Joint Progress Update Meetings in Capstone Design Courses: Encouraging Peer Review and Cooperative Learning

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Peer review and assessment have become increasingly popular in engineering design education, mostly to evaluate individuals' contribution to a team project. In some cases, peer review is also encouraged between design project individuals/teams to foster learning and cooperation, similar to the traditional 'studio' method in architecture. Borrowing from the architecture studio paradigm, and with the goal of increasing between-team interactions, a pilot implementation of joint progress update meetings was launched in a management engineering capstone design course. Project teams were paired based on topic similarity. In biweekly progress update meetings, teams took turns presenting to and critiquing each other's presentation and design progress. The format was well-received by students and was successful in increasing the diversity and wealth of knowledge teams could draw from during the meetings. An increase in the number of ideas generated in the initial design phase was also noted. Finally, the new format strongly encouraged inter-team interactions, collaboration, and competition. Although some questions remain with respect to what an ideal implementation would look like, the format will be reused and refined in future course offerings.

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Introduction

Peer review and assessment have gained considerable traction in post-secondary education and become a common teaching methodology in engineering and engineering design education. The method has been used in varying contexts and forms, but broadly speaking it has three main uses: peer evaluation of assignments (usually against a given solution)[1], peer evaluation of a student's contribution to a group project in order to improve assessment 'fairness'[2], and peer review/evaluation of another student's or group's work (specifically when working on different projects and where no given solution exists). The following discussion concerns the latter use.

In the context of engineering design capstone courses peer assessment is commonly used to assess individuals' contribution to the group. However, students in capstone courses can also greatly benefit from between-group peer review, a far less common practice. In this paper I report on a pilot implementation of between-group peer review in progress update meetings of a capstone design course.

Background

The engineering education literature strongly supports the use of peer review and assessment. It has been linked to many positive outcomes such as improving feedback received by students, improving the quality of work submitted, fostering learning autonomy and depth, and supporting the development of 'soft' skills such as giving and receiving criticism[3]. In addition, it has been shown to increase collaborative learning and student engagement[4].

In architecture, the practice of allowing students - in addition to instructors - to critique design (i.e., peer review) has been a long standing practice. The 'studio' is a very common teaching methodology where students (whether individually or in groups) benefit from interactive sessions in which they receive feedback from the instructor, their peers, and sometimes professional architects. This approach perpetuates a 'culture of critique', where feedback is frequent in both formal and informal settings throughout the design process[5]. For example, in the 'studio desk crit', two or more students meet with the course instructor who then reviews the design progress of each student. The students benefit from the interactive sessions and learn from the reviews of the instructor as well as from the comments of peers[6].

The architecture studio strongly resembles engineering design project reviews. For example, a diverse audience of peers, professors, industry, and the larger community are invited to critique capstone designs at final design symposia, common at many universities. Interestingly, within the engineering

context, the peer review paradigm has mostly been applied in software or information systems design courses. Some examples from the literature include the use of peer review to facilitate and better the software inspection process[7]; the implementation of 'studio laboratories' that allowed students to get to see how other students were addressing design problems[8]; and inter-group evaluation activities that required design project teams to summarize their observations and recommendations on another team's presentation in a formal memo[9].

Between-group peer review activities can be well-suited to progress review meetings, which are a common component of capstone courses. Traditionally, progress review (or progress update) meetings have been used to (1) facilitate better project management (i.e., to drive steady project progress and to ensure sufficient participation by all team members)[10], and (2) to communicate progress to the instructor and, in some cases, to the whole class. An additional (third) use could impact the technical core of the design: progress update meetings could be a tool through which technical aspects of the design are directly addressed and improved. Here I further explore the idea of using peer evaluation/review and the architecture studio model as helpful paradigms for structuring progress update meeting such that all three identified uses are accomplished.

Implementation

Below, I describe a pilot implementation of two-group (joint) progress update meetings in a capstone design course and discuss its effectiveness, shortcomings, and directions for future implementation.

General overview of the program

The Management Engineering program at the University of Waterloo is a co-operative engineering program accredited by the Canadian Engineering Accreditation Board (CEAB). The program is in many ways similar to other modern industrial engineering programs, encompassing the themes of information systems and applied operations research, and, to a lesser degree, management of technology. Students take a breadth of core courses in all three themes. Many specialize in their theme of choice through a combination of selected technical electives and five to six four-month cooperative terms in industry.

The senior capstone engineering design project is composed of two mandatory courses taken in the students' final year. Students are scheduled to go on their final (sixth) co-op term between the two capstone courses. Two cohorts of 38 and 44 students have so far completed the final year capstone design program. As of the time of submission of this document, a third cohort of 46 students has completed the first course. Teams of 3 to 4 students work on open-ended design projects under the guidance of a faculty advisor. The program as a whole is coordinated by two course instructors who are responsible for soliciting industry projects, lecturing, and evaluating the students.

In the first course of the series, students define their design problem, complete a needs analysis, and engage in a conceptual and preliminary design process that culminates in a low-fidelity prototype. Throughout the first course, they also participate in lectures covering relevant topics such as engineering design, engineering impact on society and the environment, project management, and conceptual design. In the second course, students proceed with the detailed design phase, progressing to a medium and a high-fidelity prototype, and to design verification. The completed designs are showcased and reviewed at a public symposium in conjunction with other disciplines in the university's faculty of engineering.

In about 70% of all cases projects are sourced from industry, while the rest are initiated by professors or students themselves. Examples of typical project topics include assignment and scheduling of resources and facilities in local hospitals, design and optimization of manufacturing and retail facilities, design of new distribution and inventory management systems for multinational companies, and various smart phone and web applications to help with project management, expense management, e-learning, and e-commerce.

Most projects incorporate both of the program's main themes; hence it is not uncommon for groups to have a balanced representation of members specialized in applied operations research and information systems.

Progress Update Meetings

Throughout both courses groups attend semi-formal 30 – 40 minute progress update meetings (PUMs) where they present their progress and receive feedback. In the first two offerings of this capstone program, the PUMs were only attended by one group at a time. Each group presented to and obtained feedback from the course instructors and sometimes their faculty advisor. Groups were thus fairly isolated in their design experience, only seeing the work of other groups at major review meetings (4 in total throughout the entire capstone program). Poor knowledge of other groups' design projects, progress, and challenges was a common student complaint.

In the third iteration of the program we sought to address this issue by pairing groups in joint PUMs. In the new format, which was piloted in spring 2013, each team presented their progress not only to one of the course instructors but also to another team, seeking feedback and suggestions from everyone in attendance.

Each joint PUM was 1 hour in length, allowing for a 15-minute presentation by each team and for sufficient discussion time during and after the presentations. Each group participated in 4 PUMs throughout the term. Most of the twelve groups were paired with two other groups, meeting with each in alternating PUMs. Pairings were based on the project topic and specialization; for example, a group working on an expense-sharing application was paired with a group working on a grocery cart optimization application in PUM 1 and PUM 3, and with a group working on a long-term illness symptoms' tracking application in PUM 2 and PUM 4. Four of the groups did not alternate pairs; instead, they formed two pairs throughout all four PUMs. These 'stable' pairs were created as a result of the more unique topics pursued by these groups. At the same time, this configuration helped us assess whether alternating pairings were more successful than stable ones.

The meetings were kept informal and the environment supportive. At the end of each meeting, teams summarized their feedback in 2-page memos, not unlike the experience in at least one other capstone program[9]. Teams did not formally evaluate their peers; rather the feedback provided by each team was used to inform the instructors' evaluation of the assessed team. Each team was also evaluated on the quality of their feedback, with the main criteria being its thoroughness and usefulness.

Evaluation

Overall, the joint PUMs were very well received and they were recognized by the course instructors and the students as highly effective.

When midterm course critiques were conducted, over 70% of the students identified the PUMs as a specific component of the course that they found helpful as they progressed in their designs. Some of the comments were:

"*PUMs are good. Interesting to get fresh set of eyes and ears in on the presentations. Valuable feedback.*"

"*PUMs are very helpful. Discussions with profs/class/other groups provide a lot of additional input that help verify project decisions, etc.*"

"*Peer review in [PUMs] is GREAT*"

"*Like the PUMs – very informative and gives an opportunity to 'expand your team' in a way, to give more heads thinking about the project*"

"*Progress update meetings continue to be essential."*

"*PUMs are very helpful; [they pool] a variety of information and thoughts that help make the design project*"

The format had several advantages. As previously mentioned, the multidisciplinary nature of the Management Engineering program is reflected in a great diversity of multidisciplinary capstone projects, which in turn require a wealth of expertise in differing fields such as software engineering, data analytics, supply chain and operations management, and mathematical optimization. By their fourth year, through their technical electives and co-operative work experiences in industry, students have already begun to concentrate in one of the program's major specializations and sub-specializations. Having two teams present at each progress update meeting increased the probability that students with varying interests, skills, and experiences would be present to critique each project.

Another good outcome was the increased number of ideas generated at the meetings, especially in the first phase, when groups were in their initial stages of scoping their design projects and wrestling with different design concepts. The joint meetings created an economies-of-scale effect: at least during the duration of each meeting, the number of students working on each project virtually doubled. In addition, students found that they were facing similar challenges, or had faced similar challenges in the past. The shared problems resulted in sharing of solutions, thus increasing inter-group collaboration and overall problem-solving effectiveness. Additional advice and ideas would often be provided in the feedback memos – evidence that each group continued to think about their paired group's challenges even after the meetings.

Knowledge about other groups' progress, even if they were working on a different project topic (as was always the case) helped teams gauge whether their own progress was adequate. In this context, joint progress update meetings became a catalyst for inter-team interactions that increased not only learning and cooperation, but also competition.

Despite its success, this pilot implementation was not without a few problems. Though students seemed to overall respond positively to the two-team format of the PUMs, they were less receptive to the requirement of writing formal feedback memos. Many saw this as significantly increasing their workload with little direct benefit to them or to the teams for which the memo was written.

The meetings' informal format, the sometimes significant difference in quality between paired projects, the considerable effort that teams put in working on the projects, and (as a result) the considerable attachment of teams to their project topic, all contributed to sometimes poor reception to any criticisms or negative feedback. This was a minor issue - most meetings were cordial and supportive; yet, proper handling of criticism was not seen at all times. The joint PUMs reinforced the importance of knowing how to provide and receive criticism (often categorized under CEAB's graduate attribute of 'professionalism'[11]) and provided a

recurring opportunity for students to practice it and for the instructors to evaluate it.

The pilot joint-meeting format proved successful and thus, worth reusing and refining in the coming reiterations of capstone courses. As such, some questions are posed with regards to future implementations:

- How should the teams be paired? Pairings were initially based on the similarity of topic, but it is possible that groups may have something to gain from participating in a peer-review process with dissimilar teams/topics.
- Should the pairings alternate or remain unchanged throughout the term? Anecdotal evidence seems to suggest that students preferred being matched in stable pairs throughout the term. This allowed them to become comfortable and well-familiarized with the other group's project. At the same time, limiting the pairing to just one reduces the benefits that come from having a project peer-reviewed by a larger number of students.
- How should the meetings be formatted? The semi-structured format proved to be easily manageable, but the limited timeframe (sometimes less than 15 minutes per project) at times stifled productive discussion between teams.
- What should the role of the course instructors be? The new format drastically changed the role of course instructor in charge of the meetings from the sole reviewer to a mediator and coach of student discussion. One may wonder if in this new role, the authority of the course instructors to override unhelpful or misleading critiques from students is compromised.
- Are formal feedback memos necessary? As previously mentioned, the feedback memos were not perceived as adding significant value to the peer review process, but instead, were classified as 'non-design' course overhead work. It is worth considering changing this requirement to better suit course learning outcomes.

Summary and Conclusion

A pilot implementation of between-group peer review in joint progress update meetings was described. The fundamental assumption driving the introduction of such practice was that students learn not only from the feedback that they receive from the instructors, but also from the feedback and suggestions that they receive from their peers. The primary goal of this new format was not to aid the course instructors in the evaluation of each group's performance, but rather, to help improve the overall quality of projects by increasing learning and co-operation between groups. Although some questions remain about what an ideal implementation would look like, overall, the new format greatly improved the effectiveness of progress update meetings in driving design project progress, increasing collaborative learning, and introducing a healthy dose of between-group competition.

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