAA/MECH	Fluid Mechanics problem creation
Ali Cherom Kheirabadi	Part-time GAA/MECH	Fluid Mechanics problem creation
Grant Anderson	Part time UAA/ECE	Circuits II problem creation
Han Yun	Part time GAA/ECE	Electromagnetics problem creation
Richard Chang	Part time UAA/ECE	Circuits I problem creation
Tara Akhoundsadegh	Part time UAA/Eng Phys	Signals and Systems problem creation

1.5. Courses Reached – *Please fill in the following table with **past**, **current**, and **future** courses and sections (e.g. HIST 101, 002, 2017/2018, Sep) that have been/will be 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).*

We list the courses that have used the problems below. The exact courses using our problems depended on the instructor and their choices around homework. The content of these questions means they can also be used in the following courses: CIVL 230, CIVL 215, ELEC 201, ELEC 202, ELEC 204, and MECH 280. We hope that, in the future, these courses will adopt our problems. We have omitted them below because they have not done so yet.

Course	Section	Academic Year	Term (Summer/Fall/Winter)
CHBE 251 (Fluid Mech.)	201	2018/2019 to 2022/2023	Winter
ELEC 201 (Circuit Analysis 1)	201	2018/2019 to 2022/2023	Winter
ELEC 202 (Circuit Analysis 2)	201	2018/2019 to 2022/2023	Winter
ELEC 202 (Circuit Analysis 2)	202	2018/2019 to 2022/2023	Winter
ELEC 204 (Linear Circuits)	101	2018/2019 to 2022/2023	fall
ELEC 221 (Signals and Systems)	101	2018/2019 to 2022/2023	Fall
ELEC 221 (Signals and Systems)	201	2018/2019 to 2022/2023	Winter
ELEC 211 (Electromagnetics)	201	2018/2019 to 2022/2023	Winter
ELEC 211 (Electromagnetics)	202	2018/2019 to 2022/2023	Winter
MECH 221 (Dynamics and Solid Mech)	101	2018/2019 to 2022/2023	Fall
MECH 222 (Fluid Mech.)	201	2018/2019 to 2022/2023	Winter
MECH 260 (Solid Mech.)	101	2018/2019, 2020/2021 to 2022/2023	Fall
MECH 260 (Solid Mech.)	102	2018/2019, 2020/2021 to 2022/2023	Fall
MECH 329 (Materials for Mech. Design)	101	2020/2021 to 2022/2023	Winter
BMEG 220 (Circuits and Electromag.)	201	2018/2019 to 2022/2023	Winter
BMEG 230 (Dynamics and Solid Mech.)	201	2018/2019 to 2022/2023	Winter
MINE 310 (Surface Mining)	101	2019/2020 to 2022/2023	Winter

MINE 590C (Advanced Surface Design)	101	2019/2020 to 2022/2023	Winter
APSC 278 (Materials Engineering)	101	2019/2020 to 2022/2023	Winter
APSC 278 (Materials Engineering)	201	2019/2020 to 2022/2023	Winter

2. OUTPUTS AND/OR PRODUCTS

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

We will list the problems developed and coded or converted here (1019 problems), and not the existing problems that we submitted or got added to the OPL (you can find this also in the UBC folder of the OPL). We have organized our outputs into "tested" (meaning they have been tested in a class) and "untested" (meaning they were tested by project assistants and/or instructors, but not tested in a class to date, therefore not yet eligible for inclusion in the OPL).

All problems are in our GitHub repo and available for use (https://github.com/ubc-mech2/UBC-engineering-webwork). All the "tested" problems are also posted to the UBC folder of Contrib in the OPL (https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC).

Product(s)/Achievement(s):	Location:
BMEG – 24 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/BMEG/Mechanics/Untested
BMEG – 43 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/BMEG
Circuits – 53 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/MECH/MECH2/Circuits/2018
Circuits –79 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Circuits/Untested
Dynamics – 50 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/MECH/MECH2/Dynamics/2018
Dynamics – 37 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Dynamics/Untested
Electromagnetics – 67 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/ELEC/Electromagnetism
Electromagnetics – 24 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Electromag/Untested
Fluids – 86 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/MECH/MECH2/Fluids
Fluids – 57 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Fluids/Untested
Fluids – 190 converted	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/QueensU/FluidDynamics
Materials – 43 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/MTRL/APSC278
Materials – 5 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Materials/Untested
Mining – 5 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/Mining
Signals – 82 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/ELEC/Signals/2018
Signals – 3 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Signals/Untested
Solid Mechanics – 70 tested	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC/MECH/MECH2/SolidMech
Solid Mechanics – 64 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Solid%20Mechanics/Untested

Statics – 41 converted	https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/WhatcomCC/Statics
Thermodynamics – 26 untested	https://github.com/ubc-mech2/UBC-engineering-webwork/tree/master/Thermo/Untested

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

While we surpassed problem creation goals in most areas, there were a couple of subjects where our numbers were short (detailed below).

Additionally, we did not test all problems in classes (as noted above). There were a few specific reasons for this. In a few cases (Solid Mechanics in particular), some portion of the problems were not ready at the start of classes due to delayed student project assistant availability. Then, when instructors did use problems, they chose which problems they wished to include in their homework sets, and they may not have chosen to assign all the available problems. And, finally, whether problems were used in a class at all depended on the instructors for the target courses. There was substantial turnover in instructors in many of these courses, therefore instructors who originally assisted in guiding problem creation were not necessarily those teaching (e.g. none of the three solid mechanics instructors we partnered with for problem creation taught any of eight offerings of solid mechanics over the two years of this project). Ultimately, the problems remain available for courses, and we will continue to encourage instructors to use them, including testing problems not currently in Contrib. We will work on arranging departmental or other resources for problem support as instructors choose to use "untested" problems in the future.

Item(s) Not Met:	Reason:
Signals and Systems (aimed for 100, 85 questions coded)	These questions were more complex to create and code than for some other subjects, so we reduced the total slightly
Circuits (aimed for 140, 132 questions coded)	The instructor we had partnered with for these problems was not as available as we expected to the students creating problems, and this caused a delay in problem creation.
Solid Mechanics. (aimed for 155, 142 questions coded)	There was lower engagement than expected from the instructors we partnered with, partly because they did not end up teaching the courses during this project.
Complete testing of all problems in classes	As noted above, there were several reasons for this. All problems remain available for use, and departmental or other resources will be used to support "untested" problem use in future classes.

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 teaching practice and satisfaction

☐ Student wellbeing, social inclusion

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

☐ Unit operations and processes

☐ Other: [please specify]

3.2. What were you hoping to change or where were you hoping to see an impact with this project? – *Please describe the intended* *__benefits of the project__* *for students, TAs, instructors and/or community members.*

Instant feedback on homework and practice problems

Student would get feedback from the systems immediately after completing a problem, allowing them to correct any errors and re-attempt. This is in contrast to traditional graded homework, where a student waits 1-2 weeks after submission until the homework is returned before finding out if they made errors. The instant feedback may increase student motivation to find the correct answers, and positively impact learning.

Less time dedicated to marking and more time for student interaction (from both TA's and instructors)

For courses that previously used manually-marked homework, less instructor or TA time would be used marking, leaving more time to assist students directly, including with the problems.

Provide homework in courses where there was no capacity to grade homework previously

At least two major courses (ELEC 221 and APSC 278) did not have any graded homework prior to this project. Being able to assign graded homework with feedback both encourages students to complete practice and provides them with feedback on their understanding of the material.

Create a lasting resource

Once created, WeBWorK problems can be used repeatedly each year.

Provide problems on a common, known homework platform

Because students use WeBWorK within their Math courses already, thy are familiar with the system. A smaller impact we wanted to make was to provide a common platform for problems across many different second-year courses.

Increase in WeBWorK engineering problems available on the OPL, encourage others to build problems

While some engineering problems were available when we started, there were very few and the subject areas were limited. We wanted to increase the publicly-available problems in an effort to encourage others to generate problems as well (reaching a critical mass).

Create online homework resources for subjects where even paid versions do not exist

We are not aware of any existing paid online homework systems have cover topics like Biomechanics for engineers and Surface Mine Design. We aimed to make similar resources available to courses where publishers have not created resources.

In addition to the above, there is a potential to reduce student cost in cases where paid systems were being used. We are not aware of any paid systems replaced by WeBWorK during this project (courses tended to just not have graded homework instead of using a paid system).

3.3. Were these changes/impacts achieved? How do you know they occurred? – *What evaluation strategies were used? How was data collected and analyzed? You are encouraged to include copies of data collection tools (e.g. surveys and interview protocols) as well as graphical representations of data and/or scenarios or quotes to represent and illustrate key themes.*

We created, coded and/or converted 1543 WeBWorK problems for engineering which will be a permanent resource for future instructors at UBC. We were able to create problems for at least two courses (BMEG 230 and MINE 310) where we are not aware of paid problems existing. At least two courses (ELEC 221 (4 offerings to date) and APSC 278 (2 offerings to date)) did not previously have marked homework because of a lack of marking capacity, and are now able to offer students both practice and feedback on the material.

We have submitted many of our newly created problems to the OPL, and facilitated the submission of previously-created problems to the OPL. We also worked to perform admin tasks to get engineering problems entered into the OPL proper. We provided some assistance and encouragement to faculty teaching third-year courses to create WeBWorK problems – we are aware of two sets of problems created by others during this project (MECH 375 and MECH 380). We also disseminated information about the project, the problems, and how to use WeBWorK through multiple channels (papers, workshops, presentations, media).

To evaluate student and instructor experiences, we completed surveys.

Student surveys

We conducted student surveys on Qualtrics at the start and end of the term in both terms of 2018W (offering a gift card draw as incentive). This covered 16 course offerings, and we had 331 students respond to the pre-survey and 239 students respond to the post-survey.

Pre-survey

The pre-survey was primarily meant to determine what factors students found important, and their experience with WeBWorK in the past. We statistically compared WeBWorK with other online homework systems students used in the past, and typically WeBWorK was more positively rated than other systems (statistically significant differences).

Rate your experience with online homework systems in the past, considering the most recent time. (1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree)	**WeBWorK (n = 320)**	**Other Systems (n = 295)**
The system was easy to use	**4.3***	3.7
The site was easy to navigate	**4.2***	3.7
The question presentation was clear	4.0	3.9
The required answer formats were straightforward	3.5	3.7
The feedback was clear and easy to access	3.3	**3.8***
The system enhanced my learning	**4.0***	3.7
The system motivated me to persist in finding the correct answer	**3.8***	3.6
I would like to use the system in the future	**4.0***	3.2

We also asked about features of an online homework system that they found important. Students identified “low cost or free”, “easy to use”, and “motivates me to correctly solve problems/complete homework” as important features. WeBWorK is free, and was rated as significantly more “easy to use” than others system. We asked about motivation in the post-survey, and it appears that WeBWorK also motivates students (see below).

How important are the following factors to you when it comes to online homework systems?	**1 = Not at all important, 3 = Neutral, 5 = Extremely important**
The system is easy to use	4.5
The system is low cost or free	4.7
The system is open source	3.4
The same system is used by many (or all) of my courses	3.7
The system motivates me to correctly solve problems/complete homework	4.3
The system is integrated with the learning management system	3.7
The system is integrated with my textbook	2.9
The system suggests targeted additional practice problems based on my results	3.5
The system provides hints within problems based on my results	3.9

Post-survey

We asked students about the WeBWorK questions created. Their ratings indicated that we had issues with errors and tolerances, although we did have troubleshooting help. We recognized this issue, and added a second testing step by hiring separate students who had not be part of creating the problems (supported by APSC funding). This reduced the number of errors in problems being deployed to students. Our images were rated positively.

Please rate how you agree or disagree with the following statements about issues with the problems you used this term	**1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree**

The problems had few errors (missing values, incorrect answers, etc.)	2.8
The problems had few issues with answer tolerances	3.1
Problem text was almost always clear and understandable	3.6
Errors or other issues with the problems were corrected quickly	3.2
The problems were at the same level of difficulty as tests/exams	2.9
The problems were most challenging than tests/exams	3.2
Images were almost always clear and understandable	4.1
The instructor(s) and/or TA(s) knew how to use the system	3.6

We asked about motivation to complete homework and how they felt about using the system. Students reported being highly motivated to both attempt and successfully complete all of the homework to marks. They also believed that WeBWorK enhanced their learning.

How did WeBWorK impact your studies this term in your engineering courses?	**1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree**
I was motivated to attempt and solve all problems that counted for marks	4.3
I was motivated to attempt and solve all problems that did not count for marks	2.9
I was motivated to successfully complete all problems that counted for marks	4.2
I was motivated to successfully complete all problems that did not count for marks	2.7
I was motivated to correct my errors in understanding	3.8
I expect using WeBWorK will help me to be well prepared for the final exam in this course	3.8
I enjoyed using WeBWorK	3.4
I believe WeBWorK enhanced my learning	4.0

We also asked about interactions. We noted that interactions about WeBWorK problems with both classmates and TAs was high. Because the problems randomize numbers in the problems, student interaction would necessarily be about procedure and not just the final answer. Some instructors encouraged collaboration between students when working on their WeBWorK homework.

How frequently did you do the following this past term in your engineering courses?	**1 = Never, 5 = Weekly or more often**
Discussed WeBWorK problems with classmates	4.3
Visited a TA to ask about a WeBWorK problem	2.9
Emailed/messaged a TA to ask about a WeBWorK problem	4.2
Emailed/messaged an instructor to ask about a WeBWorK problem	2.7
Visited an instructor to ask about a WeBWorK problem	3.8
Posted about a WeBWorK problem on a class discussion board	3.8
Other	3.4

Students also agreed that engineering instructors should use WeBWorK in future courses.

	(10 = Highly recommend, 1 = Do not recommend)
Would you recommend that UBC engineering instructors use WeBWorK in courses like this one in the future?	7.7 (Median = 8)

Overall, the student response was positive – engineering students believe WeBWorK is a useful system, and that our problems enhanced their learning. They reported frequent TA and classmate interaction about their homework, and the system motivated them to both attempt and successfully complete the problems, by receiving feedback instantly and reattempting the problems immediately.

Instructor survey

We had 11 responses to the instructor survey. Only three instructors had used WeBWorK previously in their courses with already existing problems. The majority were either not providing marking (feedback) or doing manual marking. No one was using paid systems. Some were using additional approaches, or past problems, while simultaneously using the newly-developed problems.

Prior to using the new WeBWorK questions, how was homework delivered in your course? (Select all that apply)	Number of responses
Homework, no marking [practice problems]	4

Homework, with non-automated marking	3
WeBWorK (pre-existing problems)	3
New course, no past practice	2
No homework	1

Besides the new questions on WeBWorK, what other methods were used to deliver homework to students? (Select all that apply)	Number of responses
No homework [no other methods]	4
Homework, no marking [practice problems]	3
Homework, with non-automated marking	2
WeBWorK (pre-existing problems)	2
Delivered through Canvas (or similar system, no cost to students)	2

The vast majority of respondents were using WeBWorK for required homework. This is a large shift from past practices (shown above), and enhances the interpretation of student responses showing high motivation in completing required problems.

What did you use WeBWorK for in your engineering course(s)? (Select all that apply)	Number of responses
Required homework problems (counted for marks)	10
Optional practice problems (did not count for marks)	4
Pre-laboratory assignments	2

Instructors reported students were able to independently navigate the system, which means instructors and TAs do not need to spend time helping them. They also reported quality text, quick correction of errors, variety in topics and difficulties, and felt they were valuable for student learning. Topic coverage may need to be improved.

Critically, instructors noted that this reduced marking time and allowed for more formative feedback to students at the same time. Instructors did not report high levels of student-TA interaction (unlike the student survey), but they did report high levels of student-instructor interaction about the problems, and rated this interaction as more frequent for WeBWorK than for other homework methods.

Please rate how you agree or disagree with the following statements about issues with the WeBWorK questions you used.	**1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree**
The questions had errors (missing values, incorrect answers, etc.)	3.8
The questions had issues with answer tolerances	3.3
Question text was clear and understandable	4.4
Errors or other issues with the questions were corrected quickly	4.1
There were a variety of question topic areas	4.2
There were a variety of questions difficulty levels	4.1
The questions covered all the essential content covered in your course	3.6
The questions covered all the optional content covered in your course	3.3
Students were able to independently navigate the homework system	4.9
Questions were valuable for student learning	4.6
The new WeBWorK questions reduced the amount of time preparing homework problems	3.9
The new WeBWorK questions reduced the amount of time spent marking and returning homework problems	4.8
The new WeBWorK questions allowed for more formative feedback to be given than traditional homework styles	4.3
There was substantial student-TA interaction related to WeBWorK	3.0
Student-TA interaction related to WeBWorK was more frequent than typical student-TA interaction for other systems/homework methods	3.2
There was substantial student-instructor interaction related to WeBWorK	4.0
Student-instructor interaction related to WeBWorK was more frequent than typical student-instructor interaction for other systems/homework methods	4.0

Seven instructors reported using the provided troubleshooting support when introducing new WeBWorK questions to their courses. They indicated that technical support is essential to rolling out new WeBWorK problems.

(Only asked of those who used troubleshooting) Please rate the following items related to your confidence that new problems can be rolled out without technical support.	**1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree**
Technical support responded to queries quickly	3.7
Technical support provided quality solutions to queries	3.6
New WeBWorK questions can be rolled out without technical support provided	1.4

We also asked about whether the instructors would continue to use WeBWorK, and whether they would recommend WeBWorK to other instructors.

Rate the following.	**1 = Extremely unlikely, 5 = Neutral, 10 = Extremely likely**
How likely are you to use WeBWorK questions developed through this program in future courses?	Mean: 9.6 Median: 10
How likely are you to recommend that the WeBWorK questions developed through this project be used by other instructors?	Mean: 9 Median: 10

These results together seem to indicate that we had the desired impact of reducing marking burden, increasing formative feedback for students, and increasing student-instructor interaction.

3.4. Dissemination – *Please provide a list of **past** and **upcoming** scholarly activities (e.g. publications, presentations, invited talks, etc.) in which you or anyone from your team have shared information regarding this project.*

Conference papers directly related to the TLEF-funded project:

- AG d'Entremont, NM Harandi, J Verrett. Developing for and deploying WeBWorK across disciplines in second-year engineering. Canadian Engineering Education Association (CEEA-ACEG) Annual Conference, Ottawa 2019.

Conference papers that developed out of this work:

- H Jayhooni, CE Jones, AG d'Entremont. Student preference between single-box and multi-box homework problem answers using WeBWorK, an online homework system. Canadian Engineering Education Association (CEEA-ACEG) Annual Conference, Vancouver, 2018.
- AG d'Entremont, J Abello. Creating problem taxonomies for WeBWorK in mechanical engineering. American Society for Engineering Education Annual Conference, Salt Lake City, 2018.
- G Co, Z (Zuheng) Xu, G Sgarbi, S Cheng, Z (Ziqi) Xu, AG d'Entremont, J Abelló, NM Harandi, J Verrett. Student usage patterns in online homework and relationships to learning outcomes: a pilot study. Canadian Engineering Education Association (CEEA-ACEG) Annual Conference, Ottawa 2019.
- AG d'Entremont, J Verrett, J Abelló, NM Harandi, S Hu, T Leonzio, W Chan Wan Fong. Multi-factorial patterns of online homework usage in engineering: a pilot study. Paper accepted for Canadian Engineering Education Association Annual Conference, Montreal 2020. [Proceedings only, due to COVID-19]

Presentations directly related to the TLEF-funded project:

- AG d'Entremont, T Leonzio, W Chan Wan Fong. Practice Makes Perfect: Developing for and Using WeBWorK Open Online Homework in Engineering at UBC. Open Education Week 2020, BC Open Education Librarians: Transforming Practice through Innovative Classroom Projects, March 3, 2020.
- AG d'Entremont, J Verrett. Developing for and deploying WeBWorK in second-year engineering, Open Education Resources Faculty Panel, October 1, 2019. (Local)
- AG d'Entremont, G. Co Chua, NM Harandi, J Sibley, J Verrett. Flash Feedback for Second-Year Engineering (FF2E): Personalized Experiential Learning with Instant Feedback Through Shared WeBWorK Resources. Teaching and Learning Enhancement Fund Showcase, Vancouver, May 2, 2019. (Local)
- J Verrett, AG d'Entremont. Implementing the WeBWorK open online homework system in second-year courses across a faculty of engineering. Cascadia Open Education Summit, Vancouver, April 17, 2019. (Regional)

Presentations that developed out of this work:

- AG d'Entremont, S Hu, J Verrett, J Abelló, NM Harandi. Exploring WeBWorK Usage Factors Related to Grades in Second-Year Engineering. Celebrate SoTL E-poster Session, October 25, 2019. (Local)

Workshops that developed out of this work:

- J Verrett, AG d'Entremont. WeBWorK overview, University of Saskatchewan Engineering (online), February 6, 2019
- AG d'Entremont. WeBWorK for beginners! Using and developing for the Open Problem Library. American Society for Engineering Education, Salt Lake City, June 24, 2018
- J Verrett, AG d'Entremont, NM Harandi, L Linares. WeBWorK for beginners! Part I: Using WeBWorK. Workshop co-developer and co-facilitator, Canadian Engineering Education Association Annual Meeting, Vancouver, June 3, 2018.
- J Verrett, AG d'Entremont, NM Harandi, L Linares. WeBWorK for beginners! Part II: Developing in WeBWorK for the Open Problem Library. Canadian Engineering Education Association Annual Meeting, Vancouver, June 3, 2018
- J Verrett, AG d'Entremont, NM Harandi, L Linares. WeBWorK for beginners! Using and developing for the Open Problem Library. Invited workshop at BCIT, Burnaby, Feb 21, 2018
- J Verrett, AG d'Entremont, NM Harandi, L Linares, P Walls. WeBWorK for beginners! Using and developing for the Open Problem Library. CTLT Winter Institute, UBC, Dec 4, 2017

Media interviews/coverage directly related to the TLEF-funded project:

- J Verrett, AG d'Entremont. Interview/video about using WeBWorK open problems in engineering for CTLT Open Dialogues (posted: Nov 30, 2017, https://ctlt.ubc.ca/2017/11/30/open-dialogues-how-to-use-open-tools-and-resources-for-problem-sets/)
- J Verrett, AG d'Entremont. Interview/video about project developing WeBWorK open problems in engineering for BCCampus Open Education Stories (posted: Nov 1, 2017, https://bccampus.ca/2017/11/01/open-education-stories-creating-and-reusing-problems-using-oer/)

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?*

As noted in the instructor survey results above, a number of instructors involved in using problems created in this project moved from having unmarked, manually marked or no homework to using WeBWorK in their engineering courses. This shift is predicated on problem availability, and since the problems will remain available, with no present upkeep required, we expect that this change will endure. In fact, repeated offerings of many courses have continued to use the problems after the initial deployment.

This shift to WeBWorK also appears to change the allocation of instructor time in these courses, from marking (or supervising of marking) homework (if it existed) to student-instructor interaction.

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 achieving the expected long-term impacts listed above?*

Sustainment

The WeBWorK questions developed in this project continue to be used in the participating courses. The problems, once checked/corrected, do not require regular upkeep, and can be used perpetually.

We hope to have instructors also use the untested problems, so they get tested in a class and can be uploaded to the OPL. It is clear from instructor survey responses that instructors do not want to use untested problems without knowing that there is technical support for them, so that errors can be corrected quickly. We hope to migrate this troubleshooting to APSC CIS, so we can submit these problems officially.

Expansion

As described earlier, this project has inspired other faculty to develop WeBWorK problems for their own courses. Two instructors who did not use our problem did developed and deploy WeBWorK problems for their third-year courses (MECH 375, MECH 380). Three instructors who did use our problems (including the principal applicant) have TLEF-funded, UBC OER Fund-funded, and BCcampus-funded projects this year to develop more WeBWorK problems, and to develop ways to ask more complex questions using the system.

As BCcampus is currently considering WeBWorK as a supported open homework platform province-wide, we expect that (a) the current problems will see much more use, and (b) there will be more development of engineering problems.

Additionally, besides the partners from Queen's University and Whatcom College (where we converted existing problems), we have assisted engineering faculty at Everett College, York University and SFU in starting to use and/or develop WeBWorK problems. We have also given presentations to BCIT, University of Saskatchewan and the Canadian and American engineering education organizations – we hope that these seeds will start to grow into increased content created by others that UBC instructors and students can benefit from.

Challenges

One of the challenges is a lack of clear documentation for using and developing for WeBWorK: instructions for use and for generating/coding problems to expand the currently available question sets. Resources are available to help developers write problems, namely from the WeBWorK MAA Wiki (http://webwork.maa.org/wiki/) and UBC's WeBWorK Wiki. We hope that, if WeBWorK is selected by BCcampus, funding will be available to create further resources, and even improve the platform.

Another challenge is the need for problem troubleshooting when errors are found. Again, direct support from APSC CIS would alleviate instructor concern in this area, and ease more wide-spread adoption.