Research Proposal Innovation Fund

Project Title:

Deepening Multidisciplinarity within Systems & Control

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1.Introduction

1.1. Project Information

At Eindhoven University of Technology (TU/e), the collaborative project of the departments Applied Physics (AP) and Mechanical Engineering (ME) entitled: "3BYX0P – Challenge Based Learning (CBL) Systems and Control project" was granted. This research project was initiated in December 2020. The project included planning and management, literature review, data collection in the context of the course; 3BYX0P - CBL Systems and Control, data analysis and dissemination of the findings. The project focused on the multidisciplinary aspect of the course.

This final report of the research project: "3BYX0P – CBL Systems and Control project" presents a summary of the research findings and conclusion.

1.2. Purpose of the Project

TU/e's 2030 strategy adopts the interaction between research and education as one of its pillars (TU/e Strategy 2030, 2018). Investigation of the unique multidisciplinary teamwork during a CBL course has the potential to create motivation for course designers in creating similar learning environments. Considering the existing views that describe multidisciplinary teamwork as challenging or not rewarding for improved learning outcomes, this project can facilitate transforming these views based on student outcomes and the value of multidisciplinary teamwork. The purpose of the project was two-fold: a) to investigate students' learning and improvement regarding the multidisciplinary aspect of the course; 3BYX0P – CBL Systems and Control and b) to explore the potential factors that influence multidisciplinary teamwork in the context of the course. The research questions of the project were:

1. **How does the multidisciplinary aspect of the 3BYX0P – CBL Systems and Control course affect students?**

   What are the perceptions and experiences of students about their learning in multidisciplinary teams in the context of the course?

   What are the perceptions and experiences of the teaching team about students' learning in multidisciplinary teams in the context of the course?

   What are the factors that influence multidisciplinary teamwork in a CBL course?

2. **How does students' perceived skills to work in multidisciplinary teams change during the 3BYX0P – CBL Systems and Control course?**

2.Method

2.1. Research Design

The "Deepening Multidisciplinarity with Systems and Control" project used qualitative and quantitative data to address its research questions. Table 1 summarizes the method of the research project. Detailed information on the research design, data collection tools, and data analysis methods can be found in the project mid-report.

Regarding the first research question, a case study approach is adopted where the case is the "3BYX0P-CBL Systems and Control course" (Fraenkel et al., 2012). In an attempt to understand the potential elements that facilitate multidisciplinary teamwork, noticeable patterns are identified out of qualitative data.

In order to answer the second research question, the project adopted a convergent parallel design where elements of qualitative and quantitative research are combined in order to better understand the multidisciplinary aspect of the course; 3BYX0P- CBL Systems and Control (Creswell & Plano Clark, 2017).

Table 1. Summary of method

Research Design	Research Questions	Data Collection
Case study approach	*What are the perceptions and experiences of students about their learning in multidisciplinary teams in the context of the course 3BYX0P?* *What are the perceptions and experiences of the teaching team about students' learning in multidisciplinary teams in the context of the course 3BYX0P?*	Student interviews Teacher interviews Design products
	What are the factors that influence multidisciplinary teamwork in a CBL course?	Student interviews Teacher interviews Student reflection reports Observations
Mixed-methods	*How does students' perceived skills to work in multidisciplinary teams change during the 3BYX0P – CBL Systems and Control course?*	Survey Student interviews Teacher interviews

3.Results

The findings of the project are presented in three sections in line with the research questions: a) perceptions and experiences of students and teachers about student learning in multidisciplinary teams, b) the factors underlying successful multidisciplinary teamwork in a CBL course setting, and c) the changes in students' perceived skills to work in multidisciplinary teams.

a) Perceptions and Experiences about Learning in Multidisciplinary Teams

Student (*n* = 12) and teacher (*n* = 5) interviews were analyzed to understand perceptions about learning in multidisciplinary teams in the CBL course. Table 2 summarizes students' and teachers' perceptions of learning in multidisciplinary teams under three themes: a) content knowledge, b) skills and competencies, and c) using tools.

Table 2. Perceived learning and improvement

	AP students	**ME students**
Total (100%)	66 %	34 %
1.Content knowledge	**64**	**27**
Control theory	28	-
Kinematics	21	50
General ME content	28	-
Image detection and camera	7	33
Transfer function	10	16
2.Skills and competencies	**19**	**63**
Application of theory	25	21
Disciplinary way of thinking	38	57
Working in teams	25	14
3.Using Tools	14	10

Figure 1 shows the perceived improvement of AP and ME students across the three themes.

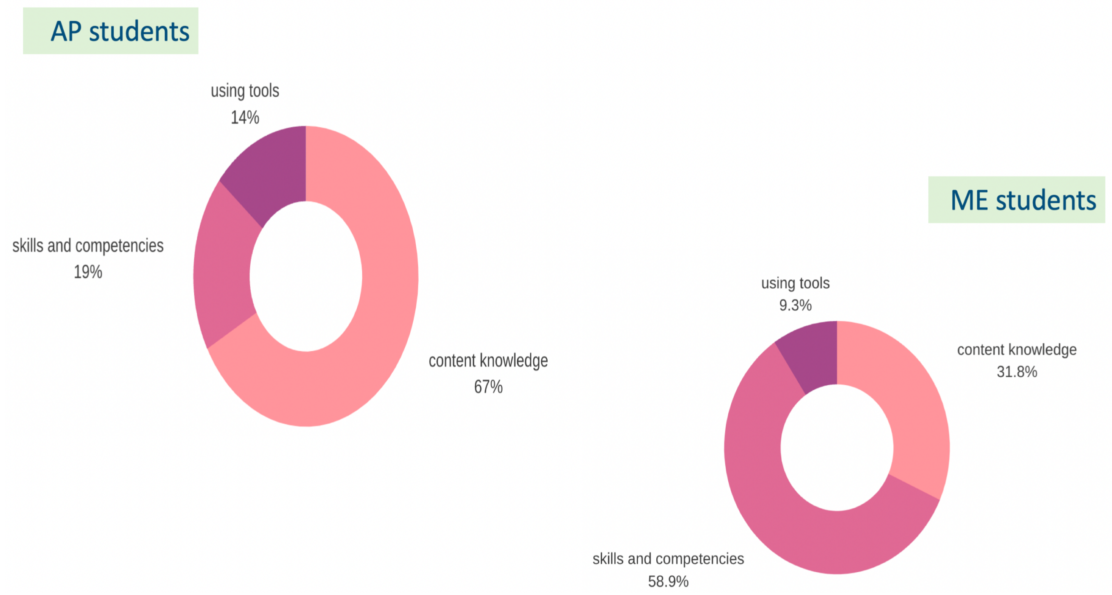

Figure 1. Perceived improvement according to department

According to the findings outlined on Table 2 and Figure 1, the students and the teachers perceived a higher improvement in AP students' content knowledge (67%) compared to ME students (27%). The perceived increase in AP students' content knowledge was in control theory (28%) and general ME content knowledge (28%). One illustrative teacher comment during the interviews was: "*I think the Applied Physics students learned a lot from mechanical engineering students, but the other way around, I've seen it a bit, but not a lot"*. For inverse kinematics, perceptions about ME students' improvement of their content knowledge (50%) was higher than AP students (21%).

For the second theme, skills and competencies, both AP (25%) and ME (21%) students were perceived to improve their skills in application of control theory. Both AP students (37%) and ME students (57%) perceived to improve their way of thinking and approaching to problems, by working with students from another discipline. One student explained this point with the following comment: "*…And that was quite interesting to me as an applied physics student, because well, we just do software theory."* The student continued to highlight how it was interesting to see ME students' way of thinking. Finally, results also addressed improvement in using the tools; Matlab and Simulink.

Examination of students’ design products: the videos and the posters also confirmed the perceived prominent improvement in ME related knowledge (e.g., controls). Figure 2 illustrates a poster prepared by one of the student teams.

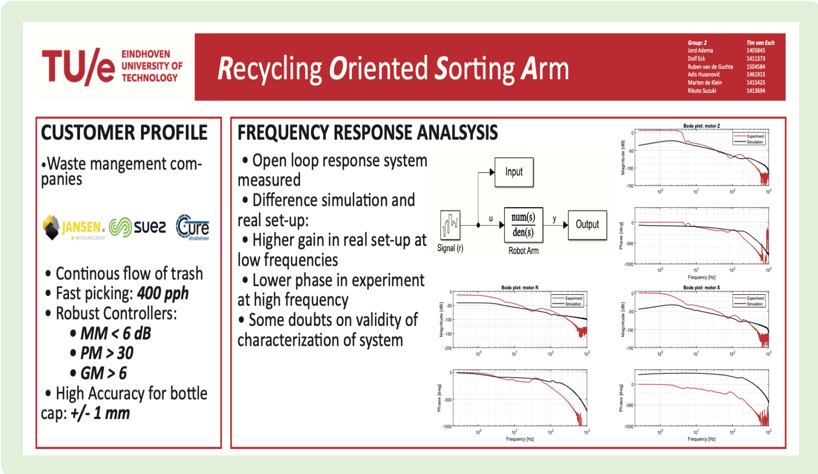

Figure 2. Design solution of a student team as a poster

b) Factors Influencing Multidisciplinary Teamwork

Examination of student and teacher interviews, student reflections, and the video recordings of multidisciplinary team meetings revealed the facilitators of and barriers to successful multidisciplinary teamwork during the CBL course.

Table 3 illustrates the frequencies and the percentages of the factors coded by the researchers using the interview transcripts and students’ reflection reports.

The findings are presented with three themes: a) personal factors, b) team factors, and c) course factors.

Considering personal factors, it is revealed that *prior knowledge* on control theory, was a factor in supporting multidisciplinary teamwork. AP students discussed the fact that their lack of prior knowledge on control theory was a major barrier for them to participate in group discussions especially during the early stages of the course. One AP student commented: “*AP students could catch up with the knowledge at the end of the project that let to more ideas…Similar level of knowledge would have saved some time for teamwork.*” Students perceived to appreciate and make use of their general skills (e. g., experience in robotics) during multidisciplinary teamwork.

Table 3. Factors to influence multidisciplinary teamwork in a CBL course

	#	%		#	%
1.Personal factors	**88**	**31**	**3.Course factors**	**115**	**40**
Prior knowledge	54	61	Disciplinary connections	62	54
General skills	19	22	Guidance	33	29
Motivation	15	17	Materials	20	17
2.Team factors	**81**	**29**			
Communication	33	41			
Exchanging perspectives	23	28			
Presentations	13	16			
Student composition	12	15			

For team factors, open communication where everyone could ask questions and express oneself emerged as a critical enabler of multidisciplinary teamwork. A student noted in his reflection report: "*…during the meetings the group had clear communication while not too serious allowing for a friendly environment.*" To continue, exchange of AP and ME disciplinary perspectives was suggested as another facilitator of successful teamwork. An exemplary response from the interviews was*: "…we were stuck in the methods part….and they (AP students) brought a different view, more open minds to the project...".* Finally, making presentations during team meetings, and a balanced proportion of AP and ME students in the teams were evaluated as facilitating teamwork.

Considering course factors, a student remark in relation to disciplinary connections to the challenge during interviews was: "*I would make the knowledge required for Controls a bit less because at this point, and we, when we were just thrown into the deep end, like figure it out.*"

The discourses of the tutor in facilitating multidisciplinary discussions, the lectures and the videos on course Canvas were also evaluated as facilitators of multidisciplinary teamwork. Results also pointed towards a need for more AP related course materials on Canvas. Table 4 presents a dialogue among one AP and two ME students captured in the team observations. The dialogue shows how the course materials are addressed as support.

Table 4. Dialogue among students

ME-1	Well, so at least one person can make sure they go and watch the frequency response lecture again and pick out exactly what it said that we should use …..then someone needs to try those input functions. But you guys saying that you want to do it before your experiment?
ME-2	Well, I think it would be very important to have the useful input before the experiment because if we just go and try the step function, I don't think that…
AP-1	I will use both the notes, the books and the lecture….

c) *Students' Perceived Skills to Work in Multidisciplinary Teams*

Part of the results included the changes in students' perceived skills to work in multidisciplinary teams. To measure the change in this construct, two data sources were used: a) student and teacher interviews (*n* =17) and b) a survey implemented as pre- and post- on learning in multidisciplinary teams in engineering education (*n* = 21). The modified survey <u>(see project mid-report for details on survey modification)</u> included three factors: a) *identification*, skills to identify own skills and knowledge and own contributions to the project, b) *recognition*, skills to interact with the team members to clarify own disciplinary contributions to the project, and c) *integration*, skills to appreciate and synthesize other disciplines' knowledge in relation to the project outputs (Schaffer et al., 2012).

Findings of the two data collection tools were analyzed following a convergent-parallel mixed-methods research approach (Creswell & Plano Clark, 2017). A repeated measures t-test on the quantitative survey data collected at two points in time were conducted. Table 5 presents the results of the t-test. The test resulted in a significant difference between post-administration (M = 42.33, SD = 6.01) and the pre-administration (M = 40, SD = 6.19). There was an increase in students' perceived skills for learning in multi-disciplinary teams, t (21) = 2.11, $p<.05$.

Table 5. t-test results for differences in sub-factors at pre- and post-administration

	pre-test	post-test			
	Mean (SD)	Mean (SD)	T2-T1	*t* value	*p* value
Identification	13.95 (2.80)	15.24 (3.01)	1.29	2.59	0.02*
Recognition	12.81 (2.30)	12.81 (2.73)	0.00	0.00	1.00
Integration	13.14 (2.76)	14.38 (2.55)	1.75	1.59	0.08

As shown on Table 4, the mean score for the first sub-factor; *identification* also increased significantly. For the sub-factors; *recognition* and *integration*, the results did not produce significant changes.

The internal consistency reliability coefficients for the pre- and the post-implementation of the survey respectively were: .81 and .78.

The interviews conducted with the students and the teachers included questions created in line with the three sub-factors of the survey; identification, recognition, and integration. Table 6 illustrates the results of the interviews. The three columns; identification, recognition and integration illustrate the reported perceptions of each student and each teacher during the interviews, by assigning (X) for perceived progress and (–) for no observed change.

Table 6. Interview results for perceived skills to work in multidisciplinary teams

	Identification	**Recognition**	**Integration**
Student1	x	x	x
Student2	x	-	x
Student3	-	x	-
Student4	x	x	-
Student5	-	-	x
Student6	x	x	-
Student7	x	x	-
Student8	x	x	x
Student9	x	x	x
Student10	x	x	-
Student11	-	x	-
Student12	-	x	-
Teacher1	x	x	-
Teacher2	x	-	-
Teacher3	-	x	-
Teacher4	x	x	x
Teacher5	x	-	x

More than half of the interviewees reported a progress for *identification* (n = 12). This result is in line with the findings of the quantitative analysis. Different from the t-test results, for the second sub-factor; *recognition*, the interviews responses reported a growth (n = 13). To continue with the third sub-factor; *integration* a greater portion of the interviewees ($n = 10$) did argue that there was no improvement in students' skills for integration.

Results of both the survey and the interviews evidenced a perceived improvement in students' skills to identify the connection of their own disciplinary knowledge skills to the design challenge that they worked as a multidisciplinary team. The results together address a need to improve students' skills for integration of multiple disciplinary knowledge and methods in their preparation of a design solution.

5.Conclusion

Focusing on the multidisciplinary teamwork aspect of the course; "3BYX0P-CBL Systems and Control Project", this research project investigated the perceptions and experiences regarding student learning in multidisciplinary teams. The potential elements that influence the functioning of multidisciplinary teams for enhanced student learning were also explored.

Our findings address improvement in students' understanding of the course content; kinematics, transfer function, image detection for all students. For control theory and ME-related concepts, we see a difference between perceived improvement of AP and ME students. AP students are revealed to improve themselves significantly on control theory.

The results also show improvement in students' perceived skills for identification of own's disciplinary skills and knowledge to a given design challenge.

Main factors to facilitate/hinder multidisciplinary teamwork were revealed as prior knowledge on control, the connection of the challenge to AP and ME content, open communication environment in the team, theory- and practice-oriented perspectives, tutor guidance, and course materials.

We see complementary results, for example, different perspectives offered by ME students; more practice-oriented and AP students; more theory-oriented was seen as a facilitator of multidisciplinary teamwork. Similarly, the results showed that AP and ME students learnt from each other how to approach problems in different ways.

Collectively, the results address unique contributions to the students that could not be possible in a regular team environment, for example improvement in approaching problems with a more practice-oriented perspective, and gaining expertise and occupational identity with regards to one's own discipline (Almajed et al., 2016; Heikkinen & Isomöttönen, 2015).

Implications for Practice

In light of the findings, the main improvement points for the re-design of the course address a balance in number of AP and ME students in teams and balance of AP and ME disciplinary connection to the challenge content.

Empirical findings from the project together with the experiences of the teachers and the tutors led to the improvement of the course; “3BYX0P– CBL Systems and Control”.

<u>The course revisions can be summarized as:</u>

- engaging student teams in a challenge that draws on equally from both disciplinary perspectives (AP & ME),
- more attention to the role of the tutors,
- having increased number of AP students in the course and in each team,
- keeping the presentations that students make during their team meetings,
- adding more course materials to Canvas on AP related content, and
- revising the short orientation lecture on multidisciplinarity to focus more on integration of the disciplines.

Further Dissemination

Our findings will further be disseminated through:

- a presentation at the NARST International Conference organized in Vancouver, Canada, March 27-30, 2022,
- a presentation at the EARLI SIG 6 & 7 Combined Conference organized in Zollikofen, Switzerland, August 22-24, 2022,
- articles in peer-reviewed journals, and
- a poster that will visually illustrate the practice-oriented take-away messages emerged from our findings.

References

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