ACADEMIC IMPACT AND PERSONAL EXPERIENCE OF DESIGN TEACHING ASSISTANTS IN UNDERGRADUATE COURSES

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Abstract – This paper presents the impact that the Design Engineering and Design (DE&I) program offered in 2013 has had in the Faculty of Engineering at the University of Victoria. Through this program a pool of nineteen graduate students were trained as Design Teaching Assistants (DTAs). The purpose of this program is to train DTAs in engineering design principles and pedagogical skills for mentoring students working on design projects. During the year DTAs continued their training by attending seminars presented by guest speakers. To date, eight DTAs have been appointed to either assist as qualified Teaching Assistant in already established engineering design courses (two DTAs), or to develop new design projects in courses that are primarily engineering science (six DTAs). The latter was supported by the course instructor and the coordinators of this program. The paper describes the development and management of these design projects, their impact on undergraduate students, and the personal experience gained by the DTAs. Also, the paper presents a review of the 2013 DE&I program including a new strategy for the upcoming 2014 DE&I workshops that will focus more on the development and execution of design projects of the DTAs.

Keywords: Graduate Teaching Assistants, Engineering Design, Mentoring Undergraduate Students, Developing Design Projects, Engineering Education.

1. INTRODUCTION

The UVic Faculty of Engineering established in the Spring of 2013 a unique training program for graduate students called Design Engineering and Instruction (DE&I) [1]. This an initiative by the NSERC Chair in Design Engineering whose mandate is to improve and expand the instruction of engineering design within undergraduate courses.

Engineering design is the development of new objects or systems that meet specific needs by integrating multiple

disciplines such as mathematics, engineering sciences, basic sciences, and complementary studies.

Strong [2] indicates that most engineering graduates are perceived by industry as technically competent but with marginal practical design skills. This is ratified on surveys [3,4] that report that industry is not satisfied with specific design skills of the engineering graduates such as creativity, communication, project management, and product testing. Therefore, there has been a significant effort to improve teaching in design by the Engineering Accreditation bodies [2].

Engineering design projects require specific guidance from the Teaching Assistants. Ringenberg et al. [5] recognized that a Teaching Assistant would occupy different roles in a design course. Teaching Assistants should guide students through their design project, strengthen the teamwork dynamics, create an atmosphere where the students would feel comfortable to discuss their team problems, and advise the undergraduate students how they can make their work more interesting.

The purpose of the DE&I program is to give graduate students specialized training to support design projects in undergraduate courses across the Faculty. The learning objectives of this training program involve engineering design principles and pedagogical skills for mentoring students with group activities. A series of three consecutive workshops were conducted:

Workshop on Engineering Design: Here the graduate students reinforced their knowledge in engineering design by solving an engineering design problem while working together in teams of four students. The process of engineering design was reviewed and different techniques for group work were presented.

Workshop on Mentoring Skills: Graduate students were exposed to a role play activity in which each team had to identify problems or challenges related to teamwork, guidance, project management and ethics. After acting out, graduate students received feedback from the other teams and the facilitators.

Workshop on Developing Design Projects: Graduate students had to develop a non-existing design project for a course. They had to identify learning objectives. Then,

teams had to develop a design mini-project, establish the design objectives and a suitable strategy for managing the students (e.g. project schedule, expectations, rubrics, etc.). Each team presented their mini-projects and received feedback from other teams and a workshop coordinator.

The details of these activities are covered in an earlier publication (see reference [1]) and will not be discussed further here.

During the summer and fall terms, graduate students attended seminars given by industry experts and other professionals. The seminars provided valuable industry perspectives that reinforced many of the learning objectives. Upon completing the series of workshops and attending a minimum of five seminars, the graduate students are certified as Design Teaching Assistants (DTAs).

In addition to reporting the progress of the program, this paper presents the academic impact that the DTAs had in their assigned courses by consulting undergraduate students and the supervising professors, as well as the professional experience that the DTAs gained with their appointments.

Also this paper discusses the changes made for the 2014 DE&I training program. In particular, the program will focus more on the development of design projects and less on engineering design principles.

2. SEMINARS

A total of nine seminars were offered in the summer and fall terms. The seminars involved guest speakers from different disciplines. The topics of the seminars can be categorized in three major themes: industrial design, pedagogical education, and organizational behavior (conflict resolution).

Industrial design: Five of the seminars involved industrial design. Guest speakers from mechanical, electrical, software and civil engineering presented their experience as designers. Most of the talks emphasize the importance of problem definition as a critical stage for the design process. The design process was explained from the industrial perspective and since the speakers came from different backgrounds (as the DTAs), it was important to expose the graduate students to the different design approaches that are taken in each discipline. Another important aspect was norms, regulations, ethical behavior and the impact that a particular design can have in society. These topics were not covered in the workshop.

Pedagogical education: To reinforce pedagogy, the program required the trainees to attend at least one seminar (most of the DTAs attended two) offered by the Learning and Teaching Centre (LTC). Every year the LTC organizes a conference for Teaching Assistants. Although the conference is generic for all the faculties, there are particular sessions that focus on science and

applied science. In particular, there were sessions on communication, group formation, developing rubrics and international students that were valuable to reinforce the ethics, guidance and project management learning objectives presented at the workshop.

Organizational behavior: Two seminars were focused on how to resolve conflicts between members of the same team. One speaker exposed real team problems in industry and the other speaker was a distinguished academic from the UVic School of Business, expert in Organizational Behaviour.

3. OBJECTIVES OF THE DE&I PROGRAM

The DE&I program has two main objectives: The certified DTAs will support our Faculty with following two assignments:

- (i) Assist as qualified Teaching Assistant in already established engineering design courses, and
- (ii) Develop new design projects in courses that are primarily engineering science with the support of the course instructor and the coordinators of this program.

The latter assignment is more laborious as the DTAs have to develop, organize, coordinate, and mentor undergraduate students. *A fundamental objective of this assignment is to create a design mini project that is centred on the learning objectives of the course itself and therefore the deliverables will reinforce the theoretical contents of the course.* By contrast, most of the engineering design courses, particularly the capstone design projects, focus on the design process and the students have to apply all the knowledge gained during their careers. Consequently, the majority of the capstone design projects are based on mechatronic projects where the students combine the knowledge previously learned in numerous mechanical, electrical and software engineering courses. Instead, by developing design mini-projects for specific courses, the design problems are centered on the course itself. For instance, an electronic circuit course will focus on designing simple electronic circuits, a thermodynamics course will focus on design a problem based on energy conversion or energy storage, a mechanisms course will focus on designing simple mechanical machines, etc.

4. ACHIEVEMENTS OF THE DE&I PROGRAM

To date, 9 of the original 19 graduate students had satisfied these requirements with 6 more expected to fulfill their commitment in the coming spring.

In 2013, two DTAs were assigned to provide support in engineering design courses and three DTAs were appointed to help developing design projects in courses

that were primarily engineering science. For the engineering design courses, one of the DTAs was appointed to help the instructor to develop a fourth-year capstone design project (MECH 400), the other DTA was appointed to guide students through their design project in a second year engineering drawing course (MECH 200). For the engineering science courses, one DTA helped with the development of a design project in a third-year core course in Mechanical Engineering, Theory of Mechanisms (MECH 335). Since this course was offered prior to the DE&I program, the DTA received one-on-one coaching from one of the coordinators of the DE&I program. The course served as a pilot, which allowed the coordinators to identify particular problems that had to be tackled during the workshops. The other two DTAs began preparing ideas on how to coordinate and manage design projects: one for a third-year core course in Electrical Engineering: Linear Circuits I (ELEC 330), and the other improved the Theory of Mechanisms (MECH 335) project of the previous year that required major changes [6].

In 2014, once the DTAs were certified, five DTA appointments were established for the development of design projects for engineering science courses. In the spring term, the two DTAs who had prepared the design project for ELEC 330 and MECH 335 carried out their projects. Both of these courses are taught in the first term of third year. During this term, a number of students join the university program after completing successfully a two-year college-level technology program. Therefore, not all the students are familiar with each other, and more importantly, the formation of these students is diverse. While the students who started their post graduate education at the University have stronger theoretical understanding of the mathematics and physics, those that started in the college program are more familiar with the different manufacturing processes and the aspects of the skilled trades. Another DTA was appointed to mentor the design project of a fourth-year elective course, Digital Visualization (ELEC 483). The remaining two DTAs are currently working together to develop a novel design project for a second-year core course in Mechanical Engineering, Thermodynamics (MECH 240). The following is a summary of the design projects and how they were implemented into the courses:

Linear Circuits I (ELEC 330): This is an introductory course of electronic circuits that includes: diodes, bipolar junction and field effect transistors, small signal and multistage amplifiers. This course includes four laboratory experiments that are supervised by regular TAs. Since the college-formed students had previous experience working with electronic circuits, the laboratory experiments resulted redundant. As an alternative, the instructor of the course and a DTA offered all students (both college and university formed) who already had such experience to design, build, and test an electronic circuit as a project in

lieu of the laboratory experiments. Twelve, two-person teams worked on the project instead (20% of the overall class). The DTA received and evaluated the proposals on the fourth week of the course. The DTA made some changes to the proposals to maintain the same level of difficulty among all the projects. The projects included an audio amplifier for portable devices, a vacuum tube based audio effects amplifier, a charge pump power supply, a constant current load, an H-bridge motor driver, a three-stage 5W audio amplifier, a temperature display, a USB LED lamp circuit, a two-stage boost power supply, an audio amplifier with A/D converter, an audio amplifier for home subwoofer systems, and a wireless music transmitter. All the projects met the expectations and two of them exceeded the expectations: One of these project was the three-stage 5W audio amplifier which required a comprehensive analysis of circuit design, such concepts are taught in a later course (Linear Circuits II); and the other project was the wireless music transmitter which transmitted music through light and the students would like to extend their concept using conventional house light bulbs. The DTA met every team every two weeks and the students submitted their prototypes and reports in the last week of the course. Students presented their projects to the Faculty and submitted a project report.

Theory of Mechanisms (MECH 335): The course is primarily theoretical and includes four laboratory projects that are based on deterministic problems. The course is structured to teach the kinematics and dynamics of each mechanism (linkages, cams, gears), separately. A set of learning objectives were established to select a feasible design project [6]. A common design problem was given to all the teams (30 teams of up to four members): Design and build an automaton, preferably made out of wood, in the form of a mechanical toy for young children that tells a story. The design project was originally implemented in 2013 by the instructor with the support of a regular TA. In 2014, it was necessary to establish a new strategy as a the time allotted for the students was reduced in half due to the increase in the class enrollment that limited the time available for this course in the design facilities. In order for the students to complete their project within a very short time (first five weeks of the course), it was necessary to provide greater assistance. The DTA introduced the mechanisms and functions during a one-hour tutorial in the first week of the term. In order to accelerate the building process, the DTA was in charge to acquire and distribute mechanical components, such as spur gears, bevel gears, shafts, worm gears, collars, and pulleys (these components were hand-built in 2013). Also, the DTA was in charge to find local facilities where the students could work or produce particular pieces that were difficult to craft, e.g. 3D printing. During the five weeks of the project, the DTA met the teams three times, in which the project requirements were revised, students assigned

project responsibilities, and the DTA ensured that all the members of the team were working together and the progress was aligned with the expectations of the team calendar. Overall, all the teams developed creative and functional prototypes. In addition to meeting the learning objectives, the project was also used to study the displacement and velocity problems of the mechanical components. This complemented the lectures where only a few mechanisms were studied in detail. Since each design was different, the students had to analyze their own designs and calculate the displacement and velocity mathematically. A comprehensive report was submitted near the end of the course, which included a critical section of reflection, in which the teams had to discuss how their project can be improved.

Digital Visualization (ELEC 483). This is an elective course that involves digital video representation, image formation models, spatio-temporal sampling and sampling structure conversion, two and three-dimensional motion estimation techniques, block-based and pel-recursive methods for motion estimation, methods of image and video compression. The requirements of the project were to design and implement a video signal processing function such as motion estimation, deinterlacing, rate conversion, video compression, etc. In video encoding, there are existing algorithms that are used to process video signals, students were encouraged to design algorithms that improve their efficiency. Teams of two students submitted project proposals to the instructor and DTA, who made appropriate modifications to meet the learning objectives. After the proposal was accepted, the DTA was available to discuss with the students two hours a week, although the meetings were not mandatory the students regularly met the DTA for guidance. If the team was unable to meet the DTA during the office hours, they arranged an appointment. A total of five teams (the whole class) developed a design project. Three of the teams work on performance analysis of different block matching algorithms (each team developed different algorithms), another team worked on performance analysis of different image compression techniques and video standards, and the last team worked on motion vector refinement techniques. At the end, teams of students were required to make a presentation to the class and to submit a comprehensive report.

Thermodynamics (MECH 240). This is a core course in Mechanical Engineering (180 students in 2013). This is a theoretical course where students are introduced to the fundamental laws of thermodynamics: ideal gas law, first law of thermodynamics, second law of thermodynamics, energy conversion, properties and properties relations, reversible systems, and closed and open system cycles. Two DTAs are currently developing a design project where the objective is to maintain the temperature of a house in rural area constant (20°). Students have to use

renewable energy (wind and solar). Since both of these energy sources are intermittent, it is necessary to develop an energy storage system that has to be included between the wind turbine or solar panels and the heating device. Students can store this energy in the form of thermal energy (e.g., heat storage), electric energy (e.g., battery charge), kinetic energy (e.g., flywheel), potential energy (e.g., hydraulic head), phase-change material (e.g., liquid to solid), etc. Then, students have to design the system that will convert the energy and dissipate the heat in the house. Due to the large number of students, teams of eight students will be working together. However, each team will be divided in two groups and each will be working on a particular part of the project. The first group will be working on the problem definition and conceptualization and then the second group will be working on selecting the concept and detailed design (optimization). In order to ensure that each group of a team understands and accepts the work done by the other group, they have to review the work done by the other group. Once the review process is complete, a major meeting with the DTAs takes place with the complete team.

5. ACADEMIC IMPACT AND PERSONAL EXPERIENCE

There has been an effort to expand engineering design in second and third year courses. Most engineering programs include design programs in the first year (introductory engineering design) and fourth year (capstone design project) [7]. The second and third year courses usually carry the heavy load of engineering science courses. Undergraduate students have benefited from this initiative, as they learned the fundamentals of the course contents through design projects. Despite being an optional requirement for ELEC 330, over 20% of the class decided to work on the design project as opposed to the simple laboratories, an option that in the previous offering no one had chosen. In MECH 335, a five-point Likert scale survey (1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree) was conducted and the students reported that the automaton project was adequate for the course (3.95), motivate them to learn more about mechanisms (3.90), and found the project and the course complementary (3.98). Although they agreed that the project has increased the course workload considerably (4.01), they would not drop the project from the course and, instead, they proposed strategies to reduce the workload of other activities (e.g., laboratories).

Another important aspect is the professional experience that the DTAs receive from these activities: (i) development of design projects and (ii) guiding, managing and coordinating design projects. Successful DTAs who are exposed to this experience gain valuable skills that can

be used in their professional lives. The following are some of the comments given by the DTAs:

I really liked and enjoyed working as a DTA. In my point of view, the main difference between the experience obtained by being a regular lab TA and a DTA is that the former has to work with the limited pre-designed material (4 or 8 laboratory experiments) whereas the latter has the opportunity to be exposed to more versatile material. Due to this, a DTA has the opportunity to learn many more things and gain much variety of experience that would really help for a career in either academia or industry. Also, by being a DTA, we can learn many things (including soft skills) related to engineering design and project management that cannot be learned by using only books. DTA for ELEC 330.

At the first weekly meeting, I got the chance to meet each team. We shared the concept of group dynamics and how to work with the group, we talked openly about the team formation and the expectation of working within the group. I encouraged the team members to have an open dialog among each other's. Through the weekly meeting, I observed the teams' group dynamics and most teams were able to form a mutual respect and form a team to achieve their work within that short period of time. As a DTA, I felt so privileged to be part of this exciting and rewarding project and to be able to guide the students through the design process. DTA for MECH 335.

As coordinators of the program, we also noticed the appreciation of the undergraduate students towards the work and effort of the DTAs.

6. MODIFICATIONS TO THE DE&I PROGRAM

After reviewing the effects of the first DE&I program, we were pleased with the results but also we felt that there is a great room for improvement. First, we consider that the second objective of the program (Develop new design projects in courses that are primarily engineering science) had a greater impact in the curriculum of the Faculty. The first DE&I program focused primarily on teaching the fundamentals of design engineering. This had a counterproductive effect: graduate students who were already familiar with the process and techniques employed in engineering design would not be interested in taking an introductory course on engineering design. Therefore, our next DE&I program will focus more on developing design projects and mentoring undergraduate students.

Engineering Design Principles (EDP) remain an important learning objective to the new format, the major difference is that EDP is no longer the emphasis in the active learning component. Instead the DTAs will be receiving some reading material the weekend before the

workshop. To help guide the comprehension, the DTAs will also receive a set of open-ended questions drawn upon a broad range of topics in the reading. Then, during the workshop, the DTAs will work in small groups discussing the reading material. Each group will be assigned a couple of the questions given earlier to form a five-minute statement on the major conclusions. At the end of the discussion they will be given other five minutes to share the conclusions with the rest of the class. At this point the coordinators will have a good idea on how well the DTAs grasp engineering design principles. The coordinators will then give a brief lecture emphasizing topics that were not adequately understood.

By shifting the EDP learning to outside the workshop, there is more time for active learning on the developing of design projects. The goal of this year's workshop is to elevate the position of the graduate students so they play the role of DTA in a design challenge. The central idea is to allow the graduate students to develop a small design challenge and then give this project to a group of students who will carry out the project on the last day of the workshop.

The learning objectives for this new component will be focused on Design Project Development and Supervision (DPDS) that are listed below:

- 1) Process of developing and executing a design project:
 - a) Select learning objectives.
 - b) Establish the scope of the project (e.g., fully working prototypes vs. a single step in the design process).
 - c) Choose the project design concept.
 - d) Establish a detailed description of the roles and responsibilities of the DTA and student.
 - e) Develop a management strategy for the project (i.e. weekly meetings, critical design reviews)
 - f) Develop an assessment strategy.
 - g) Execute the design project and adjust it when unforeseen problems arise.
- 2) Learning objectives dictate all aspects of the project.
- 3) Respect the constraints and limitations placed on the students from other courses.
- 4) Recognize your intrinsic assumptions on how the students will react to the project.
- 5) Communication skills in presenting the project to the students and assisting them in the execution.

The DPDS learning activity will start with the coordinators giving a brief lecture on the development of design projects following all the topics listed above.

Then, the DTAs will form groups (2 or 3 people) and work together to develop a small design project. They will be expected to select one or more learning objectives, apply some constraints on the project so it will be feasible to develop a management and assessment strategy. The execution phase occurs on a later day. This gives the

coordinators a chance to review the design project and make changes to ensure that it will be feasible for the execution phase.

In the execution phase, the DTAs will present their design challenge to a group of students (student group). The student group will then carry out the project under the supervision of the DTAs. The coordinators will then observe and give feedback to the DTAs.

Since this learning activity is still under development, the authors have a wide range of ideas on how to structure this activity. The most important aspect is how the student group is formed. Currently the authors are looking into recruiting senior high school or undergraduate students to attend the workshop as students during the execution phase. This will give the DTAs real experience in relation to supervising a project of their creation.

If these students cannot be recruited then the student group will be formed from the DTA attendees. This can be done in two approaches. The first approach involves two execution phases where in the first phase a group is either solely a “DTA group” or a “student group”. The student group will work on the project developed by a DTA group. Then in the second phase they switch roles and the DTA group will become a student group for a different DTA group that was formerly a student group. In the second round the groups will work with different groups so the DTAs are exposed to different group dynamics. Since a pair of DTA and student group will be performing their roles together in the execution phase, there is a potential problem that the DTA group takes over on the design project. The second approach considers both groups working on a design project while simultaneously supervising another group working on their project. This will teach time management and prevent them from over-supervising or taking over the design project. This second approach, however, introduces the potential problem of scheduling conflicts where one student group may want to meet with their DTA group at a time the DTA group is too busy working on their own (student) project.

7. CONCLUSIONS

The 2013 DE&I training program has prepared graduate students in engineering design and pedagogical skills. Once certified as DTAs, they have successfully assisted to improve and expand engineering design across the undergraduate courses of the Faculty. It is worth mentioning that in addition to the clear impact that these design projects have had on undergraduate students, there is another important component, which is the valuable experience gained by the DTAs. This gained experience includes both management and engineering skills that will be useful in their professional lives, whether academia or industry. Despite the success of this program, we have

reviewed the deliverables of the project and established a new strategy that will give DTAs a greater exposure to developing design projects, guiding teams of students and managing design projects

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