First Year Engineering Design: Course Design, Projects, Challenges, and Outcomes

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***Abstract*—This paper outlines the essential components of developing an introductory course in Engineering Design for the first year, first semester students at Thompson Rivers University (TRU). The course design accounts for the teaching context, stakeholder interests, and Canadian Engineering Accreditation Board (CEAB) criteria. The proposed course design scaffolds engineering design projects of three different levels. Through the described course, students become familiar with the engineering design process including translation of the design idea into virtual and physical prototypes. The course design is built around the concepts of engineering sustainability, ethics, and professionalism helping students understand the linkage between engineering design and social and human factors. The course is lecture and laboratory based with a focus on experiential hands-on learning where the Course Learning Outcomes (CLOs) are achieved by means of PowerPoint slides, presentations, lecture and laboratory notes, class discussions and activities, teamwork, lecture and lab video recordings, hand sketching, and virtual prototyping via Computer-Aided Design (CAD) software (Solidworks). Student performance was evaluated through quizzes, reports, homework assignments, laboratory assignments, projects, midterms and final exams. To ensure effective communication between students, anonymous team member peer review and evaluation were incorporated. Continual improvement of the course design was achieved by modifying the course structure based on student feedback.**

***Index Terms*—Engineering design, curriculum development, first year course.**

I. Introduction

FIRST year engineering courses at Thompson Rivers University (TRU) in British Columbia (BC), Canada, contribute to the success of the software engineering program, providing students with knowledge and skills foundational for their future careers as engineers. Moreover, they support the accreditation of the program by the Canadian Engineering Accreditation Board (CEAB) [1]. Graduation from CEAB accredited academic institutions is one of the mandatory requirements for engineers to apply to become a licensed Professional Engineer (P.Eng.) in Canada (e.g., Professional Engineers Ontario (PEO), Engineers and Geoscientists BC (EGBC), and Association of Professional Engineers and Geoscientists of Alberta (APEGA)). Accreditation criteria of CEAB are based on twelve Graduate Attributes (GAs) [1]. The engineering design component is a critical part, and is one of the twelve GA accreditation criteria of CEAB. The design component requirement is generally fulfilled through engineering design projects and other activities, such as assignments and formal examination. Engineering design projects not only fulfill the engineering design GA, but also contribute to other GAs, including 1) the use of engineering tools, 2) individual and teamwork, 3) communication between team members, 4) professionalism, 5) impact of engineering on society and the environment, and 6) economics and project management. Therefore, development of engineering courses, in particular engineering design courses, is not a trivial task. In turn, design of high-quality projects for the engineering design courses is critical for achieving course objectives.

Engineering design: It is essential that the engineering courses prepare undergraduate students for their future careers. As such, course design was guided by the following questions: what is the role of an engineer in the society [2]? what is the best way for an engineer to approach a new problem? what knowledge does an engineer need to translate a problem at hand into a search space? What are effective strategies for independent work and teamwork for successful engineering task completion? How can engineers solve complex problems in an ethical and professional manner? It is crucial that answers to the above questions guide the creation of the engineering design courses in order to equip engineering students with the skills they need to be able to meet the needs of the society [3,4]. In addition, such an approach will allow to bridge the gap between the theoretical and practical knowledge which is a notable challenge faced by universities [5,6]. To develop engineering design courses and engineering design projects, it is important to understand the definition of design according to CEAB. CEAB accreditation "Design" criterion 3.1.4 (the fourth GA) is defined as "An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations." Closely following the above definition, we have created the "Engineering Design I" course (course code: "ENGR 1100") which forms the focus of this paper. Note that "Engineering Design I" and ENGR 1100 will be used interchangeably throughout this paper. This paper demonstrates how to translate the CEAB definition of "Design" into an effective engineering design course with an emphasis on the project component.

Objectives: TRU administration had a vision of creating engineering courses for the software program that provide not only a strong theoretical foundation but also significant

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To cite this article: **H. A. Hashim, C. Tatarniuk, and B. Harasymchuk "First Year Engineering Design: Course Design, Projects, Challenges, and Outcomes," In Proc. of the the 2022 IEEE Frontiers in Education (FIE) conference (FIE'22), Uppsala, Sweden, pp. 1-9, 2022.**

practical experiences. This vision has been translated into three objectives. The first objective was to develop an "Engineering Design I" course that aligns with the CEAB GA definition of "Design" as well as with the Graduate Attribute Indicators (GAI) definition of the Department of Engineering at TRU. The second goal was to design a course that provides an excellent student learning experience, lays a foundation for successful and ethical professional practice, and paves the way for the students to become licensed Professional Engineers (P.Eng.) [7,8]. The third goal is to build the student knowledge base necessary for progressing to more advanced engineering design. In addition, we aimed to place special emphasis on teamwork, communication, and concepts of professionalism and ethics. When creating "Engineering Design I",, special attention was given to the role of an engineer in society, and strove to promote sustainable engineering design and teach students to work with open-ended problems within the design solution space reaching the best solution.

Structure: This paper consists of seven sections: Section II provides a brief overview of designing the "Engineering Design I" course at TRU. Section III presents the process of compiling the "Engineering Design I" course outline, and describes a typical week and course content. Section IV focuses on projects which constitute an essential part of the "Engineering Design I" course. Section V presents important results and statistics collected during and after the initial delivery of this course in this format). Section V summarizes course outcomes and challenges. Finally, Section VII draws a conclusion of this work.

II. Course Design

Course design is composed of three key components, namely (i) course context in accordance with up-to-date student skills, (ii) departmental and institutional context, (iii) stakeholders who may be engaged in the process.

A. Course Context

The first-year engineering program at TRU consists of approximately 60-70 students. In their first year, students study a variety of introductory courses that lay down a solid foundation in core subjects and meet the program and CEAB requirements. These courses include math, natural sciences, computer science, English, and an introduction to engineering. The first-year courses constitute a total of 36 credits. Also, the proportion of lecture/lab hours per topic area closely aligns with other Canadian schools (e.g., University of Western Ontario, McGill, Queens, and University of Victoria). Majority of students take a 3 to 5-credit engineering courses that consists of 3 hours of lectures and 2 hours of experiential laboratory work.

At TRU, Engineering Design is a fundamental part of several courses in the Software Engineering program and TRU's Engineering Transfer program, which is described in the following section. However, the three main courses that focus on introducing the students to the engineering design process are Engineering Design I, Engineering Design II, and Engineering Design III.

B. Stakeholders

The "Engineering Design I" course is a first year, first semester 5-credit engineering course with an enrollment of approximately 60-70 students. Approximately one-third of these students are enrolled in the Bachelor of Software Engineering program at TRU, and the other two-thirds are enrolled in the Engineering Transfer Program. "Engineering Design I" is an outcome of a comprehensive stakeholder consultation. The comprehensive engagement and consultation contribute significantly to the success of the course and program outcomes. Consultation and engagement occur of multiple levels are described below:

1) Departmental level meetings (committees and members): Department consultation included meeting with
    - faculty members
    - Curriculum and Quality Assurance Committee, and
    - Engineering Design Committee
2) Institutional TRU level meetings: TRU consultation included meetings of
    - TRU program chairs (e.g., engineering, mathematics, physics)
    - Curriculum Committee members, and
    - Education Planning Committee
3) Leveraging TRU experience teaching Engineering courses: TRU offers a one-year Engineering Transfer program which allows students to complete one year of engineering studies at TRU prior to transferring to an Engineering program at the University of British Columbia or University of Victoria. Thus, we consulted the Engineering Transfer program acting chair, instructors, and the Associate Dean of Science.
4) Leveraging Engineering Transfer student experience and support: Voluntary meetings and surveys have been conducted among the Engineering Transfer students to collect information on
    - preferred teaching methods
    - teamwork insights and challenges of engineering design projects

Engaging with the stakeholders is a key element of shaping the course content [9]. The main objectives of our meetings and extensive consultations with the stakeholders were to

- learn from ways in which design is incorporated in the curriculum of other programs,
- identify best ways to incorporate design into the first-year engineering courses,
- gain an understanding of design in the context of CEAB,
- learn ways to integrate teamwork into engineering courses, and engineering design courses in particular,
- identify best practices of promoting ethics and professional development, and
- determine best ways to integrate equity, diversity, and inclusion into engineering design courses.

III. Structuring Engineering Design I

The main components of ENGR 1100 are 1) the role of an engineer in society, 2) engineering design process, 3) hand sketching, 4) virtual prototyping based on Computer-Aided Design (CAD) software, and 5) physical prototyping using cardboard and other simple tools and materials.

A. Course description

In ENGR 1100, students 1) are introduced to the engineering profession and various engineering disciplines, 2) become closely familiar with the structure for the engineering design process, and develop skills to identify and prioritize the requirements of an engineering project through multiple iterations, 3) are introduced to the sustainability considerations applicable to engineering design while emphasizing regulatory, environmental, health, and safety-related issues, 4) learn the decision process necessary to select from alternate design options, 5) work on a engineering design problem and develop a prototype, and 6) experience CAD tools, learning to sketch and prototype in 2D and 3D. In addition, ENGR 1100 includes guest speakers from academia, industry, and government who give talks illustrating various aspects of the engineering profession.

B. Educational objectives and expected outcomes

A mix of high and low order educational objectives were created for ENGR 1100 and are as follows: 1) gain understanding of the engineering profession and the role and responsibilities of a professional engineer in a broader context, e.g. as it pertains to the environment, health, safety and public welfare, 2) become familiar with the engineering design process which includes learning to meet the desired needs/requirements within realistic constraints of product development with a focus on environmental, social, ethical and safety regulations, to name a few, 3) learn to articulate engineering problems and translate them into a structured design to reflect the product requirements, 4) master applying formal iterative formal decision making methods to assist in choosing between alternative conceptual designs, 5) acquire basic 2D and 3D sketching skills using engineering CAD tools, 6) experience developing virtual and physical prototypes based on an engineering design using various engineering tools, and 7) learn to work collaboratively in teams and communicate effectively using oral, written, and graphical forms. Chapters (1-4) [10] Chapters (1, 4-10, 13) [11]. These seven learning outcomes are hereby referred to as CLO's (Course Learning Outcomes).

C. A typical week

ENGR 1100 is a 3-credit engineering course that runs for 13 weeks over the length of a semester. Every week students have 3 hours of lecture and 2 hours of laboratory work. Since the total number of the first-year engineering students is 60-70, the course is taught in two sections: one section for the TRU Software Engineering program students (approximately 25 students) and another section for the Engineering Transfer students (approximately 40 students).

The lecture component includes presentations given by the course instructor, supplemented with educational videos (1-3 per week, 4-12 minutes in length), and 20-minute guest presentations. Throughout the course, 4-6 guest speakers from academia, industry, and government are invited to share their role, associated duties of a typical day as an engineer, and importance of P.Eng. licensing in their field. Guest speakers provide a meaningful connection to work opportunities after degree completion, and can help students with selecting their specialization/discipline [12]. Each lecture contains two individual or group activities that reinforce the theoretical lecture topics. Students are given the activities, allowed 5-10 minutes to discuss and work out a solution, and the solution or potential solutions are discussed as a class. The three extended learning assignments provide further reinforcement of the lecture material.

The experiential hands-on learning laboratory component consists of nine sessions where students become closely familiar with the complete engineering design process and learn the basics of hand and computer sketching using CAD software. The CAD software used in ENGR 1100 is Solidworks. The laboratory instruction manual consists of two parts. The first part introduces students to a new topic and provides a step-by-step guide to completing a specific task(s) associated with the topic. The second part contains two to three small problems for the students to solve allowing them to brainstorm and assess their understanding of the new topic. The hands-on learning that takes place in the laboratory further bridges the gap between the theoretical focus in the lectures and the real world experiences shared by the guest speakers [13].

Since engineering design is a core component of the ENGR 1100, design projects constitute a critical part of the course. The course projects are presented in the subsequent section. Table I presents a brief summary of the proposed course design outlining lecture and laboratory topics, project and report requirements, and the associated mandatory deliverables. Table II presents the breakdown of the student evaluation.

D. Homework, Quizzes, and Labs

ENGR 1100 includes multiple extended learning assignments, quizzes, and laboratories as listed in Table II. Each homework, quiz, and laboratory report are written/answered individually by the student. Homework and quizzes include a combination of multiple choice, short answer, and scenario-based questions that prepare the students for midterm and final examinations. Each laboratory report includes two to three small CAD problems.

E. Midterm and Final examinations

ENGR 1100 includes one midterm and a final exam as stated in Table I. All of the examinations are completed individually. Exams include a combination of scenario-based, multiple choice, true and false, and short answer questions.

IV. Engineering Design Projects

Projects are a fundamental part of the course evaluation as they demonstrate student understanding of the engineering design process. After extensive meetings and consultations with faculty member, members of the Engineering Design

TABLE I
SUMMARY OF ENGR 1100 COURSE DESIGN

Lecture topics	Lab topics (Solidworks)	Duration in weeks	Project / Report	Deliverable
Introduction to engineering, P.Eng. licensing, professional ethics, and engineering societies	Creation of 3D parts, 2D engineering drawings, and models	3	Report contains three parts. (i) Question: why you want to be an engineer? (ii) Case study: answer ethical problem, and (iii) Interview with a professional engineer	Report 1
Definition of design, needs and information, and customer requirement	Assembly, animation from exploded and collapsed view, and virtual prototyping	3	Build a prototype to address a societal problem: Design a portable ramp for a wheelchair	Project 1
Design specification, conceptual design, evaluation, selection criteria, and introduction to computer-aided design	3D sketching, weldments, material selection, and stress and strain analysis	4	Virtual prototyping solution for small-sized homes: Use computer-aided design software (Solidworks) to design a multi-purpose furniture item	Project 2
Concept prototypes, introduction to finite-element analysis, material selection, and cost analysis	Working on Project 3	3	Virtual to physical prototyping: design-build a cardboard walker for children with cerebral palsy	Project 3

TABLE II
"ENGINEERING DESIGN I" COURSE EVALUATION

Type of evaluation	Number	Percentage (%)
Quiz	2	2
Report	1	2
Homework	3	6
Labs	9	15
Project	3	25
Midterm	1	20
Final exam	1	30

Committee, and the Curriculum Committee members, the course instructors (Hashim and Catherine) decided to assign three projects. In each project, students are asked to work in a group of three. Teamwork is a critical element for the course as it aligns with the CEAB requirement for communication and teamwork and prepares the students for working as part of a team in their future careers. The project component is designed and scaffolded in the form of three phases where each phase represents a separate project but completing the three phases allows students to experience the engineering design process from start to finish and progressively gets more difficult. The phases are as follows:

- Phase 1. (Project 1) Getting started with prototyping: This phase requires the students to design a prototype with an objective of assessing student understanding of
  - engineering design definition
  - needs for a solution and gathering information, and
  - customer requirements
- Phase 2. (Project 2) Computer-aided design for virtual prototyping: This phase requires the students to design a virtual prototype. The objective of this phase is to build on Phase 1 in addition to assessing their understanding of
  - design specifications,
  - conceptual design, and
  - evaluation and selection criteria with respect to the design solution space
- Phase 3. (Project 3) From CAD to prototyping: The objective of this Phase is to build on Phase 1-2 and complete the last stage of the engineering design process. In this Phase students build a virtual prototype using Solidworks and translate it into a physical prototype using cardboard and other simple materials/tools.

It is expected that students may struggle in the beginning with their understanding of the design process. Each subsequent Phase requires the use of knowledge and skills gained through previous Phases. Consequently, the task complexity increases from Phase to Phase. As such, the project component mark, places most weight on Phase 3 which accounts for 70%, while Phase 1 and 2 constitute 30%. In their project presentations and/or reports, students are asked to clearly state 1) potential stakeholders, 2) stakeholder needs, 3) project functions, objectives, and constraints, and 4) novelty of the solution.

A. Phase 1. (Project 1) Getting started with prototyping

Objective: The objective of this project is to familiarize the students with 1) physical prototyping, 2) needs for a solution, and 3) engineering design process while designing and building a portable ramp that makes buildings and vehicles accessible for people of all needs.

Project description: One of the leading causes of disability in community-dwelling Canadians is mobility impairments, whether permanent or temporary [14]. Walking sticks, wheelchairs and mobile scooters are tools used to facilitate mobility for people with mobility impairments. However, these tools are only helpful given necessary accessibility structures. Although most new buildings incorporate accessibility accommodations, for example, in a form of a ramp, many older buildings are virtually inaccessible to people with special mobility needs. Making older buildings more accessible is not only expensive but also can be very challenging due to the location and architecture of the building. Fig. 1 presents an example of accessibility provision in a house and a car [15].

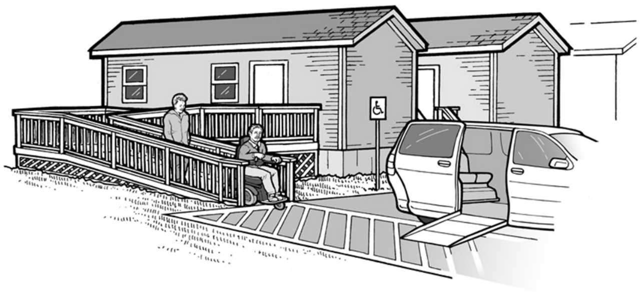

Fig. 1. Examples of accessibility provision in a house and a car [15].

Accessibility ramps are necessary not only in buildings, but they are also needed on vehicles to facilitate getting in and out for people of all needs. Although Canadian public transport is generally equipped with such ramps, the majority of personal cars and even cabs often lack this necessary structure limiting access for people with special mobility needs. The purpose of this project is to make most buildings and vehicles accessible for people with all mobility needs by designing a portable ramp. To satisfy the portability requirement the ramp will need to be easy to carry/transport.

Project requirements and constraints: A set of requirements have been presented to impose constraints and the necessity for trade-off. Teams are expected to design and implement a fully-functional portable ramp. The designed ramp should take into account all the aspects of an engineering design problem, such as evaluation of product limitations and the impact of the ramp on the environment, as well as consideration of professional ethics and calculation of risks. The design process, in addition to meeting the product requirements, should also give proper attention to health and safety risks, applicable standards, and economic, environmental, and societal considerations. Every team is required to identify all the necessary features of the ramp that would make it portable, versatile, and compliant with all the requirements. Some of the design requirements and constraints are as follows: 1) The ramp must be able to sustain a weight of at least 10 kg; 2) The ramp should be easy to build; 3) The ramp must not weigh more than 1 kg; 4) The ramp length must not exceed 100 cm; 5) The ramp should be foldable to satisfy the portability condition; 6) The ramp must not pose any safety-related issues to the user; 7) The ramp should be versatile and suitable for different height levels (up to 15 cm); 8) The ramp should be weather resistant so that it can be used outdoors; 9) The design cost must not exceed $15.

Project deliverables: By the due date, each group of students is required to submit: 1) A fully-functional prototype, and 2) A technical report.

B. Phase 2. (Project 2) Computer-aided design for virtual prototyping

Objective: The objective of this project is to use Solidworks to design a multi-purpose furniture item that is convertible and can serve as both a chair and a table. The second Phase allows students to become better versed in virtual prototyping.

Project description: People in many countries around the world dwell in small houses where space is a scarce resource. To take full advantage of the available space, the furniture used in the house should be 1) light-weight, 2) compact, 3) portable, and 4) multi-functional. Students, working in teams of three are asked to use Solidworks to design a multi-purpose furniture item that can be used as a chair, and that can be easily converted into a table.

Project requirements and constraints: The design process, in addition to meeting the product requirements, should also give proper attention to health and safety risks, applicable standards, and economic, environmental, and societal considerations. Some of the requirements of the multi-purpose furniture item are as follows: 1) Easily foldable; 2) Made of wood; 3) Able to convert into a chair; 4) Able to convert into a table; 5) The item must not exceed the size of 40 x 40 x 40 cm; 6) The seat of the chair must be at least 30 cm off the ground; 7) The tabletop must be at least 40 cm off the ground; and 8) There should be no sharp edges. Note that the final product must be made of multiple parts.

Project deliverables: By the due date, each group of students is required to: 1) Present the assembly of the project, 2) Sketch from the assembly, 3) Create a video, at least 40 seconds in length, that demonstrates the assembly of the multi-purpose furniture item. The video should demonstrate the designed item exploding into multiple parts and then being assembled together.

C. Phase 3. (Project 3) From CAD to prototyping

Objective: The objective of this project is to design and build a cardboard walker for children with cerebral palsy, using Solidworks for the virtual prototyping.

Project description: Cerebral palsy is a group of movement disorders that manifest before the child is born or in early infancy [16]. The performance of the child with cerebral palsy may vary from day to day, i.e., some days a child may need more help than others. A walker is one of the tools which can help individuals who are not independently mobile. The walker should be easily convertible into a chair that would accommodate a child. The proposed walker design should be usable on dry as well as snow-covered pathways.

Project requirements and constraints: Safety is of paramount importance. As such, the following constraints must be observed: 1) Absolutely no rough or sharp edges. The surface must be smooth; 2) All surfaces must be adequately sealed; 3) There should not be any choking hazards; 4) There should not be any pinching hazards; 5) The walker should support a child with a weight of up to 35 pounds; and 6) The groups are asked to go through the structured design process, including concept generation and concept selection processes.

Also, the students are asked to give special considerations to safety, impact on the environment, cost, and appearance in the design.

Project deliverables: Each group of students is asked to 1) Develop a virtual prototype using Solidworks, 2) Translate the virtual prototype into a fully-functional physical prototype using standard craft materials, such as empty cardboard containers, beverage cups, string, wire, and glue, 3) Create a video presenting the exploded and collapsed view of the project assembly in Solidworks, 4) Write a technical report, 5) Create a power point presentation, and 6) Compile a poster.

D. Peer review and evaluations

To ensure fruitful teamwork and successful project completion, a peer review process is implemented where each student submits an anonymous evaluation of all the other team members [17,18]. Implementing this evaluation system early in the semester allows the instructor to determine whether teams have to be reshaped to avoid conflict and maximize learning outcomes.

In addition, peer evaluations are used to ensure fair mark distribution among team members and avoid situations where some members carry all the load. Team members evaluate each other in terms of 1) availability to conduct regular meetings and 2) contribution. The evaluation is fully anonymous to prevent conflict. The peer evaluation uses the scale between 0 to 10 where the average score contributes to the student's project mark. It should be noted that the instructors conduct biweekly meetings with each group to provide guidance and assistance in resolving challenges and identify any potential conflict early in the semester.

E. Project / Report deliverables

Report 1 is the first more extensive written deliverable. It requires the students to work on a case study of an ethical problem that can be faced by an engineer in a workplace. The above subsections detail the deliverables of Projects 1-3 which include video demonstrations of virtual prototype assembly, fully functional prototypes, embodiment design, technical reports, and PowerPoint presentations. Evaluation of the above-listed deliverable is done using grading rubrics. The rubric is designed to align with the Engineering Design GA of the CEAB as well as GAIs of the software engineering program at TRU.

V. Results and Statistics

The effectiveness of the course design has been evaluated using various tools. These tools include Course Learning Outcomes (CLOs), information submitted to the CEAB, student exam results, student projects, evaluation submitted by students, and feedback collected during a meeting with student representatives.

A. Learning outcomes: CEAB GA vs departmental GAI

"Engineering Design I" has the following seven CLOs: CLO1 - Understand the engineering profession and the role and responsibilities of a professional engineer in a broader context, e.g. as it pertains to the environment, health, safety and public welfare. CLO2- Demonstrate ethical behaviour and describe the importance of ethics at the student and professional level. CLO3– Describe contributions that an engineer can make to society as well as impact that an engineering project can have on society. CLO4- Describe an engineering design process to meet desired needs/requirements within realistic constraints of product development with focus on regulations, environmental, social, ethical and safety aspects etc. CLO5 - Articulate an engineering problem and translate it into a structured design to reflect the product requirements. CLO6 - Apply formal decision making methods to assist in choosing between alternative conceptual designs iteratively. CLO7 - Demonstrate skills to use an engineering tool to draw 2D and 3D sketches. CLO8 - Develop a prototype engineering design using an engineering tool. CLO9 - Work collaboratively in teams and communicate effectively using oral, written, and graphical forms.

CEAB has the following twelve GAs [1]: (1) A knowledge base for engineering, (2) Problem analysis, (3) Investigation, (4) Design, (5) Use of engineering tools, (6) Individual and teamwork, (7) Communication skills, (8) Professionalism, (9) Impact of engineering on society and the environment, (10) Ethics and equity, (11) Economics and project management, and (12) Life-long learning. Table III aligns CEAB GAs and departmental GAI with respect to Course Learning Outcomes (CLOs). Table IV matches the CEAB GAs with the appropriate development and/or assessment activities. The GAI's that are met with each of the CLO's in ENGR 1100 as identified in III can be found on TRU Software Engineering Department webpage.

TABLE III
CEAB GA vs departmental GAI with respect to CLOs

CLO	GAI
CLO1	6a, 8a, 10c, 12b
CLO2	6b, 8f, 10a
CLO3	4g, 8d, 9c, 10d
CLO4	4a, 9a, 11a
CLO5	4d, 9e
CLO6	4e, 5a. 9e
CLO7	5b, 11f
CLO8	4h, 5b, 9g
CLO9	6e, 7g, 10b, 12f

TABLE IV
CEAB GA with respect to development and/or assessment activities

CEAB GA	Development and/ assessment
GA (4)	3 open-ended engineering design projects.
GA (5)	Virtual prototyping and video simulator using CAD software (Solidworks). Also, students used hand sketching engineering tools.
GA (6)	teamwork (Project 1-3), individual work (Report 1), and peer evaluation and assessment.
GA (7)	2 technical reports (Project 1 and 3), 2 videos of virtual prototypes (Project 2 and 3), 1 PowerPoint presentation (Project 3), 1 poster (Project 3)
GA (9)	Sustainability is a critical component of Project 1-3.
GA (10)	Report 1 includes working with an ethical dilemma

TABLE V
SUMMARY OF AVERAGE GRADES FOR CLOS IN THE FALL 2020 DELIVERY OF ENGR 1100.

CLO	1	2	3	4	5	6	7
Average Marks	82	80	84	28	84	81	72
Marginal Students	2	5	3	0	1	2	3
(>=50 and <60)	0	0	0	0	0	0	0
#fail students <50%	2	4	2	20	4	2	4

B. Accreditation

In Canada, accreditation of an engineering undergraduate program by the CEAB means that regulatory authorities who regulate the practice of engineering in each Canadian province or territory will recognize the graduates of the program as meeting the academic requirements for licensure as a professional engineer. During the accreditation process, samples of coursework as well as grades for each student are provided for each CLO. Lectures slides, labs, assignments, and project assignments are also provided. As part of accreditation, a continual improvement process for all courses is required. A self-reflection report is completed by instructors for each course and provided to the accreditation board. Included in this report is a summary of the average grades for each of the CLO's, provided in Table VI.

All seven CLO's were met and reasonable average scores were obtained for most of the CLO's, aside from CLO4. The assessment method listed for this CLO was a question from the final exam. However, students were also assessed on this CLO "Apply formal decision-making methods to assist in choosing between alternatively conceptual designs iteratively" during their term projects. All of the CLO's are covered in this course via more than one assessment method.

Upon reflecting on ways to improve the course delivery and how learning outcomes are met, the following action items were identified:

- Another comprehensive method of assessing CLO4 should be added to the course.
- In order to reduce student workload and facilitate a more digestible method for learning the engineering design process, reducing the three term projects to one project with multiple deliverables throughout the course as concepts are taught will be considered.
- An important part of this course is introducing students to methods for communicating their design. A report template was provided to the students, along with a presentation about how to write engineering reports. Verbal student feedback indicated that this was very helpful to students. However, further improvements to the report template are needed to further clarify the design report preparation process.

It is expected that in order to adhere to the continual improvement process, there will be, at a minimum, minor alterations to the course each time it is delivered.

C. Design projects

Engineering design projects are key for assessing student understanding of the engineering design process. As discussed in detail in Section IV, three engineering design projects have been assigned to facilitate student familiarization with the engineering design process over the first semester. Incorporation of Solidworks virtual prototyping not only facilitated design visualization, introduced the students to industry-level prototyping, and prepared them for more advanced engineering design courses, but also increased their motivation and eagerness owing to interactive and engaging virtual work environment. Fig. 2 and 3 present examples of Solidworks virtual prototyping of a multi-purpose furniture item created by one of the student groups as part of Project 2. As depicted in Fig. 2, the furniture item can be easily converted from chair to table and vice versa. Fig. 3 demonstrates student understanding of 2D sketching (front view, side view, and top view), ability to build a 3D model using assembly from parts, awareness of sustainability manifested in selecting widely-available and recyclable materials, safety awareness through rounding all corners and avoiding any sharp corner. Fig. 4 illustrates the efforts of one of the student groups to solve an urgent problem of designing an inexpensive and functional cerebral palsy children's walker. Fig. 3 presents the student proposed solutions in a form of a virtual prototype created in Solidworks and a fully-functions physical prototype of the cerebral palsy children's walker made of cardboard. It is worth noting that for all the three projects students had to apply the steps of the engineering design process iteratively to identify the best final solution.

Fig. 2. Project 2: virtual prototyping using Solidworks of a multi-purpose furniture item. The designed item can be a chair or a table.

VI. OUTCOMES AND RECOMMENDATIONS

A. Student evaluation

Student evaluation is a critical component of the programs continual improvement process. The student course evaluations are created by the TRU Center for Excellence in Teaching and Learning and are provided to students to complete anonymously at the end of the semester. They are not provided to the course instructors until well after the semester is completed and final marks have been provided. The first

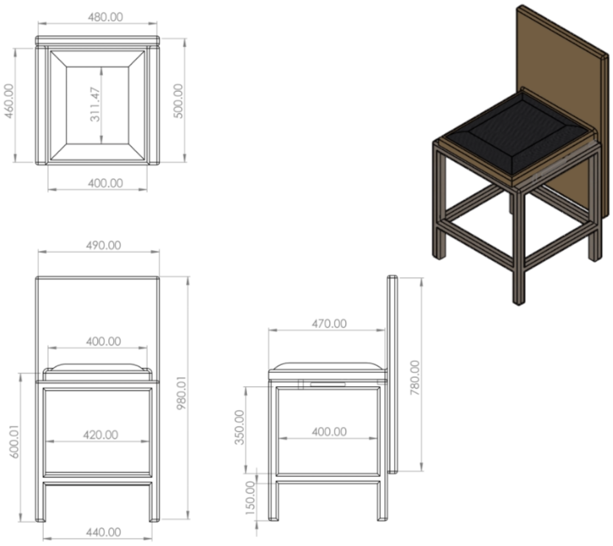

Fig. 3. Project 2 sketching (2D detailed front view, side view, and top view) and 3D model view (assembly from parts).

(a) **(b)**

Fig. 4. Project 3: (a) virtual prototyping using CAD software (Solidworks) vs (b) real cardboard fully-functional prototype of child walker for children with cerebral palsy.

four questions in the student course evaluation are TRU Senate approved and pertain to the overall evaluation of the course. The average participation rate in the "Engineering Design I" course evaluation in 2020 was approximately 70%. The first four questions, and the combined student responses are as follows:

- The course was a valuable learning experience for me: strongly agree 45%, agree 50%, and disagree 5%.
- The course challenged me to do my best work: strongly agree 45%, agree 50%, and disagree 5%.
- I think the course content reflected the learning outcomes as stated in the course outline: strongly agree 25%, agree 70%, and disagree 5%.
- The course experience increased my appreciation for the subject matter: strongly agree 30%, agree 55%, and disagree 15%.

Although there is always room for improvement and growth, the above evaluation indicates that majority of the students were satisfied with the course design and plan.

B. Student recommendations

The course was taught during the COVID 19 pandemic, and was thus held online. Although students maintained a high level of attendance, it was harder to maintain student engagement and motivation. Most of students were satisfied with the course material (PowerPoint slides, hand notes, class discussion and activities, video related topics, lecture records, and lab records). Solidworks sketching and prototyping was identified by many students as the most engaging part of the course. Fortunately, Solidworks access was not compromised during the pandemic. The following topics were introduced using Solidworks: creating a new part, engineering drawing, creating models, assembly and animation, exploded and collapse view, multi-sheet drawing from an assembly, 3D sketching and prototyping, weldments, and stress and strain analysis. Most students advised us to keep the Solidworks training as part of the course. Another component enjoyed by the students was the transition from virtual to physical prototyping. However, they recommended that we include more detailed project instructions and details. We intended to provide more detailed information in Project 1, reducing the amount of details as students progress to Projects 2 and 3. The reason behind this strategy was to motivate the students to improve their abilities to independently brainstorm, define the engineering problem, and extract the associated constraints. Additionally, frequent regular meetings with students assist with project success [19]. This will be implemented in future course deliveries.

VII. Conclusion

This paper introduced the development, implementation, and evaluation process of an introduction to Engineering Design course for the first-year, first-semester students at Thompson Rivers University (TRU). The development process has been guided by the following three objectives: teaching context, stakeholder consultation, and Canadian Engineering Accreditation Board (CEAB) requirements. Engineering design projects have been considered as a fundamental part of the course development. The majority of students were satisfied with their learning experience. Several essential engineering skills have been introduced in this course in alignment with the CEAB requirements, namely design, engineering ethics, professionalism, communication, the use of engineering tools, and impact of engineering on society. The skills gained by the students through the proposed course design are expected to lay out the foundation for more advanced engineering courses, as well as their professional careers.

Acknowledgment

The authors would like to acknowledge the support of the Software Engineering Department (Drs. Faheem Ahmed, Waleed Ejaz, Muhammad Hanif, and Omer Waqar), Faculty of Science, and the Dean's Office at Thompson Rivers University.

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