IMPROVEMENTS IN A CROSS-COHORT MECHANICAL ENGINEERING COURSE PROJECT

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Abstract- *A cross-cohort project was created and implemented as part of the core curriculum for mechanical engineering students. A team of second-year students in “Dynamics” course was grouped with a team of third-year students in “Kinematics and Dynamics of Machines” course where they designed, prototyped and conducted dynamic motion analysis of a pick and place mechanism. Each cohort was tasked to create a sub-mechanism, combining these two mechanisms created the final machine. The teaching and learning activities are defined towards accomplishing four main interrelated objectives: (1) To provide a design challenge to guide students to implement creative potential solutions. (2) To allow second-year and third-year teams to analyze the dynamic motion of their mechanism while considering the design of the other group’s mechanism. (3) To introduce industrial dynamic simulation tools and hands on prototyping skills. (4) To facilitate cross-cohort collaboration within teams with more emphasis on students’ peer exchange of knowledge and experience.*

With the experience gained from conducting the project, evaluating the students’ reports, and student feedback, several modifications can be implemented in future iterations to allow the students to benefit more from this kind of project structure. This research discusses improvements based on the lessons learned.

Keywords: Cross-cohort, Experiential Learning, Engineering Course Project, Simulation Tools, Feedback.

1. INTRODUCTION

Engineering educators are constantly seeking methods to improve the education of their students. This paper will discuss an experiential cross-cohort project and suggestions for improvement of its effectiveness.

1.1. Problem Definition

In practice, engineers often work in teams where the experience levels and specialties of the members are diverse [1]. However, this is hardly reflected during their undergraduate education since students usually work in projects within only their own cohort. Subjecting students to a cross-cohort project is one way to introduce them to a dynamic team with different knowledge and experience levels, reflecting the industrial senior-junior teams. It has been shown in

research that mechanical design projects allow students to apply course concepts [2-4]. Therefore, a cross-cohort design project would give students an experiential learning opportunity and introduce them to working in teams of variable experience levels.

1.2. Cross-Cohort Motivation

An interdisciplinary study on a joint project between grads and undergrads was developed by ElZomor et al. in 2016 [5]. During this experience, each team consisted of six to eight civil engineering graduate students and approximately five construction management undergraduates collaborated to propose a safe house with flooding mitigation. Ultimately, the outcomes of students’ feedback showed that both groups of students improved their self-reported skill levels and skill confidence. Similarly, in a cross-cohort group project, conducted by Giralt et al. [6], the first-year group members solved an open-ended design challenge and the fourth-year students managed the project. The students rated the experience with an average score of 7/10. Moreover, the first-year students “considered that working with the fourth-year students increased their learning abilities and confidence”. Therefore, a cross-cohort project introduced in the core-curriculum of mechanical engineering students, similarly is expected to create positive results.

1.3. Feedback

Researchers have found feedback to be a key contributing factor in the enhancement of student learning in higher education [7-9]. Specifically, for some mechanical engineering classes, it has been shown that feedback implementation could help students to understand the concepts better [10, 11]. This research has used student feedback as one of the core tenets of quantitative and qualitative data regarding learning outcomes. In this study, collection of the feedback from students who were exposed to a cross-cohort project for the first time, would help instructors of both courses to gain an understanding of the students’ perspectives and experience to assess their opinion on this new project format and to gauge the effectiveness of the learning outcomes of this project.

2. METHODOLOGY

2.1. Initiation

During the spring semester of 2019 (May - August), second-year (2B class) and third-year (3A class)

students, in “Dynamics” and “Kinematics and Dynamics of Machines” courses respectively, were subjected to a collaborative cross-cohort project.

The project was a “*program-level project*” which allowed students in Mechanical Engineering program to hone the following skills:

- Being able to solve an open-ended dynamics problem, synthesize/design a machine/mechanism to do specific tasks, analyze motion of a mechanism and machine elements.
- Using tools to fabricate and simulate the designed mechanism/machine:
  - Prototype simulation using commercial software ADAMS (Automated Dynamic Analysis of Mechanical Systems) to obtain the motion variables
  - Motion simulation and modeling of their mechanism by writing a code in MATLAB (Matrix Laboratory) based on the theoretical equations learned throughout the term
  - Laser-cutter experience by fabricating the mechanism, which was validated through MATLAB and ADAMS simulations
- Enhancing the communication skills by working with multiple students across both cohorts

2.2. Project Description

The project directly involved students with a realistic industrial design challenge to provide them an opportunity to explore and research existing mechanisms, synthesize and analyze a new one, and fabricate the designed machine using the provided tools. The project exposed students to a cross-cohort teamwork by grouping 2B and 3A students. In total, 28 groups were formed, each with approximately five 2B members and four 3A members. Each cohort had specific constraints to work with and developed a unique mechanism; by combining the two mechanisms they built a machine capable of the requested tasks.

The project is also the students’ introduction to ADAMS and MATLAB, where ADAMS was used by both cohorts to model their mechanism and analyze the kinematic performance with respect to time under a constant input. The students plotted and visualized linear and angular velocities and accelerations of different bodies of the mechanism in their project, either at different time intervals or different positions. The 2B students also used MATLAB to generate plots, which gave them firsthand experience applying kinematic equations and allowed them to validate their results.

Communication was stressed as an important practical skill throughout this project in three distinct ways.

Firstly, as a group project, the students were in a situation where they had to coordinate with each other to ensure their success in the project. Secondly, the students were asked to present their final prototyped machine at the end of the term in front of the class. Finally, asking the students to work with members from another cohort was a unique challenge for the students in this project. Working with students from a different cohort puts some students in an unfamiliar situation, which is not normally seen in core curriculum projects. To promote the students to meet with their counterparts from different cohort, an online workspace was created, and multiple in-person meeting opportunities were scheduled to let all the group members work together.

To encourage teamwork and cross-cohort collaboration, and to teach students effective communication skills, workshops was held to allow them to work with their corresponding group from their own and other cohorts in scheduled meeting times. The workshop was facilitated by the University of Waterloo Writing and Communication Center to advise students on effective and constructive team communication. The teaching staff was present at the workshops to provide the students with insight and resolve any questions the student had.

2.3. Project Assessment

The main evaluation breakdown of the students’ assessments was slightly different for each cohort. For the 2B students the breakdown was: 50% kinematic analysis, calculations and simulations, 30% final report, and 20% appearance and functionality of the fabricated mechanism, and the project was worth 10% of their final grade. For the 3B students the project was worth 15% of their final grade and the breakdown was: 40% kinematic analysis, calculations and simulations, 40% final report and 20% appearance and functionality of the fabricated mechanism, with a 2% bonus mark for creativity. A considerable portion of the mark was allocated for the experiential components of the project to encourage students to participate in all these activities and to emphasize their importance beside just analytical or numerical dynamic analysis. The main goals of having these assessment components for the project were to develop technical skills and promote teamwork contribution.

2.4. Reflective Critique

Once the project was completed, the effectiveness of the project was determined based on student feedback. Student feedback was collected from an optional anonymous online survey that was provided to the students in January of 2020. The survey featured a

collection of multiple-choice questions with answers reminiscent of the Likert scale and long answer (open-ended) questions. In total, 41 students responded to this survey, where 19 were from the 3A cohort and 22 were from the 2B cohort. The student feedback was then utilized by the course instructors to determine potential areas of improvement for the project structure, which is highlighted in more detail below.

3. RESULTS

3.1. Presentation

Upon the completion of the project, the students were asked to present their mechanism as a team. Therefore, all 28 teams made up of both cohorts were asked to present in the same space and time block. However, there were a few challenges or issues associated with planning and scheduling the presentations:

- Challenges addressed in the initial project implementation:
  - setting up a space that fits all 200 students across 28 teams
  - setting up a time that works for both cohorts, and all the instructional team
  - facilitating the presentations in such a way to allow presenting teams to show their prototypes to the instructional team and to the other teams and answer their questions
  - Evaluating each team for all the assessment criteria (functionality, creativity, ect.) within the short period of presentation time (~5-7 min)
- Challenges to be addressed in future implementations:
  - dealing with fair/unfair order of presentations (last presenting team stayed the entire time)
  - dealing with lack of preparation and coordination of team members for their final presentation (as shown in Figure 1).
  - scheduling the presentation for each team and tracking the time

Figure 1. Percentage of students who prepared for the presentations with members from the other cohort

The survey result revealed that only 20% of students were actually prepared for the presentation with the other cohort (Figure 1). Despite the lack of preparation and coordination of team members in their presentations, many students preferred this method of final evaluation, an average of 58.5% of students preferred to demonstrate their project in the form of an in-class presentation (as shown in Figure 2).

Figure 2. Most effective way to demonstrate the project, as reported by the students

3.2. Creativity

To give the students the freedom to create innovative mechanisms and to motivate them to think about their unique designs and solutions, some of the requirements were left open ended. A creativity mark was allocated only for the section of the project that was supposed to be done by 3A students. Creativity was not considered for 2B students, as with the current project format, there was not much room for this. It seemed that creativity was already encouraged by the existing project requirements based on the student feedback. Even, one student noted: "Would have liked more freedom, so less design constraints to make a more complex mechanism."

Since creativity was evaluated by the complexity of the mechanism and not by how the students designed their mechanism, many students may not have used innovative design techniques. One student even stated, "I know many groups just used trial-and-error to determine their final designs." The prominence of trial and error was also evident while marking the reports and by asking the students during the presentation.

3.3. Simulation Tools

To complete the project, the students had to use specific simulation tools (MATLAB and ADAMS) to conduct dynamic analysis of their moving mechanism. Tutorial packages for application of each of these tools were provided in the form of online materials which allowed student to self-study, get familiar with their workspace, or run some codes. Figure 3 demonstrates how students received these tutorials and could

effectively use it towards completion of their projects. In general, the reviews for ADAMS were more positive than MATLAB, and 75% of students decided to pursue external MATLAB resources, as opposed to only 37% of students who chose to pursue additional ADAMS resources.

Figure 3. Student opinion regarding the provided MATLAB and ADAMS tutorials

3.4. Project Requirements

This was the first time these courses incorporated such a collaborative project and it mattered how the students reflected their experience in this project. Among the students who responded to the survey, it seemed that some students expected more clarification, specifications, instructions or explanations throughout different phases of the project. Some of the related feedback have been reflected in Table 1 and Table 2.

Table 1. Student Feedback - "What Did You Dislike About the Project?"

"There was a lack of explanation."
"Lack of clarity and explanation of deliverables and how to do them."
"Lack of information regarding the project."
"Lack of organization..."

Table 2. Student Feedback - "Any General Recommendations/Improvements if a Cross-Cohort Project Were Implemented in the Future?"

"Actually explain what the project is and if we need to use a programming language- teach it to us."
"Provide better instructions. Ensure both professors are on the same page."
"Iron out the details of the project before assigning it..."
"From what I remember, the project description was sort of vague...."

4. DISCUSSION

4.1. Presentation

To improve the quality of student presentations, one alternative would be asking the students to prepare a simple video to describe their mechanism, which 27% of students preferred. A similar strategy was conducted by Siller et al. where a video presentation

was added to the curriculum to improve the students' communication skills [12]. As mentioned previously, asking all the students to present in the same time slot and allowing the earlier groups to leave is unfair to the later groups. Moreover, many of the students did not prepare for their presentation and coordinated their presentation with the members of the other cohort. By asking the students to prepare a short video of their moving mechanism both problems could be avoided in the future. The students can skip waiting for other groups and it may increase cross-cohort collaboration towards completion of their video, they can also document their design process and the instructors would have more time to review and evaluate the prototypes or their explanations. The students can also be asked to peer review a minimum number of their peer's videos as well to encourage more engagement.

4.2. Creativity

Initially, the 3A students could receive 2 bonus marks on creativity based on the complexity of their part of the mechanism. The 2B students, however, were asked to design a four bar for their section of the mechanism. Though they had freedom to choose the length of the links in their mechanism, considering ILO, demonstration of creativity was unfit and unnecessary for this section of the current project for 2B students. In case, the next iterations of this project are planned to include the creativity mark for both cohorts, the mechanism requirements should be considerably changed to let them have more freedom in the complexity of their design.

Alternatively, the design can be kept the same, but the students can have a creativity mark associated with how they decided on the optimal link geometry. As mentioned above, many of the students used trial and error to determine their geometry, this represents a low level of creativity. But adding an assessment to this component would encourage students to think of other ways to determine the geometry of their mechanisms.

4.3. Simulation Tools

The effectiveness of the provided self-learning online resources for MATLAB and ADAMS were different. It should be noted that ADAMS is a more specialized dynamic analysis software, and available resources are not as many or are not at the undergrad levels. MATLAB is more widely used software and comparatively there are way more resources available online than ADAMS. The fact that some students opted to pursue external resources for MATLAB, may suggest that further correlation to students' need and their current knowledge is required. Pre-diagnosis of MATLAB knowledge of students, in-class tutorials, and coding assignments and one-in-one interaction with

TAs and instructors, would be helpful additions in the future. Less usage of ADAMS may suggest that provided resource was sufficient for students towards completion of their project. The same modification as MATLAB, can be done for ADAMS as well.

4.4. Project Requirements

There was some confusion regarding the project requirements. It is also noteworthy that for the 2B part of the project there was an error with the initial project description which were updated after a few days of initial release of the project. Another thing which caused some ambiguity for 3A students was the dimensions of the working area of the mechanism, as larger boards were provided to be used as platform for their assembled mechanism. Since the project was only implemented once, these mistakes may not be as prevalent in future terms. The project requirements should also be changed to reflect the other improvements discussed throughout this paper.

4.5. Assessment

The assessment criteria of the project can also be modified to facilitate the students to learn more effectively from this project. As mentioned earlier, the in-class MATLAB and ADAMS tutorials can be planned in such a way that the students finish some tasks at the end of each class to ensure there is enough exposure these tools. Previously, since the students were marked based on their group's performance, it is possible that only some of the members used the simulation tools. The assessment for the creativity can also be changed as described above to allow for the 2B and 3A students to be assessed more evenly.

4.6. Cross-Cohort Challenges

There are challenges associated with organizing a project between 2 cohorts, most notably the knowledge gap between the students and each cohort's schedule. To ensure that the students would be able to work together despite being in different places in their education, the project was designed with specific deliverables that correspond to the current class the students are in. This allowed them to focus on the relevant course material while not being overwhelmed with too much new information. To accommodate the cohorts' different schedules, the communication seminars were organized as mentioned above. These meetings were organized to ensure the students had time to discuss and work on their project with the partnered cohort. Moreover, virtual forums were created which all the students were added to, which allowed the students to work on the project remotely with all team members. The instructors' goal was to make a project in which students were able to practice course concepts with a hands-on activity as part of a

team. Based on the quality of machines the students fabricated, and the grades they earned, the instructors believe their goal was successfully met.

5. CONCLUSION

Overall, it appears that the main concerns that the students raised during the first trial of this project can be addressed in future iterations to improve the learning outcomes. Since the purpose of this paper is to highlight potential improvements to the cross-cohort design project, many of the shortcomings of the initial implementation were discussed. However, just over half of the students, 51%, had a positive impression of this structure of project and 85% of students rated the project as an effective way to apply course concepts. The students also expressed interest in having slightly smaller group sizes in future iterations, with 66% of students preferring groups of 4 per cohort. This aligned with instructor expectations, since the students reacted mostly positively to this project structure, though some resistance is due to this being the initial iteration of the project. Therefore, a cross-cohort project can be an effective teaching tool for undergraduate mechanical engineering students and changing the project requirements in the ways highlighted in this paper should improve its effectiveness.

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