Fostering Self-Directed Learning in Engineering Undergraduates: A Collaborative Approach

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Abstract. This paper highlights the implementation of a collaborative learning method in a final-year engineering module at the University of Nottingham Ningbo China. To achieve this, students were grouped into pairs based on their preferences, and they worked together throughout the semester on weekly unassessed problems and research assignments. The traditional seminar style was replaced with interactive tutorials held in a teaching lab, where students were presented with engineering design problems and encouraged to develop solutions together. To assess the effectiveness of the collaborative learning approach, a survey consisting of both Likert scale and open-ended questions was administered to 52 students. The aim was to obtain a more comprehensive understanding of the student's perceptions of the collaborative learning approach, how it was implemented in different module exercises, and its impact on their learning experience and skill development. The results indicated that incorporating collaborative learning strategies with technology positively affected how engineering modules were taught and that developing skills such as communication, problem-solving, and critical thinking made the classes more enjoyable and increased student engagement and confidence. Overall, the findings suggest collaborative learning is a valuable pedagogical approach that should be utilized more frequently in engineering education.

Keywords: Engineering education, collaborative learning, interactive learning, student engagement.

1 Introduction

Engineering education has seen essential changes in the past two decades [1]. Different programs of study have been updated to include some group work, especially in modules focusing on project-based learning [2, 3]. Group work benefits undergraduate students by developing essential skills not taught in the classroom, such as teamworking and the development of their communication skills. However, sometimes students face challenges when doing group coursework, impacting their engagement and motivation to study and learn [4, 5].

When students are asked to work in a group to complete an assessed assignment, they sometimes struggle to work together, focusing on the task rather than working as

a team. It was found that they are often driven by achieving marks and not learning outcomes [6]. This can be due to different reasons, including how many students are in the group and being in a group they don't like. However, collaborative learning can still be used to inspire non-engaging students during lectures and tutorials. This study aims to empower the next generation of engineers through a self-directed and collaborative learning approach. The study applies collaborative learning and hybrid approaches to deliver a final-year engineering module. The goal is to increase students' interaction in the module and make them more self-directed learners to prepare them for their future post-graduate study and professional career. More importantly, to promote research practices among undergraduate students. The primary research question is: how can paring students in a small group influence their engagement in learning and impact their learning of a final year engineering module? This approach is expected to help students learn widely and deeply. Comprehensive learning results from searching for more topics than those discussed in the classroom. In contrast, deep learning is an outcome of researching issues in detail. The paper is organized as follows: section 2 is a brief literature review on collaborative learning and its application in engineering education. In section 3, the methodology of this study is explained. In section 4, the results from the student survey are presented and discussed, while section 5 concludes.

2 Literature Review

In the near future, many universities will likely adopt a hybrid approach that blends face-to-face teaching with virtual classes. This presents a significant task for educators to ensure that all students, regardless of their learning mode, receive a top-notch educational experience. To achieve this, classes and teaching material should be redesigned to accommodate online teaching and integrate interactive activities that foster student engagement, motivation, and teamwork [7]. By utilizing a blend of qualitative and quantitative research methods, a study was conducted to explore the various elements that could impact the satisfaction of learning in flipped education [8]. Out of surveying 171 students, the findings revealed that two critical factors - collaborative learning and the desire for cognition - were instrumental in predicting learning satisfaction. In-depth interviews were also conducted with 12 participants to delve deeper into the collaborative learning process. The outcomes indicated that engaging students in activities that enabled them to become familiar with each other helped enhance their collaborative learning abilities, ultimately promoting innovative and mutual learning skills.

For engineers, working in isolation is not the preferred approach. Instead, they tend to collaborate to tackle complex projects and achieve success. As such, engineering students must cultivate teamwork skills that will equip them to address real-world challenges in the future [9]. By studying undergraduate engineering courses, researchers found that active and collaborative learning methods improved students' design, problem-solving, communication, and group participation skills more effectively than traditional lecture and discussion methods [10]. The study involved 480 students from 17 courses and six schools, with statistically substantial learning improvements observed even after accounting for student pre-course characteristics. A study that employed a

collaborative learning approach as a dynamic teaching technique for foreign languages described the pedagogies for teaching English to students who capitalized on the various features available in the online learning environment [11]. The study highlighted the advantages of collaborative learning in enhancing interpersonal, analytical, and communicative competencies through collective undertakings and its vital role in forming a virtual learning society, acquiring foreign language abilities, and attaining linguistic proficiency. Strategic preparation, unambiguous guidelines, and pertinent material can surmount these challenges despite the potential hurdles associated with orchestrating group work online. In a seven-year study, engineering students were trained to present lectures to their peers using project-based and cooperative learning methods [12]. The study tracked daily progress and discovered that this approach boosted students' motivation and skill development while improving their ability to retain knowledge. Additionally, attendance increased, and students became more proactive learners. A group of 42 mechanical engineering students participated in a study that utilized several experiments to differentiate between individual and cooperative learning [13]. The researchers carefully monitored the time spent on task to compare the efficacy of the two approaches. The findings revealed that collaborative learning yielded superior results among students who were granted ample time to develop their skills. To encourage active participation among students in an online engineering education program, a structured approach was introduced. This framework aimed to address the challenges of maintaining student engagement in the online learning environment [14]. The research highlighted various strategies that both teachers and learners could adopt to promote collaborative practices. By taking a proactive approach, these practices could help sustain a constructive and effective learning experience for students pursuing engineering education online. This is evidenced in a review of 62 published articles on flipped learning in engineering education found that students in flipped learning environments outperformed those in traditional classrooms [15]. However, the study highlighted a shortage of qualitative research on the effectiveness of flipped learning in engineering education, and recommended further investigation into whether it can improve students' professional skills, such as interpersonal, self-directed, and lifelong learning skills. The challenges of implementing flipped learning in engineering education were explored in the same article, with studies highlighting issues such as instructor workloads and technical difficulties. There was also a risk of disengagement among students in a flipped classroom [16, 17]. Educators are advised to gradually integrate flipped learning into their modules to mitigate these challenges and communicate the changes to students. Innovative class materials should facilitate collaborative problem-solving among students and their instructors, leading to increased attendance and engagement in lectures [18].

3 Methodology

Previous students who attended the module used in this study were surveyed to explore their preference for collaborative learning. Students expressed their preference for collaborating with other partners rather than studying on their own. Additionally, they said

they like working in a small group or a pair and, where possible choosing their partner. They also preferred to collaborate on unassessed research tasks than assessed coursework. The existing students were informed to partner in pairs with a collaborator of their choice during the first week of the semester. Students were briefed on the collaborative approach which was then used in the module. A weekly unassessed exercise was created to promote collaboration and was shared with the entire class at the end of each weekly session. Students were asked to work out the weekly exercise with their partners. During the weekly teaching sessions, students were encouraged to take notes of the keywords they wanted to search for and discuss their search with their partners. Students could then bring their questions, if there are any, to the class for further discussion. Students were given some unassessed research assignments based on the scenario of the actual teaching session and debate in the classroom—those small research assignments aimed to further promote collaboration in each pair. Additionally, a few tutorials were moved from the regular classroom to an interactive technology-equipped teaching lab named (WonderLab). In the lab, students were divided into small groups of 2 pairs per group. Students were given small tasks of problem analysis or design. They used the interactive touch displays in the lab for annotation, brainstorming, and discussion among each group first. Then each group shared their idea with the whole class. A survey including 17 Likert of a five-point scale and open questions was shared with final-year engineering students attending the 10-credit module. Completing the student survey was optional, and students were required to fill out a well-informed online consent form before engaging in the survey. The survey was conducted online using MS Forms at the end of the semester. All students attending the module were encouraged to complete the survey by word of mouth, and participants completed the survey voluntarily. The responses were analyzed using Excel and SSPS.

4 Results and Discussion

In order to examine the effects of collaborative learning on students' problem-solving and research skills, the researcher asked the participants to share their experiences of completing problem solutions with their partners instead of receiving the entire set of problems and solutions at once. The study results depicted in Fig. 1 indicate that most (75%) participants agreed that discussing the problems with their partners positively impacted their learning experience. In comparison, 88% acknowledged the benefits of information sharing during collaborative learning, followed by individual research. Additionally, all participants strongly agreed (38%) or agreed (62%) that collaborative learning encouraged weekly tutorial assignment discussions. Interestingly, 75% of participants strongly agreed or agreed that writing down detailed solutions for weekly module problems in pairs after discussing them during tutorial sessions was beneficial for their learning. However, 13% of participants did not agree, while the remaining 13% were neutral (see Fig. 1).

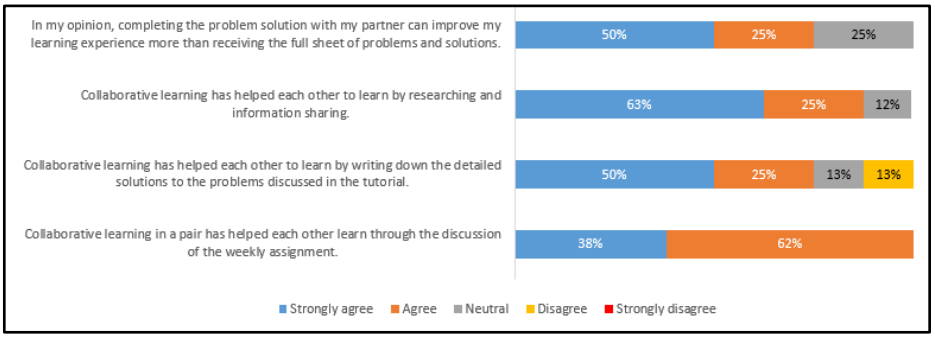

Fig. 1. The Impact of Collaborative Learning on Problem Solving and Research Skills.

To investigate the impact of blending collaborative learning pedagogy with the technology provided in the teaching lab on engineering students' learning experiences, the participants were asked whether they preferred to attend the tutorial in the teaching lab or the regular classroom venue. As their responses demonstrate in Fig. 2, 88% of the participants either strongly agreed or agreed they preferred the interactive teaching lab known as (WonderLab) to better discuss the colored layout design problems learned in this module. The same percentage of the participants (88%) strongly agreed or agreed that the massive touch screens in WonderLab encouraged discussion among each group of two pairs of students. The same percentage of participants either strongly agreed or agreed that the touch screens made the interaction enjoyable. 63% of the participants strongly agreed that they prefer to have more tutorials, not just the colored layout design problems, in the lab than in the regular classroom, while 12% agreed. Most participants (75%) strongly agreed that, where possible, they encourage other engineering module convenors to arrange their teaching sessions in the interactive lab, to benefit from the interactive technology and discussion among students.

To evaluate the deployed collaborative learning approach for enhancing students' engagement and learning experience, the participants were asked a group of Likert questions, as illustrated in Fig. 3. 38% of the participants strongly agreed that collaborating in pairs and the interactive discussion increased their confidence, while 50% agreed. The participants strongly agreed and agreed equally that, overall, the collaborative learning approach they used was enjoyable. All the participants strongly agreed (38%) or agreed (62%) that the learning approach improved their learning experience in general. 50% of the participants strongly agreed, and the other 50% agreed that the learning approach promoted effective collaboration and communication in each pair during the entire semester or among the small group of two pairs during the teaching lab sessions. 88% of the participants either strongly agreed or agreed that the approach used in this study effectively helped them to understand the learning material better. Moreover, this approach effectively prepared them for their assessment, including coursework and final exam.

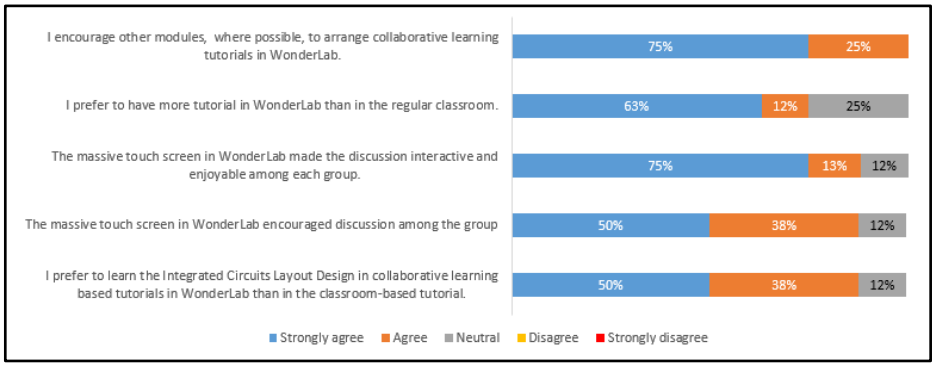

Fig. 2. Exploring the Effectiveness of Collaborative Learning in an Interactive Teaching Lab for Integrated Circuits Layout Design Problems.

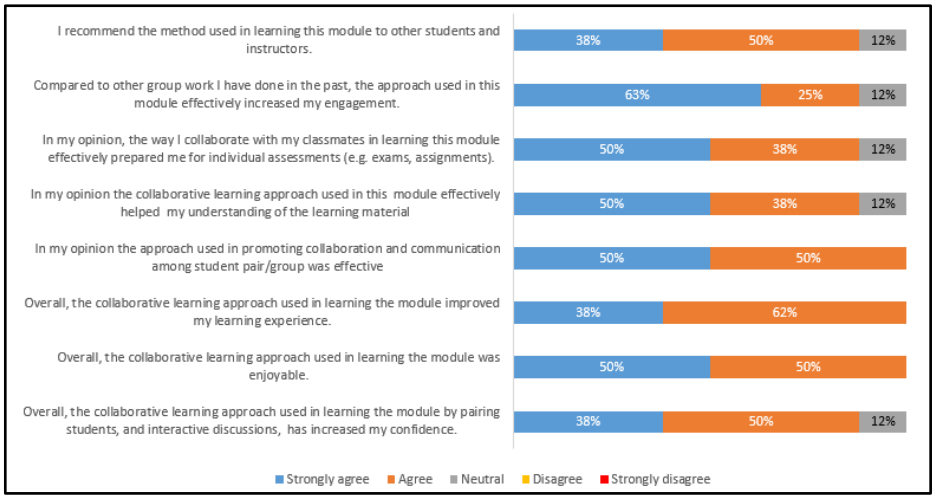

Fig. 3. Evaluation of Collaborative Learning Approach for Enhanced Learning Experience and Engagement.

Interestingly, 63% of the participants reported that the approach in this study effectively increased their engagement compared to other group work they did in other previous modules. This is evidenced by students' comments below:

"*The approach implemented in this module felt different than the previous group work. This semester I was able to discuss with classmates and deal with the problem immediately*", "*This semester, it felt easier to communicate with classmates*", "*It gave us more freedom*" and "*This class was absolutely different. The collaborative learning objective was clear and interesting and encouraged me to learn outside the given learning material*". 38% of the participants strongly agreed, and 50% agreed that they recommend using similar methods for learning engineering modules to other students and instructors.

Adopting collaborative learning in teaching the module presented in this study has helped students take ownership of their learning and become more self-directed. This was clear from students' comments:

"*I can obtain more information than by myself which showed me more ways to study than before*" and "*Made me confident. To be honest, I was a loner before this semester. I studied all by myself, even in the group project, I used to finish my assigned part without any communication with others. Unlike in this semester, I communicated with others frequently*". Students further explained that the learning approach used in this study helped them to develop their skills and commented, "*It helped me to think critically as well as develop my communication skills as in the group we discussed our different ideas, before we brought the discussion to the whole class*", "*I was more encouraged to learn. I asked any question came to my mind freely as our teacher tried his best to get us engaged in the class and communicate with each other*" and "*It made me think in more aspects based on the discussion and comments from my paired student and other classmates*". The findings align with prior research that suggests a correlation between academic autonomy and active student involvement, resulting in heightened student motivation and enhanced creative thinking abilities [19]. This is presumably why students are strongly inclined to attend classroom-based teaching, even when presented with alternative options within a blended learning paradigm [20].

5 Conclusion

This study explored collaborative learning to foster self-directed learning and research practices, focusing on final-year engineering students. The approach involved forming small groups and encouraging students to work together on unassessed tasks. The teaching lab also utilized interactive technology to aid problem analysis and design. The study uncovered that students preferred collaborating with peers and working in small groups, which positively impacted their engagement and motivation. Engineering students reported that the collaborative approach facilitated extensive and profound learning, supported their confidence, and improved their understanding of the subject matter. The study's findings emphasized the effectiveness of collaborative learning, particularly when combined with technology in the lab, highlighting the benefits of research and information sharing. Consequently, it is recommended that collaborative learning pedagogies be widely implemented in final-year engineering modules, with students being paired or grouped with a few collaborators. Additionally, incorporating pedagogies like collaborative learning and learning technologies in seminar layouts can promote interaction, self-directed learning, research practice, and skill development.

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