Enhancing Learning Outcomes in Engineering Education Through Peer Assessment

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Abstract:

Peer assessment is an essential component of engineering education that fosters collaborative learning, critical thinking, and effective written communication among students. This design case study illustrates the implementation of a peer assessment strategy in an engineering capstone design course. It aims to elucidate how peer review, feedback, and grading were utilized to enhance students' learning outcomes, knowledge retention, and the development of professional competencies. The study discusses the design and execution of the strategy based on instructor observations, highlighting the benefits of peer assessment on student engagement, motivation, and the acquisition of essential engineering skills such as problem-solving, communication, and teamwork. Additionally, the paper addresses challenges related to bias, reliability, and implementation barriers, offering practical strategies and practices to overcome these obstacles.

Introduction

Assessment plays an important role in education, providing essential data and evidence that educators use to inform instructional interventions [1]. Assessment serves as a practical means for educators to make informed decisions, enhance student learning, and contribute to overall educational improvement. Traditional methods of assessing students' understanding, knowledge, and skills include standardized tests, quizzes, exams, and assignments. However, as educators increasingly embrace student-centered learning and design open-ended learning environments, these assessment methods fail to meet their needs for accessing necessary data and evidence to inform students' learning. Consequently, alternative forms of assessment in education have received attention due to their potential to provide a more comprehensive insight into students' achievements in student-centered learning environments. These alternative methods offer authentic information about their knowledge, abilities, skills, attitudes, and competencies, especially in project-based learning environments [2].

Project-based assessment strategies, such as e-portfolios, case studies, and performance tasks, are designed to give students the chance to evaluate their strengths and areas for improvement, and to set goals for future learning [3], [4]. For instance, Prastiwi et al. [5] conducted a sequential exploratory mixed method study to investigate the effectiveness of using e-portfolios in evaluating the scientific literacy skills of higher education students. The researchers found that students had a positive view of e-portfolios, describing them as a convenient and learning-focused alternative method of assessment. Other assessment strategies include self-assessment and peer-assessment. Research has shown that these strategies can significantly improve learning and achievement when properly implemented [6]. Self-assessment involves individuals evaluating their own work, performance, or understanding against set guidelines [7]. Conversely, peer assessment involves students evaluating their peers' work based on specific criteria. Peer assessment has become increasingly popular in education [8] and is the main focus of this study. It is being explored as an alternative assessment strategy in a project-based, student-centered learning environment in a senior level engineering capstone project class. In this study, we

investigate common methods of peer-based assessment to understand their effectiveness in teaching fundamental skills for engineering.

Peer Assessment

Peer assessment is a process where students give feedback and grade their peers' work, a practice commonly used in educational environments to enhance learning [9]. It motivates students to take responsibility for their own learning as well as their peers', fostering critical thinking and independence [10]. Peer assessment is a two-way process, with students benefiting from both giving and receiving feedback [11]. Moreover, peer assessment has been recognized as an authentic assessment strategy, offering potential effectiveness and advantages [12]. Huisman et al. [13] conducted a synthesis of 24 quantitative studies that reported on the impact of peer feedback on the academic writing performance of higher education students. The researchers discovered that peer feedback had positive effects and emphasized that formative peer feedback positively impacts students' writing performance, leading to enhancements in their academic writing. This study highlights the role of peer feedback as a formative assessment tool in higher education. In a separate study, Papinczak et al. [14] investigated the attitudes and perceptions of first-year medical students towards peer assessment at a higher education institution. They found an increase in responsibility and learning, although there were some challenges associated with the discomfort of grading the work of classmates and providing feedback. Contrarily, Chen et al. [15] studied the perceptions and experiences of graduate students with peer assessment in a computer science classroom. They found no impact on students' learning and reported mixed feelings among the students.

Peer assessment in engineering education is a valuable tool that fosters critical thinking, independence, and professional development. It requires students to evaluate their peers' work based on specific criteria, provide feedback, and grade their classmates' work. Numerous studies have shown interest in the subject of peer assessment in engineering education. Cruz et al. [16] carried out a case study that centered on web-based peer assessment, specifically among civil engineering students, showcasing the practical execution and efficacy of peer assessment in the context of engineering education. Additionally, Idrus et al. [17] delve into the successful application of peer review assessment for engineering students, pointing out the relevance and utility of peer assessment as an impactful educational instrument within the realm of engineering.

In the current study, the instructors guided the engineering students to review and assess each other's senior level capstone projects. The objective of this study is to demonstrate the implementation of peer assessment in this year long-project, emphasizing the instructors' observations of the design process and its results through a design case study.

Design Case Study

This is a design case study aiming to describe a design of how the instructors of the capstone course used peer assessment strategy as a formative assessment. The students provided each other feedback and grades at the end of the Fall semester and used their classmates' feedback to improve their work in the Spring semester. In a design case study, a comprehensive description of a process or experience crafted for a specific purpose is explained, accompanied by design

recommendations for designers addressing similar situations [18]. Design case studies emerge from a systematic and theoretically supported experiential approach but differ structurally from traditional research. Sections such as method, participants, results, and generalizations are not implemented in these studies [18]. Instead, these studies offer a detailed account of the design and articulate the designer's profound insights into the design process and its outcomes [19].

Introduction to Capstone Design Course

Engineering Capstone Design is a requirement for all engineering students. ENGR-E 490 (fall) and ENGR-E 491 (spring) comprise a two-semester capstone senior project. Students in this course design engineering projects based on their areas of concentration. Students may choose to conduct advanced research, develop prototypes, design new products or redesign existing products. This course uses a team-based design using real-world industrial constraints. During this course, students' ability to work both individually and within a design team is a critical part of a successful project and is a factor in their project grade as well as their performance grade. Students in this course are supported by dedicated faculty members or industry supervisors.

The major learning outcomes of the Capstone Design course are designed to help students gain familiarity with various aspects of team-based engineering work, including requirement formulation and flow down, project planning, constraints management, interface specification, and prototype integration. The course also focuses on developing students' abilities in preparing and delivering technical presentations to multiple contributors, integrating their individual contributions into the broader team project. Overall, the course aims to equip students with the practical skills and knowledge needed to excel in collaborative engineering environments.

Assessment Tools in Capstone Projects

The major deliverables for the capstone design include oral presentation, project report, and prototype. The grading policy for the Capstone Design course allocates 30% of the grade to the average of weekly lab assignments, ensuring students' consistent engagement and performance in practical project work. Attendance and performance contribute 10% to the overall grade, emphasizing the importance of regular participation and active involvement in class activities. The remaining 60% of the grade is dedicated to the individual capstone design project, with specific breakdowns:

- 35% for the final report, emphasizing comprehensive documentation of the project's objectives, methodologies, and outcomes;
- 20% for the team presentation, evaluating the group's ability to effectively communicate their project's key aspects to an audience;
- 15% for the individual presentation, focusing on the student's ability to articulate their specific contributions and insights within the team project;
- 15% for the demo, evaluating the functionality and practicality of the project prototype or implementation; and
- *15% for peer evaluation*, emphasizing the importance of teamwork, collaboration, and mutual respect among peers in the assessment process.

Teams and Projects

In the Fall of 2023, the Capstone Design class comprised 32 students divided into six teams. Each team had a varying number of members, with three teams consisting of six students, three teams with five students, and one team with four students. These teams embarked on diverse projects, all of which were sponsored by clients.

Implementation of Peer Assessment in Capstone

To implement peer assessment in capstone design we give the students a form to evaluate the contributions of each other's towards the project. At the beginning of the from the students given the following instructions:
"For each member of the team, assign a number between 1 (lowest) and 10 (highest) for each category. This information is intended to provide honest feedback to your teammates, so your assessment should be as honest as possible. You should use the full range of numbers from 1 to 10. If you simply award "grades" of 9 and 10, team members who have worked unduly hard or provided extraordinary leadership will go unrecognized, as will those at the other end of the scale who need your corrective feedback [20]." Before the form we provide the students with a more detailed description of the evaluation's criterion.

Table 1: Description of the Evaluation's Criterion.

Quality of Technical Work:	Is the work correct, clear, complete, and relevant to the problem under discussion? Are equations, graphs, and notes clear and intelligible?
Ability to Communicate:	Does he/she understand what is being said? Does he/she communicate effectively with the team members? Does he/she follow the team's directions?
Ability to Provide Leadership:	Does she/he take initiate activities, make suggestions, provide focus? Is he/she a sparkplug?
Commitment to Team, Project:	Does she/he attend all meetings? Arrive promptly? Prepared? Ready to work?
Demonstrated Effectiveness:	Has he/she done what is been promised? Could this project have benefited from more (or less) of this person's contributions?

Table 2: Peer Assessment Form

Team Members (Names) Rating Categories	Name:	Name:	Name:	Name:	Name:
Quality of Technical Work					
Ability to Communicate					
Ability to Provide Leadership					
Commitment to Team and Project					
Demonstrated Effectiveness					
Sum of Ratings					

At the end of the form the students are asked to provide any comments about any members of their team.

Instructors' Observations of Benefits of Peer Assessment

Instructors of the Capstone Design class reported several benefits of peer assessment. Firstly, it provided instructors with a comprehensive understanding of the team dynamics, offering insights into aspects of teamwork that may not be observable during traditional class settings. For example, it allowed instructors to assess the effectiveness of students' meetings outside of class, which is crucial for project success.

Secondly, peer assessment gave students the opportunity to reflect on their contributions to projects and correct any issues they may not have been aware of during their collaboration with the team. For example, teams reported issues related to ineffective communication skills, inadequate project contributions, or deficient leadership skills. This corrective aspect of peer assessment helped improve individual performance and overall project outcomes.

Thirdly, by fostering more effective teamwork, peer assessment contributed to timely project completion, ensuring that prototypes, reports, and presentations are finished on schedule. All the teams successfully completed their projects on time sharing peer assessment as a form of constructive feedback and encouragement for completing the work.

Finally, peer assessment helped students develop skills that are valuable in professional environments, such as accepting and providing constructive feedback, as well as enhancing their leadership and communication skills. This exposure to industry-like environments prepares students for their future careers and enhances their overall learning experience.

Instructors' Observations of Challenges with Implementing Peer Assessment

There were challenges that the instructors faced when implementing peer assessment in the engineering capstone course. One common issue was bias in grading, where students may unfairly assess their peers. Additionally, some students were reluctant to participate in the assessment process, leading to incomplete evaluation forms. Another challenge was the lack of clear assessment criteria, which made it difficult for students to provide accurate evaluations. Furthermore, measuring soft skills, such as teamwork or communication, can be subjective and challenging for students to evaluate on a scale. Lastly, when teams were small, it was challenging to obtain a comprehensive peer evaluation, as seen in a case where a team had only two members from a previous semester. These challenges highlight the importance of careful planning and implementation strategies to ensure the effectiveness of peer assessment in engineering education.

Instructors' Suggestions with implementing peer assessment in Future

Challenges in implementing peer assessment in engineering education have been addressed with various solutions and best practices. One such solution involved the introduction of a new bi-weekly assignment called the progress report. To solve the bias in grading challenge where

students may unfairly assess their peers, we asked teams to keep and submit attendance records for all out-of-class meetings. This included the team members' meetings and the meetings with their mentors.

To enhance student engagement in peer assessment, instructors consistently prompt students to submit their peer evaluation forms. Instructors utilize email communications to remind students who have not yet submitted their assessment forms, ensuring completion prior to the final grade posting. In certain semesters, instructors have also distributed paper copies of the peer assessment forms, requesting students to submit them in person during class sessions.

Another approach was to accompany the peer evaluation form with a more detailed rubric to guide students in their peer assessments. A new approach was implemented recently for instructors to take charge of team formation, as opposed to leaving it to the students, which has proven beneficial in addressing past team formation issues. By controlling team formation, instructors were able to avoid and rectify issues related to small team sizes. Additionally, role assignments were implemented, providing students with specific roles within their teams, which could facilitate more accurate peer judgments based on each member's responsibilities. Moreover, students were provided with references and books covering not only technical skills but also soft skills, such as Electronics Project Management & Design by Stadtmiller [21] and Strategies for Engineering Communications by Stevenson [22]. These references were included in the syllabus to further support students in their learning journey.

Conclusions

The instructors of the Capstone Design class noted several benefits of peer assessment. It provided a comprehensive understanding of team dynamics, revealing insights into teamwork not easily observed in traditional settings, such as assessing the effectiveness of meetings outside of class. Peer assessment also prompted students to reflect on their contributions and address issues like ineffective communication, leading to improved individual performance and project outcomes. However, implementing peer assessment came with challenges, including bias in grading, student reluctance to participate, and difficulty in measuring subjective skills like teamwork. These challenges underscore the need for careful planning and implementation strategies in incorporating peer assessment into engineering education.

In conclusion, this paper presents insights into the effectiveness of peer assessment as a pedagogical approach in engineering education, offering recommendations for educators to optimize its implementation. It suggests avenues for further research to explore nuanced aspects of peer assessment and its continuous improvement within the dynamic landscape of engineering education.

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