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A Cross-Cohort Dynamics Project Study

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INTRODUCTION

Engineering educators are constantly seeking methods to improve the education of their students. This paper will discuss the motivation behind introducing the students to a cross-cohort project and its effects on the learning outcomes of engineering students.

Problem Definition: In undergraduate programs students often work on their projects within their own cohort. However, this is hardly reflected outside of the undergraduate world where engineers are often working in groups consisting of peers of different levels of age, knowledge and experience [1]. Therefore, exposing students to a cross-cohort project would introduce them to an environment more similar to what they would experience in the future. This type of projects, has had positive impact on students' learning by providing the opportunity for them to see the application of theoretical course concepts through design and analysis of engineering systems [2].

Literature Review: Current research has shown that multidisciplinary group projects in engineering education is beneficial to students since it better reflects the standard practice in industry [3, 4]. Though this paper is discussing an interdisciplinary project, there may be similar benefits because pairing students with differing experience levels also reflects industry environments. It has also been demonstrated that working in a multidisciplinary group and designing products are essential experiences for engineering students to have prior to graduation [5-7]. A two-year study by Foster et al. investigated the cross-cohort experience of students who were handing over their project to the next cohort. The project was carried out by 5 students in their penultimate year as undergraduates in a computer science degree, who eventually passed on their project to a group of 5 students from the following year's cohort. In this project structure, the more experienced students were taking a mentorship role towards the newer students [8].

Motivation: It has been shown that students felt improvement in communication and problem-solving skills when provided with the opportunity to work with industry partners [9]. If it is assumed that this was mostly due to their ability to work with more experienced individuals and to benefit from more senior perspectives, the effort in introducing a cross-cohort project may demonstrate the same benefits albeit to a lesser extent since the difference in experience is significantly smaller. Lu et al. in 2016 developed a project which started in 2012 and continued to the date of publishing which allowed over 50 undergraduate students from many different cohorts to contribute on a capstone project, sometimes over several years [1]. This project demonstrated the effectiveness of students working in cross-cohort teams on a database and web interface project, from the author's point of view. Similarly, the cross-cohort projects in the core curriculum could be beneficial since they might reflect a different aspect of working in industry.

Methodology: The cross-cohort project discussed here was developed in Mechanical and Mechatronics Engineering Department at the University of Waterloo; it featured collaboration of about 200 students in the second-year and third-year undergraduate program registered in "Dynamics" and "Kinematics and Dynamics of Machines" courses, respectively. The project tasked the students to design, simulate, analyze, and build a prototype of a pick and place mechanism within the parameters of the project description. Student feedback remains one of the core tenets of quantitative and qualitative data regarding learning outcomes [10]. Therefore, feedback results were collected from students to assess their impression of this new project format and to gauge the effectiveness of the learning outcomes of this project.

METHODOLOGY

Initiation: During the spring semester of 2019 (May - August), second-year (2B class) and third-year (3A class) students were subjected to a collaborative cross-cohort project. The project was a "*program-level project"* which focused more on the following "Intendent Learning Outcomes" (ILO) of both courses:

- Kinematic analysis of machines and mechanisms, which is covered in both courses using different methods. This concept studies both linear and angular displacement, velocity, and acceleration of the connected rigid bodies.
- Synthesis of the mechanism to follow certain motion criteria.

Moreover, some of the other skills that students gained during this experiential learning activity were:

- Prototype simulation using commercial software ADAMS (Automated Dynamic Analysis of Mechanical Systems) to obtain the motion variables
- Motion simulation and modeling of the prototype by writing a code in MATLAB (Matrix Laboratory) based on the theoretical equations learned throughout the term
- Laser-cutting experience by fabricating the mechanism, which is in-line with the results of analyses and simulations
- Soft skills, such as effective teamwork, giving and receiving constructive feedback, time management, and peer-learning.

Project Description: The project was prepared for the students to experience a hands-on activity where they were directly involved with an authentic - industrial design project. This provided an opportunity for the students to explore and research the existing available mechanisms and machines and to use them in their design challenge. Each cohort had specific constraints to work with and would develop a unique mechanism; by combining the two mechanisms they could build a machine capable of the requested task(s). The project was designed to expose students to a cross-cohort teamwork, to introduce them the usage of technical tools such as ADAMS and MATLAB, and to allow them to practice scientific communication skills.

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

Communication was another practical skill that was heavily emphasized throughout the project. Working with students from a different cohort puts some students in a situation of unfamiliarity with their teammates in a way that is not normally seen in projects within the same cohort. To facilitate such an interaction, an online workspace was created and multiple in-person meeting opportunities were scheduled to let group members from the same and other cohort to converse with each other. In addition to communication within the groups, the students were asked to present their final prototyped machine at the end of the term in front of the class.

To encourage the students to work together and teach them communication skills there were teamwork series workshops held which allowed the students' time to work with their corresponding group from the other cohort. The workshops were 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.

Project Assessment: The main evaluation breakdown of the students' assessments was: 20% calculation and analysis, 20% prototype fabrication, 20% simulation, 20% project demonstration, 10% miscellaneous creativity, and 10% final report. A considerable portion of the mark was allocated for the experiential components of the project to encourage students to participate in all of these activities and to emphasize their importance beside just analytical or numerical dynamic analysis. Some of the main goals of having these assessment components for the project were:

a) Technical skills development and knowledge enhancement, which was addressed in the following assessment components:
- Calculation and analyses
- Prototype fabrication
- Coding and simulation
- Progress and final reports

b) Promoting teamwork contribution, soft skills development, and appreciation of professional attitude and values, which was addressed in the following assessment components:
- Participation and contribution
- Project demonstration

c) Miscellaneous assessment component was comprised of creativity, prototype appearance, and functionality of the prototype.

Reflective Critique: Once the project was carried out with a group of students, 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 at the beginning of the Winter 2020 term (January - April). The survey featured a collection of multiple-choice questions with answers reminiscent of the Likert scale and long answer (open-ended) questions. Total of 41 students out of about 200 students responded to this survey, where 19 were in 3A cohort and 22 were in 2B cohort.

RESULTS

Application of Design and Analysis Tools

Exposure of the students to the commercial/industrial design tools was one of the key aspects of the project. The students' opinions were quantified and percentage of students who positively responded to the application of design tools in their project were summarized in Figure 1. This figure reflects the thoughts of each individual cohort, as well as the collective thoughts of both cohorts, for each tool which was necessary for completion of the defined tasks.

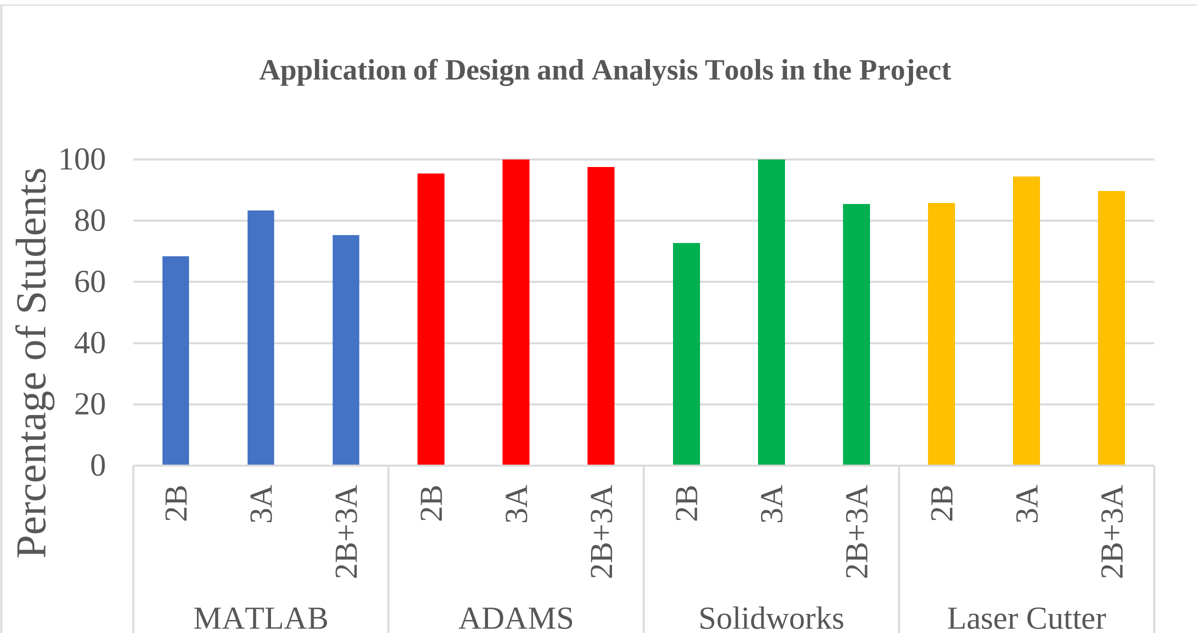

Figure 1. Percentage of students who responded positively to the design tools used for design and analysis of the project.

The results of quantitative data, as shown in Figure 1, revealed the positive impression of students towards the use of design tools for completion of their project. This included the computational tools such as MATLAB, ADAMS, and SolidWorks, as well as some practical skills in using the laser cutter machine. The quantified results from the collective opinion of students about effectiveness of provided tutorials/resources for using each individual tool was also summarized and shown in Figure 2. For instance, about 68% of students found that MATLAB tutorial was somewhat effective to very effective, but 32% found it ineffective in their analysis. Despite the overall positive students' responses about MATALB, 75% of students also sought other aids (Figure 2B), suggesting possible need for further investigation about the reason or for implementation of necessary changes.

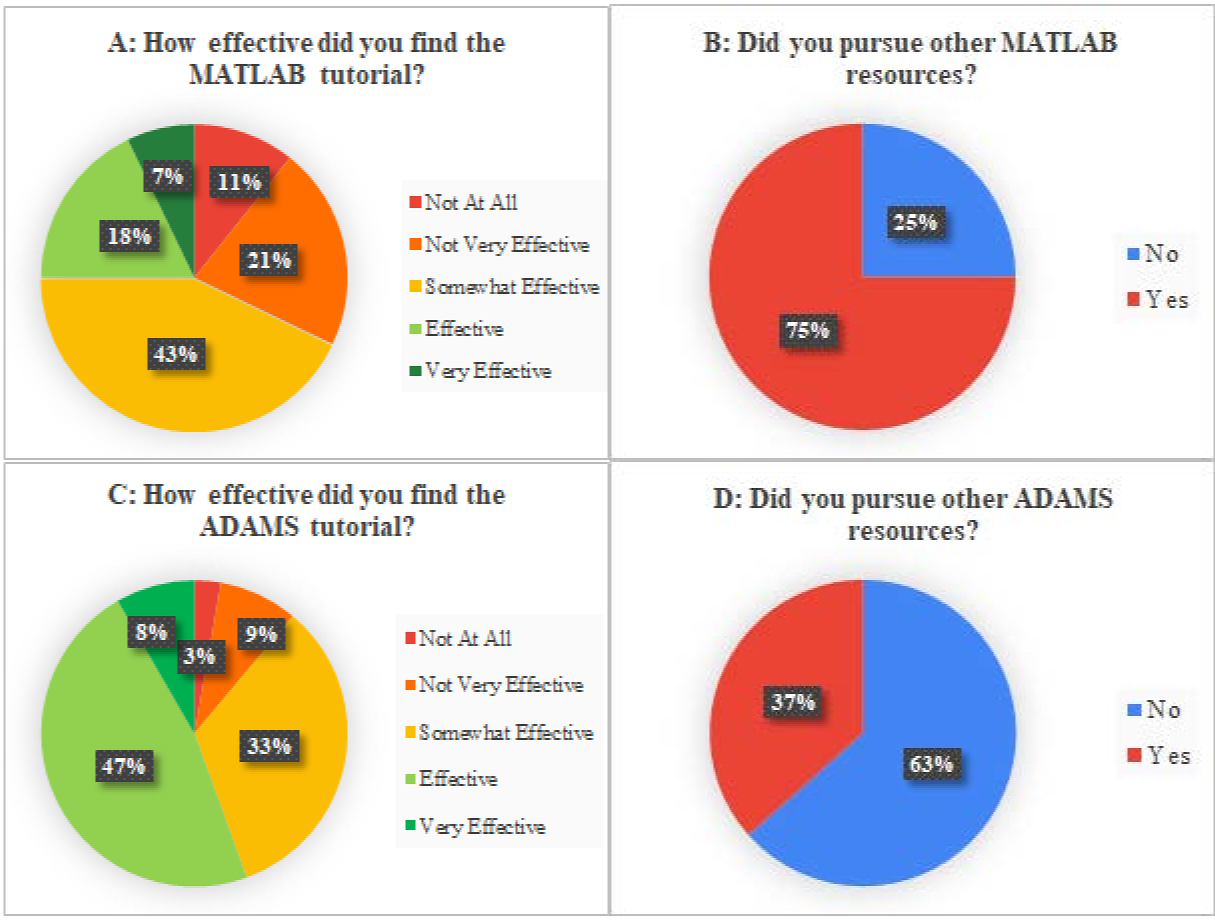

Figure 2. 2A) Student opinion regarding the provided MATLAB tutorial; 2B) Percentage of students who sought further MATLAB aids; 2C) Student opinion regarding the provided ADAMS tutorial; 2D) Percentage of students who sought further ADAMS aids.

It is also shown in Figure 2 that students had a more positive experience in general using ADAMS. With less students resorting to seeking external resources to supplement the provided tutorial.

Students' Collaboration

The collaborations of students in this cross-cohort project were considerably different from the conventional collaboration/interaction methods (e.g. same-cohort). The quantified results about the overall collaboration between cohorts (as shown in Figure 3) indicated that there was generally a lot of cooperation between the two cohorts. The quantification of students' opinion about the effectiveness of the project structure for this cross-cohort activity (as shown in Figure 4) revealed their mixed opinion about such a structure. The results showed that 2B cohort tended to be less positive compared with 3A regarding the project structure.

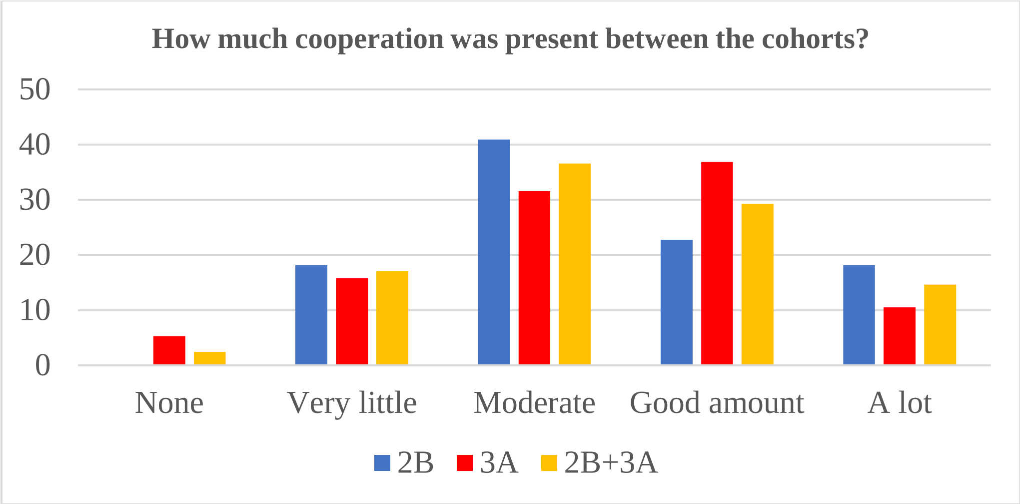

Figure 3. Cooperation between cohorts, as reported by the students.

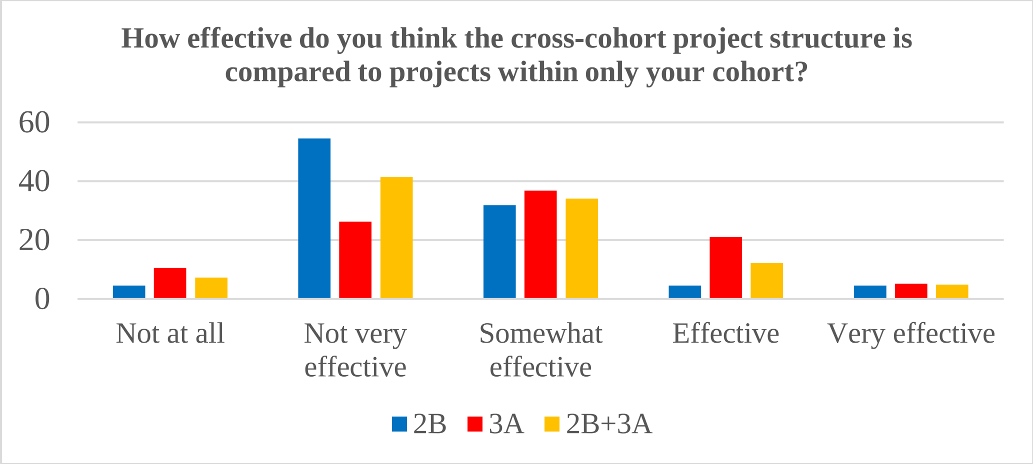

Figure 4. Effectiveness of the cross-cohort project as ranked by the students.

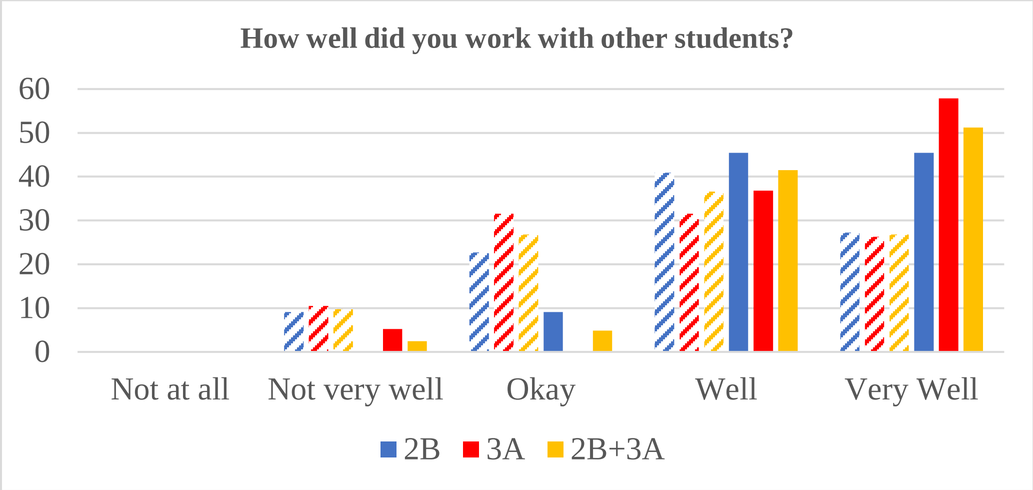

Figure 5. How well students worked with their own cohort (solid bars) and the other cohort (hatched bars.

The collective results about how well they worked with other students within the same cohort versus the other cohort (as indicated in Figure 5) showed how students reported their productivity with their groupmates of each cohort. Students felt very comfortable and worked very well with peers from their own cohort on average. Unsurprisingly, there is decreased cohesion with the other cohort, but students still reportedly worked well together.

Though the students appeared to communicate well within their groups, the size of the groups themselves might have contributed to some negative opinions regarding the project. The results of a study by Griffin et al. has shown that student preferred working in smaller groups in a capstone project [11]. With this initial run of this format of project the students were asked to form groups of five 2B students and four 3A students. After the completion of the project some students pointed out that it was difficult to coordinate a group of this size. With one student explicitly stating "smaller groups" in their feedback. This is also supported by the survey where 64% of 2B students and 68% of 3A students would prefer to have a group of 4 students from each cohort. Therefore, depending on class sizes, future implementations of this project structure should have slightly smaller groups.

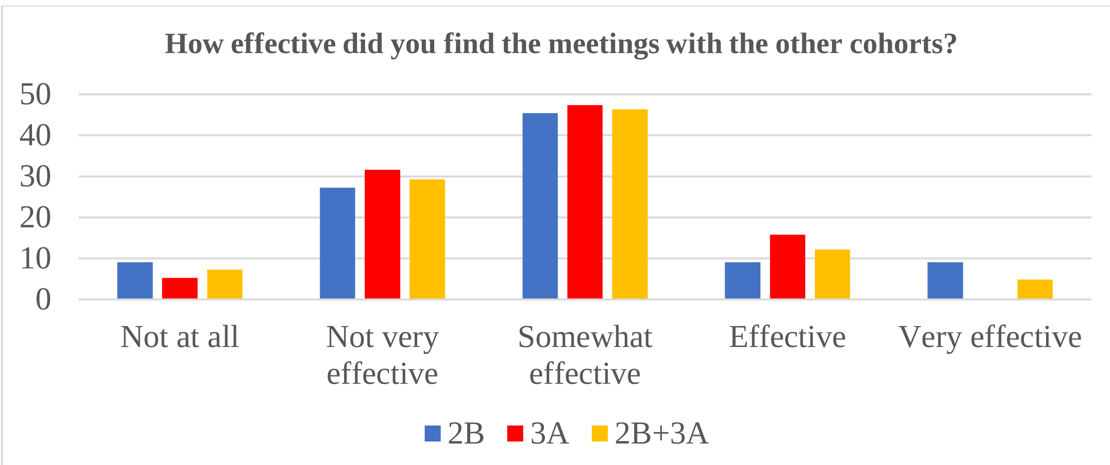

Figure 6. Effectiveness of scheduled workshops for students to meet with their groupmates from the other cohort.

As shown in Figure 6, 63% of students found the workshops to be at least somewhat effective, and that students from both cohorts would prefer more regularly scheduled meeting times. For instance, a 2B student stated, "Hard to contact or meet with them," indicating that they wanted to but were unable to meet more with the other cohort. Similarly, a 3A student provided the following as a general recommendation: "[Ensure] both cohort groups meet regularly to meet planned objectives." Additionally, there were other comments indicating that the students would have liked to meet more, but conflicts in their schedule did not allow for this. Though the negative response of some students should also be considered so the structure of these meetings should change in the future.

Finally, with regards to course application, the students felt quite positively, 68% of 3A students ranked the project as relevant or very relevant and 21% at least found the project somewhat relevant to the course material. The 2B students also reported positive results with 41% claiming relevant or very relevant and another 41% claiming at least somewhat relevant. These findings are shown in more detail in Figure 7.

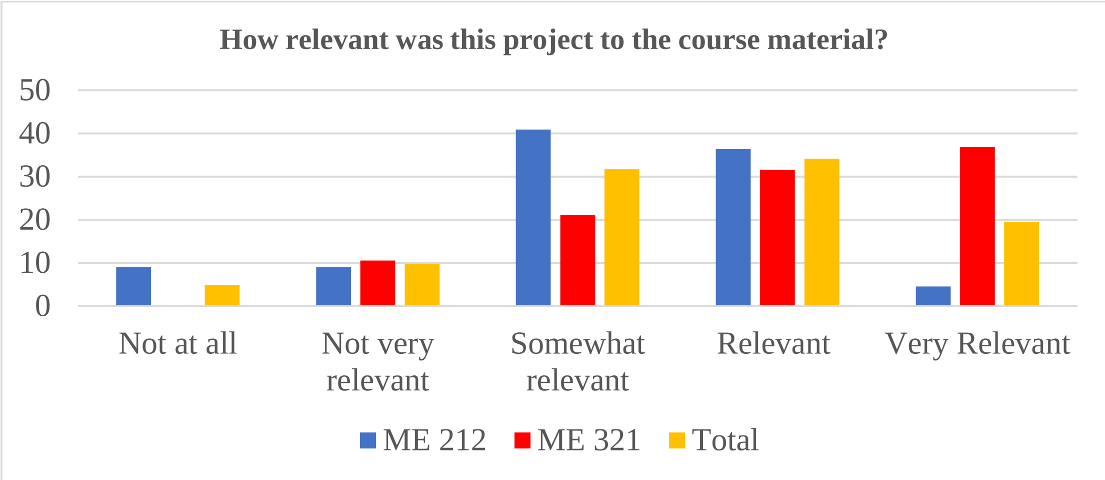

Figure 7. Application of course concepts according to the students

It can be seen through Figure 7 that the students found adequate application of course concepts in the project. This could be due to the provided clear project guidelines of what concepts to apply and how to visualize these concepts, since the students were asked to derive kinematic equations for the motion of their mechanisms.

Although students have had no prior exposure to such cross-cohort projects, it is worth noting that in general they did not find this was more difficult than other projects they were exposed to so far in their education (as shown in Figure 8).

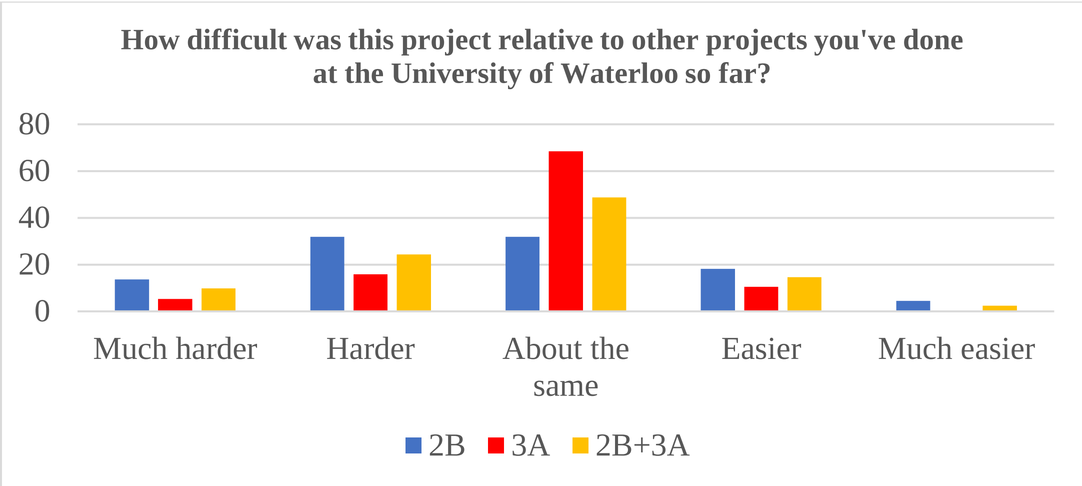

Figure 8. Perceived difficulty of the project relative to other courses.

Presentation

The final presentation of the project was meant for students to demonstrate their mechanisms and communication skills; however, this was difficult to implement. There were 28 groups in total and each group was asked to present in front of both classes. Given the number of students, most groups opted not to watch the later groups present and 80% of the students did not prepare enough for the presentation with the other cohort. Despite this, when given the choice of a presentation, video, or only a report, about 60% of students preferred a presentation. Though the presentation was well received by the students, in future iterations there should be changes to encourage the students to be more prepared to present their mechanisms r provide more specific guideline for their presentations.

DISCUSSION AND CONCLUSION

The purposes of this project have been three-fold: 1) to provide the students an opportunity to use design tools, 2) to introduce students to the idea of working in teams with various experience levels, and 3) to let the students learn when and how to apply course concepts to real-world mechanisms.

Overall, the use of computational design tools in the first round of application of this experiential learning project was positive. Many students found the usefulness of the tools in visualising the motions of connected mechanisms and in finding or calculating the required motion parameters. Some students even chose other tools such as AutoCAD and Python. This might be due to their tendency to validate or double check the simulation results of more unfamiliar software and compared them with the ones from more familiar software. Notably, SolidWorks was not a requirement of the project, but many students opted to use it anyways, likely because they were already more acquainted with its working space. This might also suggest that students were not fully aware or comfortable with MATLAB and ADAMS since the project could be completed only with these tools. The physical prototyping and laser cutter training were also received positively by the students, possibly because it gave the students a tangible representation of their work. This might be because some students faced with some challenges in the manufacturing section of the prototype and really found that not every perfect simulated model could end up in a functional working prototype. This might suggest that students realized the benefits of inclusion of this section in their project to see a tangible product of their design, simulation and analysis and be able to relate to the real materials, joints, dimensions, and moving parts.

Students' feedback revealed some evidence to support that the 2B students found insufficient communication between the cohorts. Some students had comments such as "I found that the 321 students mostly took over the project and wanted it done their way because they didn't trust the younger (212) students." Some of the 3A students also had feedback such as: "I don't think the cross-cohort project was very effective because it seemed like the upper year students would pretty much end up designing the whole mechanism to their liking in most cases." This feedback might suggest that despite a lot of cooperation between the groups, effective cross-cohort collaboration seemed a bit far from reach. One way to encourage more cooperation between the groups can be to schedule more time for the students to meet. Figure 6 below summarizes the students' overall opinion on the scheduled workshops they had throughout the semester.

Overall, the results were positive with respect to the students' opinion on design tools and application of course concepts. Since these parameters could be applied to all course projects this cross-cohort structure could be at least as good as conventional teaching methods. However, the opinion of the cross-cohort aspect was mixed, meaning that the project structure should be changed to be more beneficial for students in future iterations. Since this was only the first implementation of this project, the guidelines were not as specific as the students preferred and this was a common critique. With clearer defined guidelines and better-defined group roles in the next iteration of this activity, more lights can be shed on the future path to further understand the students' perspective of cross-cohort projects.

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