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Modalities of Peer Assessments in Team Project Based Design Courses*

PATRICK DUMOND and MOHAMED GALALELDIN
University of Ottawa, Faculty of Engineering, 161 Louis Pasteur, Ottawa, Canada, K1N 6N5.
E-mail: pdumond@uottawa.ca, mgala028@uottawa.ca

Peer assessments can be used in team project based design courses to identify problematic individuals and team dynamic issues early on so that they can be addressed and hopefully resolved before it is too late, as well as provide a basis for calculating individual grades for team project work. Although peer assessments can take on many forms, their goal is to measure individual performance within a team as rated by their peers. In this study, ITP Metrics is used to provide individual scores based on five team performance dimensions. Two different courses using different peer assessment modalities are considered. In the first case, peer assessments are conducted at the mid-point and end of the course, whereas in the second case, peer assessments are conducted after each deliverable. Results show that two peer assessments over the term are not enough to provide sufficient scaffolding to problematic individuals or teams. However, peer assessments conducted in Tuckman's forming or norming stages provide very little additional information. Multiple peer assessments conducted during the storming stage before the mid-point of the term, along with appropriate scaffolding, is shown to be most efficient in improving individual and team performance. In fact, teams that do not receive additional scaffolding are found to have deteriorating team dynamics overall as the term progresses through the second half of the term. Special cases are also considered. Moreover, the correlation between peer assessment results and team grades is shown to increase over the term, demonstrating the importance of understanding peer assessment results throughout the term. Future considerations are required to ensure peer evaluations are best used in modifying individual grades.

Keywords: peer assessment; project based learning; team based projects; engineering design

1. Introduction

1.1 Background

Determining individual student contributions in team project-based learning environments is a challenging task for engineering educators [1]. In many cases, educators cannot be aware of detailed individual contributions if they happen outside of class time [2]. Even during class time, it may be difficult to judge the quality of work produced by individual students in real-time. Two avenues are generally considered for grading students involved in team-based project work: (1) individual grades are the same as the team grade or (2) the team grade is modified by some individual factor to account for variations in individual contributions to the project [3]. In the first case, subjectivity is limited to the grading rubric, but individuals receive the same grade regardless of their contribution to the project. Those who contribute very little to the project get a free pass and those who work very hard may receive a poor mark because members who contribute less may actually hinder the result. In the second case, individual contributions are accounted for, but students tend to complain when their grade is lower than their peers regardless of the type and quality of contributions they provided to the project [4]. Complaints usually stem from perceived subjectivity involved in the determination of the individual factor.

Most often, peer assessments are used to account for individual contributions by relying on feedback provided by an individual's own teammates to understand how the individual's efforts contributed to the overall project [5]. The number of peer assessments used throughout the term has previously been considered as an important factor [6]. Peer assessments are also sometimes supplemented by teaching staff assessments provided based on in-class observations. Team project based peer assessments can come in a wide range of forms [7], from simple numerical Likert scale type evaluations, to complex, question based assessments using state-of-the-art psychological metrics based on dimensions such as communication, commitment, knowledge, skills and abilities, standards, etc. [8, 9].

1.2 Aim

Currently, the literature provides no clear cut "best" approach to assessing individual contributions to team projects and providing individualized grades. This study looks at the effect that the number and timing of peer assessments for evaluating individual contributions in team-based engineering design projects over the course of a term have on peer assessment results. Variations in the number and timing of assessments are considered.

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Relationships between peer evaluations and team grades are also discussed and special cases are considered which look at the effects of timing and type of interventions on team dynamics and subsequent peer evaluations.

2. Methodology

2.1 Team Contract

To help accelerate team development, increase individual accountability towards team performance and tasks and reduce conflict, teams were required to create and individually sign team contracts. Contract guidelines were provided as a template based on [10]. The contract is broken down into three distinct sections that need to be considered:

1. Establishing team procedures.
2. Identifying expectations.
3. Specifying the consequences for failing to follow these procedures and fulfilling these expectations.

In this way, team expectations concerning individual participation and methodology were set early on, and a formal document was available against which individuals could be held accountable if the need were to arise.

2.2 Peer and Staff Assessment

Peer assessments were conducted in second and fourth year engineering design courses (i.e. introduction to product development and mechanical engineering capstone). The purpose of the peer assessments were twofold: (1) to identify problematic individuals and team dynamic issues early on so that they could be addressed and hopefully resolved before it was too late, and (2) provide a basis for calculating individual grades for team project work.

Peer assessments were conducted using a peer assessment and feedback tool developed by Thomas O'Neill of the Individual and Team Performance (ITP) Lab (ITP Metrics: www.itpmetrics.com) at the University of Calgary [11]. The tool is presented as a survey based on Ohland's et al. comprehensive assessment of team member effectiveness (CATME) dimensions [12] and uses a five-point question based Likert scale, as well as comment boxes, to provide personal feedback and an individual performance score out of 5. An individual's team performance is measured based on the following five dimensions:

- Commitment: the student's commitment to the team's work.
- Communication: the student's ability to communicate with team members.
- KSA: the student's knowledge, skills and abilities.
- Focus: the student's ability to keep the team on track.
- Standards: the students emphasis on high standards.

Peer assessment surveys are conducted by each student only for those students who are working with them in their project team. Thus each student evaluates 3–5 of their peers. After all students in a team have completed the peer feedback survey, the tool compiles the results and provides each student with a personalized report outlining their average score in each dimension. Moreover, suggestions on how a student can maintain or improve their future scores are provided in the report as well. This provides valuable feedback and information to students to help them improve in specific dimensions in which they are found to be lacking. These self and peer assessment results also give students greater ownership over the learning they are undertaking [13]. Their average dimension scores are then provided as an overview of their team performance. This performance score can then be used by the teaching staff to quickly identify individual or team dynamic issues. Each student's report, as well as other in depth information is also available on the ITP Metrics website for further review.

Final peer assessments are also supplemented using teaching staff assessments based on in-class interactions. Teaching staff, in this case, includes the course professor, teaching assistants, project managers and any other design advisors who would have interacted with individuals during the course. Scores for the teaching staff assessment are provided out of 5 (5 – very strong, 4 – strong, 3 – fair, 2 – weak, 1 – very weak) and based on the following five dimensions:

- Teamwork.
- Professionalism.
- Communication.
- Organization and Discipline.
- Technical Contribution.

Evidently, teaching staff can only interact with students during class/lab time or during specific meetings with individuals or teams outside of regular hours. Since teaching staff have fewer personalized interactions with each student, the dimensions provided above have been developed specifically to provide an evaluation on dimensions that can be measured by teaching staff through these limited interactions and have been found to be easier to evaluate than those described by ITP Metrics. If multiple staff members provide scores for a given individual, their scores are averaged. Moreover,

since these courses are project-based and involve many hours spent working on team projects in the lab, each student/team becomes well known by at least one teaching staff member over the term.

2.3 Course Descriptions

Introduction to product development is a second year general engineering course that teaches the engineering design process along with many other aspects of the product development process (e.g., economics, sales and marketing, intellectual property, ethics, etc.). In this course, teams of 3–5 students must develop a product based on a real customer need and create a prototype. Teams must submit 10 deliverables, half of which are submitted before the course mid-point and half after. Peer assessments are only conducted at the mid-point and at the end.

Mechanical engineering capstone is a fourth year mechanical engineering course that serves as the culminating and integrative engineering design experience. In this course, teams of 4–5 students (study exception: one group of 6 students and one group that finished the course with only 2 students) must produce a final engineering design for an extensive mechanical project. Teams must submit 6 deliverables over the term, which include:

1. A literature review report.
2. A concepts report.
3. A modelling report.
4. Design and analysis dossiers (ungraded).
5. An analysis report.
6. A final capstone design report and presentation.

Again, half of the deliverables are submitted before the course mid-point and half after. However, in this case peer assessments are conducted after the submission of each deliverable.

2.4 Individualized Project Grades

In all cases, individual student project grades were calculated using the team project grade and modified using a personal assessment factor based on the results obtained from peer assessments (ITP Metrics score out of 5) and teaching staff assessments (score out of 5). Specifically, individual grades were calculated using the following scheme:

$$\text{Individual Grade} = \text{Team Grade} \times \text{Assessment Factor}$$

$$\text{Assessment Factor} = \text{average}\ (0.6 \leq \text{assessment of course staff/team average} \leq 1.05,\ 0.6 \leq \text{peer assessment/team average} \leq 1.05)$$

Peer and staff assessments are normalized by dividing by the group average to account for variations in assessors' severity (i.e. if an individual is assessed a score of 4.2/5 and the team average score is 4.8/5, then the individual normalized score is 4.2/4.8 = 0.875). This has the added benefit of not only reducing individual grades for those who do not contribute equally to the project, but can also increase project grades for those who carried extra project weight. Upper and lower limits on the assessment factor are based on personal assessment philosophy, where a lack of team contribution should affect individual grades more severely than a higher contribution. In this case, an individual's project score can be increased by a maximum of 5% if they are teamed with a student or students who contribute poorly to the project and hinder the team's performance. Alternatively, students who contribute poorly to a project, can have their project score reduced by a maximum of 60%. This scheme assumes that students who barely contribute to the team project would have been addressed before the end of term so that those who do not deserve a passing grade for the project are no longer counted as part of the team. Moreover, this scheme assumes that unless the previous case comes up before the end of the term, all students deserve a minimum 60% of the final project grade because of the team nature of the project, regardless of what their peers think.

2.5 Peer Assessment Modalities

Peer assessments were conducted either twice during the term (just before the mid-point and at the very end) or after each project deliverable (six times spread throughout the term with one at the very end, after all team deliverables had been completed). In all cases, peer assessments were mandatory, but only the final assessments were used to calculate individual grades. Intermediate assessments were scrutinized and problematic individuals and teams were brought in for a meeting to discuss performance.

Intermediate assessments were enforced via two methods. For the second-year course, an assignment worth a small percentage of the final grade was given, where students were required to reflect on their peer evaluations by providing answers to reflection questions given in the individualized ITP Metrics report. The reflections involved identifying specific, actionable, and measurable development goals on which the student could work to help improve or maintain their score on each of the five teamwork competency dimensions listed in section 2.2. For the fourth-year course, no reflections were required, but project grades for each deliverable were withheld until individual students had completed peer assessments for that deliverable. A grade of zero was attributed to a student for a given deliverable if they did not complete a peer assess-

ment immediately following the submission of the deliverable.

All intermediate assessments were reviewed by members of the teaching staff and problematic cases were addressed either individually and/or as a team depending on the situation. Meetings were held with individuals and/or teams and actionable plans were formulated to help provide additional scaffolding to these students so that their situation could improve. In some cases, teams simply required staff to check in more often, or act as a mediator in facilitating communication between team members. In more extreme cases, teams were forced to create a new team contract (and consider each point diligently) in the presence of a staff member. Strategies, such as communication, scheduling, or record-keeping tools, reasonable project quality expectations, prioritization methods, etc., were suggested by staff and recommended for inclusion in the contract.

3. Results and Discussion

3.1 Peer Assessment Results

Peer assessment data was collected in both second year and fourth year design courses. In the former case, peer assessments were conducted at the mid-term, just before students departed for their reading week, and again after all course deliverables had been submitted. In the latter case, peer assessments were conducted after every deliverable for a total of six times over the course of the term. Minimum, maximum and average scores, as well as standard deviations are provided in Table 1 for every peer assessment in both courses. Global student peer assessment scores for the second year and fourth year courses are provided in Fig. 1 and 2 respectively.

As can be seen in Fig. 1, the intermediate and final peer assessment results for the second year course provide very little indication related to team dynamics and individual performance improvement, as both the intermediate and final results cross each other haphazardly. Although, final results appear to contain more extreme negative peaks which are likely an indication of teams having had enough of lackluster participation of specific individual students. Results for the fourth-year course (Fig. 2) show similar results, whereas the last three dossier/report assessments (dossier, analysis and capstone), which occur after the mid-point of the course, show stronger negative peaks for individual student evaluations.

As early as possible in each course, problematic individuals or teams were identified using the peer assessment tool. Once identified, individuals and teams were provided additional scaffolding to aid in their success. It is important to note that individual and team identification in the second year

Table 1. Peer assessment results

	Second year course assessments		**Fourth year course assessments**					
	Intermediate	**Final**	**Literature**	**Concepts**	**Modelling**	**Dossier**	**Analysis**	**Capstone**
Min score	3.67	2.37	3.80	2.27	1.40	0.60	2.67	3.13
Max score	5	5	5	5	5	5	5	5
Average score	4.46	4.54	4.81	4.69	4.76	4.66	4.71	4.67
σ	0.416	0.552	0.270	0.467	0.484	0.616	0.424	0.442

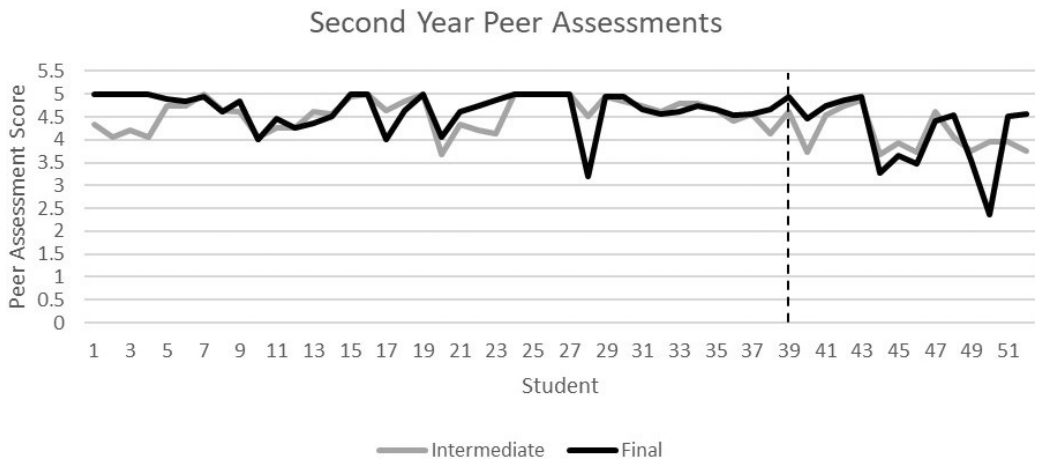

Fig. 1. Intermediate and final peer assessments for all students in the second year design course.

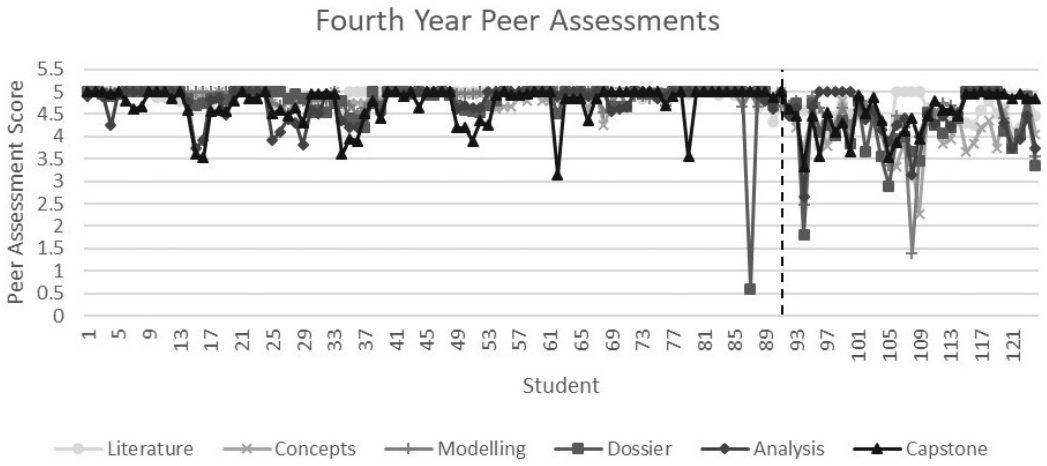

Fig. 2. Literature review report, concepts report, modelling report, design and analysis dossier, analysis report and capstone report peer assessments for all students in the fourth year design course.

course could not occur until the first peer assessment was completed at the course mid-point. Conversely, some individuals and teams were identified as early as the third week of class, following the literature review report, in the fourth year course. Dividing the results amongst teams that were provided additional scaffolding and those who were not, provides much more interesting results.

For the second year course, this can be observed by comparing those students to the right of the vertical dashed line of Fig. 1 and who were provided additional scaffolding (students 40–52), to those on the left side of the vertical dashed line who were not provided additional scaffolding (students 1–39). When comparing these two groups of students, not much can be extrapolated, peer results seem to increase or decrease from intermediate to final assessments haphazardly. This can be confirmed by Fig. 3, where the percentage of students in ranges of differences between final and intermediate peer assessment scores are shown.

Results for the fourth year course present a significantly different and more interesting story, as seen in Fig. 4, where the mid-term assessment (modelling report assessment) and final assessment (capstone report) are used as a direct comparison. In this case, students that were provided additional scaffolding (students 92–124 on the right side of the dashed line) early on appear to have similar or better peer evaluations for the final assessment in most cases, whereas those who did not receive additional scaffolding (students 1-91 on the left hand side of the dashed line) appear to receive overall much worse peer evaluations for the final assessment.

This can be confirmed by Fig. 5, where the percentage of students in ranges of differences

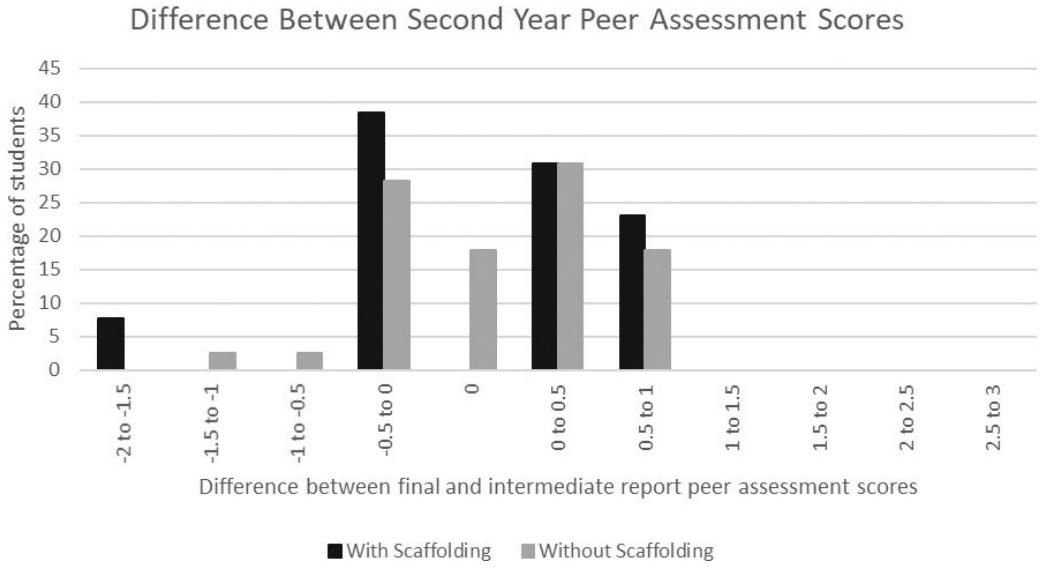

Fig. 3. Difference between second year final and intermediate peer assessment scores.

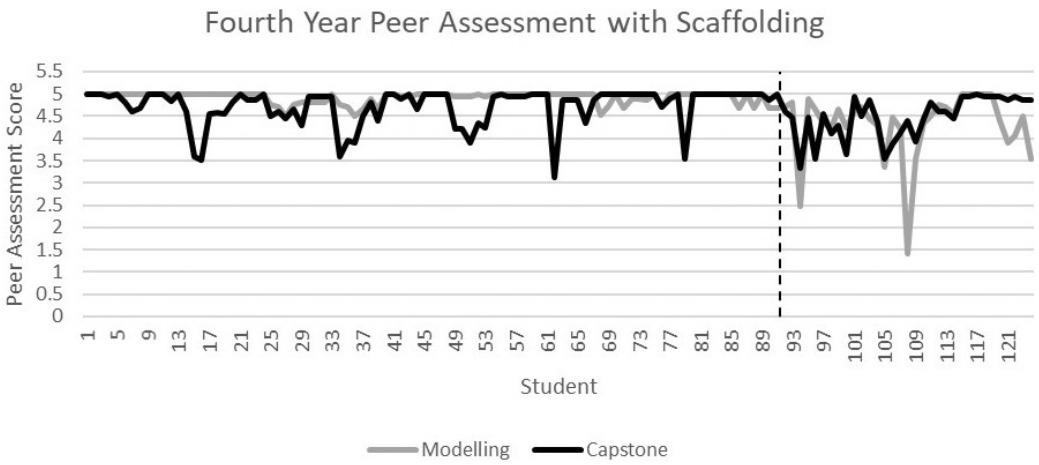

Fig. 4. Intermediate and final peer assessment results for all students in the fourth year design course.

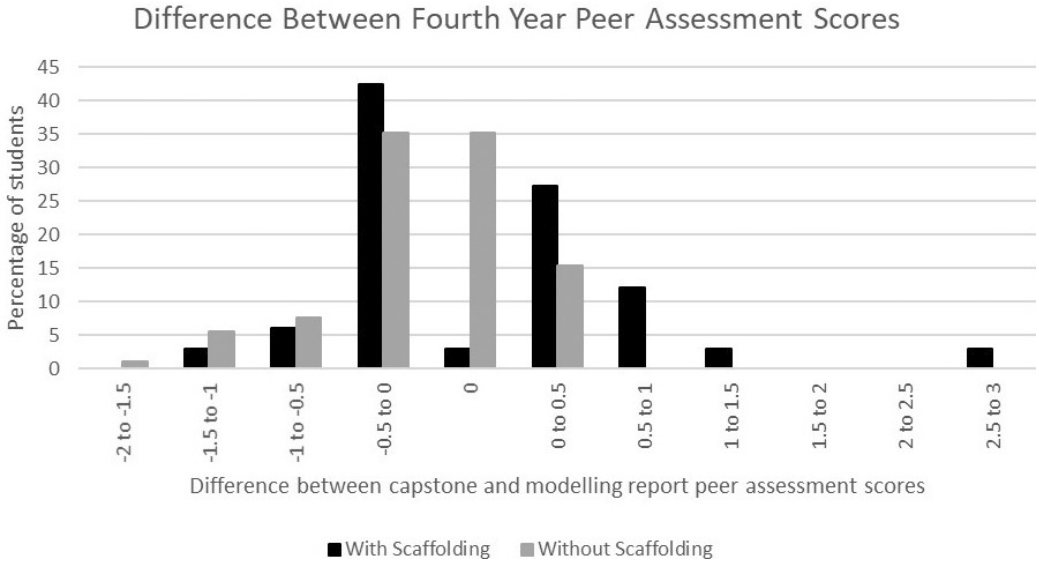

Fig. 5. Difference between fourth year final (capstone report) and intermediate (modelling report) peer assessment scores.

between capstone (final) and modelling (intermediate) report peer assessment scores are shown. In this case, 45% of students who received scaffolding improved their peer assessment scores, whereas only 15% of students who did not receive scaffolding managed to do the same. In fact, if the final capstone assessment is individually plotted against all other assessments, these inverse trends are increased as you move away from the final assessment (i.e. when the literature assessment is compared to the capstone) and reduced as you move closer (i.e. when the analysis assessment is compared to the capstone). A small discrepancy is demonstrated in these trends when you plot the dossier assessment against the capstone for those students who did not receive additional scaffolding. In this case, resulting scores are similar. This is likely due to the fact that the design and analysis dossiers are ungraded and students who are prone to being problematic feel less motivated to perform.

Positive results for those students who received additional scaffolding in the fourth year course can likely be attributed to the fact that these students were identified and received this scaffolding much earlier than their second year counterparts. Moreover, this scaffolding occurred before the norming stage in Tuckman's team development model [14], which allowed scaffolding to have an effect on individuals and their team before team processes were finalized. This is made evident on the right side of the vertical dashed line of Fig. 2 (students 92–124), where students did receive additional scaffolding. In this case, earlier assessments (concepts, modelling and dossier) demonstrate larger negative assessment score peaks, whereas later assessments (analysis and capstone) demonstrate smoother and

better scores overall. Interestingly, the first assessment (literature review report) provides the smoothest results overall. This can be attributed to the fact that students are still within Tuckman's forming stage at this point in the term and do not yet have enough knowledge to provide adequate or useful peer evaluations.

On the other hand, those students who did not receive additional scaffolding early on fared worse over time, as seen on the left of the dashed line (students 1–91) in Fig. 2. In this case, early assessments demonstrate much smoother scores, whereas later assessment scores (especially analysis and capstone) demonstrate a significantly higher number of negative peaks. Moreover, early assessments demonstrate very little variation, implying that later negative scores come as a surprise to some students.

Results given in Fig. 2 also demonstrate that teams who are provided additional scaffolding during Tuckman's storming stage, likely enter the norming stage with positive and inclusive processes, whereas those teams which are not provided additional scaffolding during the storming stage develop negative and exclusive processes which prevent or hinder students from fully participating in project tasks at hand.

To determine the Tuckman stage of each team throughout the term, each team was questioned during meetings with teaching staff that occurred after the submission of each report. Questions related to the understanding and clarity of individual roles and relationships, purpose, processes and their level of trust, attitude and commitment towards team goals. For example, if individuals understood the purpose of the work, but were not clear on their role in the team or the decision-making process, they were determined to be in the storming stage. Conversely, if individuals had a good understanding of team goals and their relationship to their teammates, while explaining how they intended to develop their project, they were considered to have reached the norming stage.

3.2 Team Performance

When comparing peer assessment progression in the fourth year course to team performance measured via team deliverable grades a correlation is observed. This progression in the correlation between average team peer assessment scores and team grades can be observed by comparing differences between literature review report assessment and capstone report assessment scores and their associated grades in Fig. 6.

As can be seen in Fig. 6, 67% of students demonstrate a difference of 1 or more between their literature peer assessment score and their literature report grade, whereas 89% of students have a maximum difference of 1.5 between their literature peer assessment score and their literature report grade. This correlation has previously been reported [2] and progressively surfaces throughout the term and could be seen when each report's assessment scores were compared to their associated grades. This indicates that as students become more familiar with the peer assessment process and each other, team dynamics (and associated average team assessment scores) become a good measure of team performance.

3.3 Special Cases

In one particularly unique case, an academically

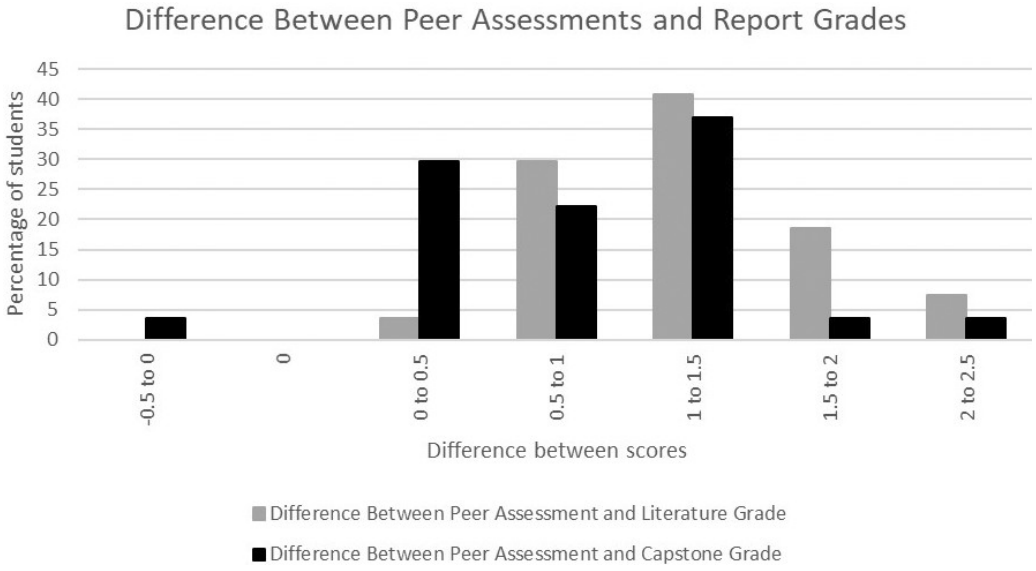

Fig. 6. Comparison of the differences between peer assessments and reports grades.

strong team imploded catastrophically at the end of the term without having shown signs of team dynamic issues in earlier peer assessments. In fact, when confronted, the team indicated that they conspired as a team to give each other perfect peer assessment scores to prevent themselves from creating team conflict. In reality, many team members ended up internalizing issues early on that ended up coming to a head at the end of the term when the course workload and individual stress levels were at their highest. Their attempt to prevent conflict by falsifying their peer assessment scores ended up causing conflict and resulted in severe team deterioration in the final weeks of the course. Thus, the peer assessments had the exact opposite effect than what was intended.

In another particular case, a team was identified as having issues very early on related to team expectations and procedures. When confronted, the team indicated that they had not taken the team contract seriously and had provided only generic answers. In this case, a new contract was drafted with the aid of a teaching staff and each point was considered carefully. Based on this new contract, team dynamics issues were progressively rectified, with the help of some additional scaffolding from the teaching staff, and the team went on to perform well.

3.4 Observations

Based on the results of the study, two peer assessments over the course of the term do not appear to be enough to provide adequate information regarding team dynamics and individual participation. However, peer assessments which occur before team storming provide very little additional information. Moreover, multiple peer assessments after the mid-point of the term also seem to provide little additional information since teams have already moved on to the norming stage. However, how teams enter the norming stage is highly dependent on whether adequate scaffolding is provided in the storming stage. Thus 2 or 3 peer assessments which occur during the team storming stage before the mid-point of the term are recommended. Only one additional final assessment is required to determine the final individual participation. Additionally, anecdotal evidence seems to indicate that too many peer assessments (using an extensive tool such as ITP Metrics) leads to peer assessment fatigue, which may affect peer assessment results that occur in the later part of the term.

It has also been observed that some students received poor final peer evaluation scores because their team participation tapers off near the end of the term, even though they were active members of their team otherwise. In these cases, significant differences are seen between final peer evaluations and other assessments throughout the term. Future considerations should be given to how peer evaluations throughout the term could be used (and possibly weighted) to account for this phenomenon.

It remains clear that even complex peer assessment tools contain a certain degree of subjectivity that may be influenced by stress levels, emotions and individual relationships throughout the term. Teaching staff should be aware of tool limitations, remain cautious in using them and should follow up on any assessments that seem out of the ordinary or extreme. In doing so, problematic individuals and teams can be identified early on, an important first step in providing them with the additional scaffolding they need to achieve success.

4. Conclusions

Data has shown that peer assessment scores can vary widely over the term, even within the same team. However, a correlation exists between peer assessment scores and team performance on project deliverables and this correlation has been shown to get stronger as the term progresses. The number and timing of assessments play a key role in their efficacy. Two assessments over the term do not provide enough details about the evolution of individuals or the team over the term. Moreover, if the first peer assessment is conducted before teams have had the chance to storm, then little, if any, information is provided by the assessment. Conversely, with peer assessments conducted after every deliverable, a phenomenon that can be described as peer assessment fatigue is observed. In this case, the quality of student responses may be reduced by the end of the term. However, early detection of problematic individuals and team dynamic issues is crucial in ensuring teams can successfully complete their project. In fact, early scaffolding of problematic individuals and teams has been shown to improve team dynamics drastically. Moreover, early detection and scaffolding can help improve final peer assessment scores. However, teams who were not provided additional scaffolding were found to deteriorate in overall peer assessment scores by the end of the term. Due to the latter case, the method used for providing individualized project grades based on peer evaluation scores should be considered carefully.

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Patrick Dumond, PhD is an assistant professor in Mechanical Engineering at the University of Ottawa, where he teaches engineering design courses and conducts research in mechanical vibrations. He has particular interest in developing experiential learning opportunities in engineering so that students can apply their knowledge and gain practical experience.

Mohamed Galaleldin is a PhD candidate in Engineering Education at the University of Ottawa. His research is focused on integrating maker curriculum in engineering design education.