Teamwork Assessment in Measurement and Instrumentation Course

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Work in Progress: Teamwork Assessment in Measurement and Instrumentation Course

Abstract

As highlighted in the Engineer of 2020 report, essential parts of engineering education include teamwork, communication, and management skills. Among these, teamwork is considered a key skill due to the complexity and scale of engineering problems. It is a must-have ability that potential employers seek in students. Furthermore, the Accreditation Board for Engineering and Technology (ABET) requires students to have the ability to function in high-performing teams, as stated in ABET (students' outcome 5): "students must be able to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." Therefore, engineering schools must prepare students with teamwork skills and incorporate teamwork as a significant part of their engineering curricula (ABET, 2021).

Team participation is typically evaluated through peer evaluations or through instructor observation of individual team members. Several tools have been developed to assess individual performance, such as the Team Effectiveness Questionnaire (TEQ) or the Comprehensive Assessment of Team Member Effectiveness (CATME). These assessment tools are based on self-reflections or peer evaluations. However, the efficacy of these tools has been questioned.

At the University of Wisconsin-Platteville, the Measurement and Instrumentation course covers the design and development of products containing multiple sensors and actuators. Students in this course work in teams to collaboratively develop these products. While each team member is responsible for their individual parts of the project, the integration of these parts requires a significant amount of teamwork. In this study, we propose indirect evaluations of teamwork by assessing the functionality and quality of the product, team presentation, and project report. We investigated 9 final projects involving 31 students and compared the indirect team evaluation with peer evaluations. The details of our findings will be discussed. Based on our findings, we conclude that peer evaluation alone may not be a reliable or comprehensive source of team evaluation.

Introduction

Engineering students must be equipped with problem-solving, communication, teamwork, and lifelong learning skills that are consistent with the ABET Engineering Criteria 2020-21 [1]. Engineering programs must demonstrate that their students have the ability to function effectively on a team, with members who can provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (ABET-Criterion3-outcome5) [2]. In addition to ABET, the industry has emphasized the necessity of teamwork skills in engineering education [3].

Students can benefit from working together through deeper learning and longer retention of information [4,5,6]. Collaborative learning activities, such as Engineering design projects, can help students clarify their understanding of a subject, make connections between different concepts, and engage in critical thinking. Moreover, social interaction in collaborative learning can increase engagement and motivation and help to create a positive learning environment. However, it is essential to note that the benefits of collaborative learning depend on the quality of the teamwork, and effective teamwork necessitates good group dynamics, clear goals, and efficient communication [7,8,9]. The question that remains unanswered is how to assess teamwork effectively.

Peer evaluations can be a useful tool to assess team skills as team members are in the best position to reflect on the skills of their fellow teammates. Ideally, peer assessments provide insight into the strengths and weaknesses of each team member and can help to improve the overall performance of the group [10]. Peer evaluation questionnaires typically include the degree of individual contributions, communication skills, problem-solving abilities, and other qualities that are important to the success of the team. By receiving constructive feedback from their peers, team members can identify areas for improvement and work to enhance their skills. Moreover, peer evaluations can promote accountability and increase motivation, as team members become more aware of their role in the group's success.

However, it is essential to ensure that the peer evaluation process is conducted fairly, transparently, and in a non-threatening manner to avoid damaging relationships or demotivating team members. Despite the benefits of peer evaluation, many authors have expressed concerns regarding their use [10,11]. For instance, peer evaluations can be biased and have negative effects on individuals in the team [12]. Furthermore, it has been observed that individuals tend to give all team members the same score or team members unite as a group against one member, potentially affecting the accuracy and validity of the evaluations.

Taking into account these concerns, peer assessments need to be evaluated and validated to ensure their accuracy and fairness. In this study, we aim to compare peer and instructor evaluations of teamwork in the measurement and instrumentation course to assess the reliability and validity of peer evaluations. Based on our findings, we conclude that peer evaluation alone may not be a reliable or comprehensive source of team evaluation.

Methodology

1. Measurements and Instrumentation course

The Measurement and Instrumentation course teaches students the fundamental principles and techniques used to measure physical quantities such as voltage, current, temperature, pressure, flow, and force, among others. Additionally, students learn how to select and design instrumentation for various applications. Some of the common topics covered in this course include measurement systems and instrument characteristics, error analysis, noise and interference in instrumentation, signal conditioning, Internet of Things (IoT), sensor applications, data acquisition, digital interfaces (A/D and D/A), and discussion of specific sensor systems.

The course incorporates hands-on laboratory work to enable students to apply the principles and techniques learned in class to practical scenarios. The laboratory work includes four design projects, where students design, develop, and build instruments. In the first three projects, students work individually to design and build instruments for measuring various physical quantities. These projects provide opportunities to apply the concepts and techniques learned in class to real-world situations. The final project is a group project, where students work collaboratively to design and build more complex products. Through the group project, students can enhance their teamwork and collaboration skills, which are crucial for success in engineering and technical fields.

2. Final project and team forming

At the beginning of the semester, each student is required to submit a project proposal describing a product that includes multiple sensors or actuators. Examples of these proposals include smart coffee maker, smart blender, and smart pet environment control system. A pool of proposals is created by gathering all the submissions. A few proposals from the pool are selected and confirmed as final projects. Students then select their projects based on their interests.

Each team member of a project must select a sensor or actuator related to their project, and the team submits a 2-page meeting note that describes the goals, team member responsibilities, and their roles in the project. The team members occasionally have meetings, but they start working together toward the end of the semester. The details and timeline of the laboratory work are shown in Table 1.

The benefits of this method include:

- Individual work is defined, and everyone has their own part to design, build, and test.
- Each student must check off their individual work in projects 2 and 3, but significant teamwork is required to build the product in project 4.

Table 1. Laboratory work

Deliverables	First month	Second month	Third month	Fourth Month
Project proposal Team forming Final project description Project 1: Design and prototype a temperature measurement system (individual)	X			
Project 2: Design, prototype And test a transducer related to their final project (individual)		X		
Project 3: adding remote monitoring/controlling to the project 2 (IoT) (individual)			X	
Final project: Integration of their parts and build the final product. (teamwork)		X	X	X

3. Teamwork assessment

Four methods of teamwork assessment were used, including peer evaluation, final presentation, final report, and evaluation of the functionality of the final project. Assuming that an individual works well with the team, this should be reflected in the quality of the final presentation, final report, and the functionality of the final project. However, there are some cases where students do well individually in projects 2 and 3 but fail to integrate their work into the final project. This can be detected when there is no strong connection between the individual part and the final product.

4. Peer evaluations

At the end of the semester, students were required to evaluate their teammates using a questionnaire that rated their peers in three categories: management, collaboration, and inclusivity. The rating structure was based on a scale of unsatisfactory (1/3 point), developing (2/3 points), satisfactory (3/3 point), and exemplary (4/3 points). Students who received an exemplary rating were assigned a maximum rating of 4 points, while those who received unsatisfactory scores in all three categories were assigned a minimum rating of 1 point. An average score was calculated for each student based on the ratings received from their peers. Table 2 shows the peer evaluation questionnaire, and Table 3 presents the results of the peer evaluation.

Table 2. Peer evaluation questionnaires

Please rate your teammate				
	Unsatisfactory (1)	**Developing (2)**	**Satisfactory (3)**	**Exemplary (4)**
(5.1) Group Management – team members provide leadership, establish goals, plan tasks and meet objectives	Does not provide input regarding the determination of team roles and is unwilling to accept responsibility associated with a given role; Does not provide assistance with the establishment of goals and plans; Does not realize the significance of meeting objectives/deliverables in a timely manner	Demonstrates some ability to provide input regarding the determination of team roles and some willingness to accept responsibility associated with a given role; Provides some assistance with the establishment of goals and plans; Maintains limited focus and ability to keep the plan on track; Demonstrates difficulty in meeting objectives/deliverables in a timely manner.	Provides satisfactory input regarding the determination of team roles and is generally willing to accept responsibility associated with a given role; Provides assistance with the establishment of goals and plans; Maintains focus and ability to keep the plan on track; Meets most objectives/deliverables in a timely manner.	Exceeds expectations in providing input regarding the determination of team roles and is always willing to accept responsibility associated with a given role; Leads and helps with the establishment of goals and plans; Maintains an excellent focus and ability to keep the plan on track; Meets all objectives/deliverables in a timely manner.
(5.2) Group Collaboration – team members recognize the significance of an individual and group contribution and work toward these goals to create a collaborative environment	Not well prepared or does not attend team meetings; Does not provide individual contribution (no ideas presented) to the group; Does not recognize the value of collegiality and teamwork, frequently claiming work as individual or blaming others; Requires strong encouragement to provide group contribution	Somewhat prepared for or has sporadic attendance at team meetings; Does not provide individual contribution to the group; Demonstrates some recognition of the value of collegiality and teamwork, sometimes claims work as individual or blames others; Requires some encouragement to provide group contribution	Typically attends team meetings and demonstrates preparedness; Provides limited individual contribution to the group; Occasionally has difficulty in recognizing the value of collegiality and teamwork and sporadically claims work as individual or blames others; Generally, provides group contribution but may require some prompting	Regularly attends meetings and is well prepared; Provides strong individual and group contribution; Recognizes the value of teamwork and encourages others to benefit from group participation.
(5.3) Group Inclusivity – team members create an inclusive environment	Does not consider the viewpoint/ideas of others; Often discourteous, inconsiderate, or impolite to others; Always tries to persuade others to adopt personal viewpoint/ideas or reluctantly considers/accepts team viewpoint/ideas	Sometimes considers the viewpoint/ideas of others; Often blaming others for errors; Sometimes discourteous, inconsiderate, or impolite to others; Often persuades others to adopt personal viewpoint/ideas or reluctantly considers/accepts team viewpoint/ideas	Considers the viewpoint/ideas of others; Occasionally discourteous, inconsiderate, or impolite to others; Rarely persuades others to adopt personal viewpoint/ideas and typically considers/accepts team viewpoint/ideas.	Values alternative perspectives and encourages participation among all team members; Remains non-judgmental when disagreeing with others and seeks conflict resolution; does not blame others for wrongdoing; Maintains courteous and considerate behavior toward all team members

5. Presentation and final report evaluations

The team's presentation was evaluated based on the quality of their project's delivery and their collaboration in preparing it. While presentations are typically assessed based on their delivery, content, and effectiveness, this paper evaluated them based on the team's ability to work together and understand each other's contributions. Additionally, the Q&A portion of the presentation demonstrated how well the team could handle unexpected questions.

The final report served as a crucial gauge of the team's overall teamwork. Poor teamwork can manifest in various ways, such as disjointed or disorganized sections resulting from inadequate coordination among team members. Furthermore, if each member works independently, there may be inconsistencies in language, formatting, and the report's overall approach. Meeting the deadline was another key factor in evaluating teamwork in the final report. While each member was assigned a section to write, the report's compilation was also indicative of the team's collaboration. The course instructor assessed the team's performance based on factors such as the presence of any missing sections, equal participation from all members, and the cohesion between different parts of the report.

As this study is still in progress, the course instructor did not use a well-designed rubric or instrument to evaluate the presentations and final reports. Therefore, the ratings given to these deliverables were based solely on the instructor's judgment.

6. Functionality of final project

Evaluating a team's performance based on the final product involves assessing the team's overall effectiveness in achieving its goals and objectives. The functionality and quality of the final product are indicators used to evaluate the teams. The nature of the projects required students to create a logic that involved all team members' instruments. The final product is rated based on how well each individual part is integrated into the final product. A high-quality product is created when team members effectively collaborate and handle any challenges or obstacles that arise during the project. Indicators of lack of teamwork include the existence of connections between parts or standalone sensors/actuators.

Results

Both the presentations and final reports were evaluated using a rating system of 1 (poorly presented/written) to 4 (exemplary presented/written) to gauge the level of teamwork. Tables 4 and 5 depict the ratings for the presentations and final reports, respectively. The results of the peer evaluations are presented in Table 3. We observed a pattern of responses, such as assigning the same score to all group members (Teams 1, 3, and 9) or collusion among group members against one member (Team 2). Except for Teams 7 and 8, most team members rated their peers

highly. The course instructor evaluated students' teamwork based on their final presentation (Table 4), final report (Table 5), and the functionality of their product (Table 6).

Table 3. Peer evaluation

Team	Project title	Overall	Student A	Student B	Student C	Student D	Student E
1	Smart blind	4	4	4	4	4	X
2	Smart clock	3.8	3.8	3.8	3	3.8	3.8
3	Smart lock	4	4	4	X	X	X
4	Coin sorter	3.95	3.8	4	4	4	X
5	Smart pet feeder	3.93	4	4	3.8	X	X
6	Smart bottle	3.65	3.8	3.8	3.5	3.5	X
7	Smart Pet environment	3.16	3.2	3.1	3.2	X	X
8	Smart Green House	3.33	3.5	3.5	3	X	X
9	Invisible fence	4	4	4	4	X	X

X means that the team did not have third, fourth or fifth member.

The data in Table 4 reveals that most teams performed well in their presentations. Notably, although team 7 rated themselves lower in the peer evaluation, they were one of the top presenters. However, Table 4 did not offer significant insights into the overall teamwork.

Table 4. Team presentation

Team	Project title	Overall	Student A	Student B	Student C	Student D	Student E
1	Smart blind	3.8	3.8	3.8	3.8	3.8	X
2	Smart clock	3.9	4	4	3.8	3.9	3.9
3	Smart lock	3.8	3.8	3.8	X	X	X
4	Coin sorter	3.7	3.8	3.7	3.8	3.8	X
5	Smart pet feeder	3.8	3.8	3.8	3.7	X	X
6	Smart bottle	3.8	3.8	3.8	3.8	3.8	X
7	Smart Pet environment	3.9	3.9	3.9	3.9	X	X
8	Smart Green House	3.8	3.8	3.8	3.8	X	X
9	Invisible fence	3.7	3.7	3.7	3.7	X	X

Table 5 highlights the issue of inadequate teamwork, as evident in the final reports of some teams. Specifically, two students in team 1 and one student each in teams 3, 6, and 8 did not make any contribution to their respective reports. Moreover, in some reports, it was observed that not all team members had read or reviewed the document. These findings suggest that

teamwork was ineffective in certain teams, potentially due to disengagement or lack of commitment among some members.

Table 5. Final report

Team	Project title	Overal l	Studen t A	Student B	Student C	Student D	Student E
1	Smart blind	2.1	3.3	1	3.1	1	X
2	Smart clock	3.42	3.8	3	3.8	3	3.5
3	Smart lock	2.25	3.5	1	X	X	X
4	Coin sorter	3.8	3.3	3.8	3.8	3.8	X
5	Smart pet feeder	3.5	3	4	3.5	X	X
6	Smart bottle	2.9	3.5	1	3.6	3.5	X
7	Smart Pet environment	3.8	3.8	3.8	3.8	X	X
8	Smart Green House	2.87	3.7	3.3	1	X	X
9	Invisible fence	3.5	3.5	3.5	3.5	X	X

Teamwork evaluation based on the overall functionality of final projects is shown in Table 6. If students' sections appeared to be standalone, they received a score of three. Teams 4 and 7 had the best products, and all the sections were well integrated. There was evidence of teamwork in the final products, but the quality of integration varied.

Table 6. Overall functionality of projects

Team	Project title	Overal l	Studen t A	Student B	Student C	Student D	Student E
1	Smart blind	3.5	3.5	3.6	3.5	3.4	X
2	Smart clock	3.4	4	3	4	3	3
3	Smart lock	3.5	4	3	X	X	X
4	Coin sorter	4	4	4	4	4	X
5	Smart pet feeder	3.5	3.5	4	3	X	X
6	Smart bottle	3.5	3.5	3.5	3.5	3.5	X
7	Smart Pet environment	4	4	4	4	X	X
8	Smart Green House	3.53	3.7	3.3	3.6	X	X
9	Invisible fence	3.5	3.5	3.5	3.5	X	X

Conclusions

Peer evaluation and instructor assessment are presented in Tables 3, 4, 5, and 6, using a rating scale of 1 (unsatisfactory) to 4 (exemplary). As shown in Table 3, peers from Teams 1, 3, 4, 5, and 9 received high ratings. However, Teams 7 and 8 rated themselves poorly, while Teams 2 and 6 received average ratings. In addition, the course instructor evaluated the teams' presentations, final reports, and products based on their teamwork contributions.

Peer evaluation is ideally a transparent process where individuals assess their peers' performance and contributions. However, this method has several limitations and shortcomings. The inconsistency between peer and instructor evaluations in this study indicates that personal biases, such as favoritism, resentment, or competition between peers, can influence peer evaluations. Moreover, students may not have the necessary skills, knowledge, or experience to accurately evaluate certain aspects of a task or project. Lack of motivation is also a reason that makes peer evaluation less reliable. These criticisms suggest that while peer evaluations can be useful in some situations, they should not be the sole method of evaluating performance or contributions. It is important to consider the potential limitations and biases of peer evaluations and supplement them with instructor evaluations.

As reported by John Forsell [13], assessing group work is a challenging and complex task for teachers. It is understandable that instructors may have limited time and resources, making it difficult to conduct thorough and effective evaluations of team projects. In addition to preparing lecture materials, grading exams, quizzes, and lab reports, the detailed analysis of teamwork in this study has taken many hours. Given these challenges, it may not be feasible for the course instructor to perform team evaluations for this course. Therefore, there is a need for an automated method to assist teachers in evaluating individual contributions to teamwork.

The use of software for peer assessment can be an efficient and effective method to evaluate team projects, particularly in large classes or online learning environments. Two commonly used tools for evaluating teamwork and team member performance in educational settings are the Team Effectiveness Questionnaire (TEQ) and the Comprehensive Assessment of Team Member Effectiveness (CATME). However, there are several concerns and limitations associated with using these tools. CATME relies on self-reported data from team members, which may not accurately reflect their actual performance. Moreover, self-reported data can be influenced by personal biases or a desire to present oneself positively. CATME also assesses individual contributions but does not account for the complex dynamics that may occur within a team. For example, team members may have different levels of influence or power or may have conflicting personalities or work styles. Additionally, CATME primarily focuses on task-related performance, such as individual contributions and participation, but does not fully capture other critical aspects of teamwork, such as communication, leadership, or conflict resolution. Likewise, this study also did not capture these aspects.

Additionally, there is limited empirical evidence to support the validity and reliability of CATME as a measure of team member performance. Although this work did not include any statistical analysis, it can serve as evidence of prior research [10, 11].

For future research, we recommend investigating the following topics:

- Comparing peer, self, and instructor evaluations, we found some discrepancies between peer and instructor evaluations in assessing teamwork. Future studies could consider collecting and analyzing self-evaluations to provide a more comprehensive evaluation of team performance.
- A well-designed rubric and instrument are necessary to minimize instructor bias when evaluating different aspects of teamwork. Further research could explore effective rubrics that are suitable for different types of projects and disciplines.
- Communication, leadership, and conflict resolution are important aspects of teamwork that can affect team performance. Future studies could investigate effective strategies for conflict resolution and assess their impact on team performance.
- Increasing students' motivation for peer evaluation could enhance the accuracy of peer evaluations. Research could explore effective ways to motivate students, such as providing incentives or emphasizing the importance of peer evaluation.
- Incorporating or developing software for peer review could improve the efficiency and accuracy of data collection. Future studies could explore the feasibility and effectiveness of using different types of software tools for peer evaluation.
- Exploring why some teams, such as team 7 in this study, gave lower teamwork scores to their peers despite their excellent final report and product, could provide insights into the factors that affect peer evaluation. Future studies could investigate the reasons behind these discrepancies and identify ways to address them.

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