A case study in the use of teaming to improve engineering education in large classes

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The average class size of a typical engineering course can be several hundred students. In particular, many service courses at Stellenbosch University have more than 800 students enrolled. Classes of this size present a number of challenges to effective teaching and learning including a sense of anonymity among the students, difficulty in gathering feedback, poor class attendance, and an increased spectrum of competency levels to cater to (among other challenges). This work is a case study in the use of teaming to combat these challenges and improve knowledge acquisition in large engineering classes. The methodology herein is an adaptation of scrum project management, a popular framework used primarily in the software development industry. We present the results of using this new curriculum focused on teaming for the course, Theory of Structures, which consisted of 150 third-year students. The primary contribution of this work is a set of best practices that can be followed and improved upon to emulate teaming in other courses.

Introduction

Although larger classes lead to more revenue, it can be debated whether the negative impact on the student experience is worth the increase in funding. There are a number of obvious drawbacks to large class sizes including: passive spectating, increased absences, poor performance, less intellectual development and anonymity (Cuseo, 2007; MacGregor et al., 2000).

This paper presents a novel adaptation of a new management philosophy to combat the negative side effects of large engineering class sizes. Using elements of the scrum methodology (also referred to as agile or lean) we devise a structure for presenting engineering courses that greatly increases the student's level of engagement and creates small *communities of learning* that foster interactive discussion, instil a sense of belonging, and provide support for wide range of student abilities.

The use of scrum has revolutionized a number of industries. As opposed to traditional project management, agile gets its name from being flexible with regard to accomplishing goals. Rather than structure a group's efforts towards rigid goals that may change throughout a project's life cycle, agile introduces a process through which a team can adapt to changing requirements. Developed mainly by the software industry, this process emphasizes constant redirection as the needs of the project evolve. For a comprehensive introduction to scrum (or agile) see (Schwaber & Sutherland, 2011).

The concept of using teamwork in large engineering classes is not a new one. Michaelsen and Sweet (2008) and Pole and Bear (2012) have done extensive studies on the outcomes of team-based learning (TBL) including some discussion of the essential pieces of any team-based approach. The focus of this work is on a new methodology developed as an adaptation of *agile* for large engineering classes. The distinguishing characteristic of this approach is the origins of its structure and philosophy in scrum project management practices (daily stand-up meetings, frequent review, retrospective and planning meetings, and flexible goal setting). The main contribution of this work to existing methodologies for scrum in the classroom (for example, Pope-Ruark et al., 2011) is an exploration of its deployment in a large engineering class (more than 150 students).

As this is the first work in an on-going series, not much data is available to judge the efficacy of this approach. It is intended that in future works more illustrative data will be provided. The central focus of this work will be the development of informed assertions related to the implementation of scrum in the classroom context for large engineering classes. The results presented were gathered from a prototype offering of the Structural Engineering course Theory of Structures 324. This third-year course is composed of a mix of continuum mechanics and computational methods and it provides a basis for in-depth structural analysis. The case or unit of analysis (Baxter & Jack, 2008) is the phenomena of poor student experience in the bounded context of a large engineering class. While this work may be considered a case study (as it investigates the use of scrum as a means of limiting the negative aspects of large class sizes), emphasis will be placed more on the qualitative outcomes of this research. The design of the case study follows the Problem-Oriented Method (as defined in Monash University, 2013) for which the problem is defined as low levels of engagement in large engineering classes and the solution investigated is the use of teaming.

Teaming vs. Group Projects

The first question that often gets raised when discussing the attributes of teaming is "how is teaming different than group work on a project?" To get at the central difference between group work and teamwork one must understand the nature of teams vs. groups. These differences are highlighted in Table 1. The most important aspect of teaming that is often under-emphasized in group projects is the team's sense of identity or the level of buy-in. Typically when group projects are assigned very little attention is given to the requisite dynamics of a successful team. Although members of a group project usually have a clear understanding of a common goal, lack of commitment can lead to detrimental outcomes.

Table 1. Attributes of groups compared to teams.

Group	Team
Little sense of identity	Strong sense of identity
Coordination between members not required	Increased cooperation
Can be a random collection	Common understanding of central objectives
Size is arbitrary	Effectiveness is closely related to size
Low level of loyalty or buy-in	Greater sense of responsibility
Unstructured supervision	Typically coached or mentored

The scrum process naturally builds into its structure foundational elements of successful group dynamics. As covered in the implementation plan, the scrum process involves regularly scheduled, short duration, stand-up meetings. These meetings are called stand-up meetings because everyone must stand during the meeting. Since most people do not feel comfortable standing for a long duration, meeting times are kept short, less than 10 or 15 minutes, and only essential information is discussed. Communication at frequent intervals leads to opportunities to address issues that detract from the team's sense of mutual commitment. On less frequent intervals, review, retrospective, and planning (RRP) meetings are held. During the retrospective section group members are able to freely discuss any obstacles to the successful performance of the team. Whether or not the scrum process is used to facilitate teaming in large class sizes, the important thing to recognize is the value in providing time in class for the teams to communicate with each other specifically on how the team is functioning and to provide a means for addressing issues that arise.

Table 2. Positive outcomes of teaming.

Greater sense of belonging and engagement
Hierarchical structure which is useful for managing administrative aspects of a course
Creation of "learning community" environment
Less need for individual tutoring
Opportunities for articulation of ideas and concepts
Frequent peer evaluation of knowledge acquisition

Table 2 provides a summary of the positive outcomes from teaming. Another essential ingredient to the teaming process, that is not present in the group work context, is the notion of the students as collaborators with the instructor towards the goals of the course. This paradigm shift towards working together to understand concepts fosters a greater sense of responsibility and participation on the student's part as they have a large role to play in how the knowledge transfer is executed. For large engineering classes this element is important as it greatly reduces passivity.

Implementation Plan and Structure

In general, teaming was incorporated in the following ways: assignment of each student to a team of roughly eight students, time allotted each week for feedback and planning among the group, weekly testing of the material as a way to gauge team performance, and in-class exercises geared toward team-based solutions.

The most central component of the scrum process that was incorporated in this case study was a simplified version of RRP meetings. These meetings were held on a weekly basis at the start of the tutorial period. During this time, students were asked to discuss within their respective teams "what went well?", "what went poorly?", and "how can we improve?" These comments were logged on a feedback website for the instructor to monitor the team's progress.

The breakdown of the final mark is given in Table 3. Weekly tests were used as a metric, in that the team's goal for each section of the course was to have each team member pass each of the weekly tests. For each test, one of the team's performance points was given only if every member of the team passed. The team participation marks were given based on a buddy rating within the teams. A subminimum of 40% on the final exam was used to prohibit students form passing without performing well on the final exam.

Table 3. Breakdown of assessment.

Category	**Percentage of final mark**
Weekly tests	45
Team performance on tests	11
Team participation	4
Final exam	40

Teams were organized by sorting the class list alphabetically by middle initial, then grouping names in sets of seven or eight. This resulted in a rather diverse cross-section of individuals from various cultural backgrounds, genders, and ability levels. This had the advantage of preventing factions, exposing students to diverse communication styles, and achieving variation in the levels of ability.

Teaming was used to study for the weekly tests, in lectures through time allotted for group work on example problems, and in the tutorial sessions to discuss misunderstood concepts as evidenced by the test results. Many of the examples done in the lectures were posed as a

competition between the teams. One example of how this was used includes an alternative approach to going step by step through a long derivation. Without the students knowing the goal of working through a long derivation, all of the important steps where distributed to each team as an identity that they could work together as a team to prove. The team that proved the most received a reward (bonus marks, etc.). Once all the important steps had been proven, as a class we pieced them together to show the overall derivation. This enabled more emphasis on the important points of the derivation rather than the details that they had already worked out as a team.

Study Methodology

To gauge the effectiveness of the proposed implementation plan the outcomes for the prototype offering of the course were tracked through the following methods:

- An anonymous feedback website for which students were able to post comments.
- Informal meetings with each of the group's facilitators.
- A typical course evaluation procedure at the end of the course.

Comments posted on the feedback site were made publically visible so that students could see what their peers were saying about the course. At regular intervals, the student facilitators from each group would meet with the instructor to discuss the group's performance and any issues related to group interaction. Also, the standard course evaluation was conducted. This evaluation includes a multiple-choice survey of questions related to the effectiveness of the instructor as well as the module in general. Additional comments could be made on this formal evaluation. At the time of writing this manuscript, the results of the formal course evaluation are not available.

Student Feedback Survey

A survey was conducted to ascertain the student's disposition towards several statements related to the use of teaming.

Each student was asked if they agree or disagree with eight statements related to teaming. The results of the survey are shown in Figure 1. The reponse rate for the survey was 63%. As seen in Figure 1, the overwhelming majority felt as if their classroom experience had been improved in some way due to the use of teaming. This suggests that most students viewed the experience in a positive manner.

Several of the statements did not result in a definitive majority opinion, including whether the course should be presented in a standard format or if the students felt that their marks would improve as a result of teaming (the latter may be due to the fact that the marks for the course had not been given at the time of the survey). Roughly half of the students recommend that group oriented learning be implemented in other courses. Although specific comments were not directly requested on the survey, several students wrote feedback on the survey enthusiastically supporting the use of teaming in other courses as well. Some cited the similarity of the team environment to what they will face professionally in their careers.

The statements that students agreed most with were related to their sense of belonging in the group and their obligation to perform (attend class) instilled by the group's expectations. Students also agreed with the use of tutorial time for strategy sessions and review, retrospective, & planning meetings.

From an instructor's perspective, the organization of the groups randomly by middle initial was effective in achieving diversity of perspectives in each team, but the results of the survey

suggest that the students would rather self-organize the teams. More investigation should be performed to determine the effect of how the teams are organized on the team's performance.

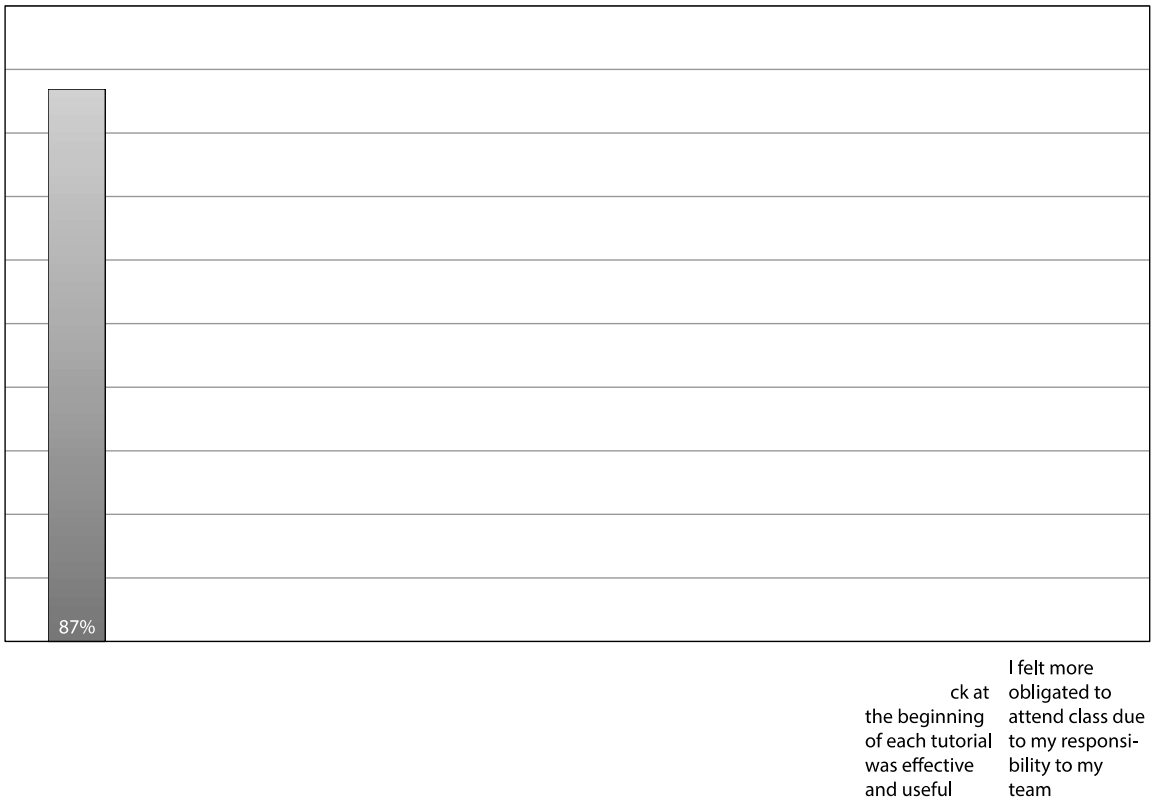

Figure 1. Student feedback survey results.

Buddy Rating

In this case study, a buddy rating system was used to determine a student's mark in terms of their participation in the team. Although the buddy rating system provides a simple means for evaluating participation there are a number of draw backs which make it difficult to use effectively. Since the RRP and stand-up meetings already provide several opportunities to address issues related to group participation, in future offerings of the course the buddy rating system will not be used.

The method by which the group ensures equal levels of participation among the members represents a good opportunity for autonomy. One of the goals of the teams, in addition to the goals related to the sections of coursework, should be to achieve a balanced level of participation from all members. The team could then devise a plan that they would implement and revise as the scrum process evolves. In further implementations of teaming this will be more directly emphasized.

Best Practices

The following list represents a number of suggestions based on the case study presented above. These recommendations also stem largely from an anonymous feedback webpage that was set up for the course. Students were allocated time during each tutorial session to write comments on this site. These items will be incorporated into a revised version of the implementation of teaming in large engineering classes.

- The way in which teams are assigned results in different outcomes. Randomly selecting teams leads to a diverse cross-section of backgrounds, but some logistical drawbacks arise. For example it would be convenient if all the members of a team were from the same residence. These outcomes should be carefully considered.
- Always provide time and tools for developing healthy relationships within the teams. This includes icebreaker activities, activities that require each member of the group to contribute thoughts, or using games in which teams compete against each other.
- Developing a strong sense of identity among the teams leads to much greater levels of buy-in.
- Rather than using a buddy rating system to determine group participation marks, allow the teams to devise a method to ensure balanced levels of participation. This should be emphasized as one of the central goals of the group.
- In-class time should be provided for the teams to evaluate how they are performing and to develop a plan to make adjustments.
- The facility in which a class is taught has a large impact on how well teaming can be implemented. The top concern raised in the student feedback was that the seating arrangement in the lecture halls made interacting in groups of seven or eight extremely difficult. Unfortunately, facilities with furniture that enables groups of roughly eight students to interact and that have the capacity for more than 150 students are not usually available. In next year's offering of the course, we will try using one of the technical drawing studios that has the proper furniture and capacity rather than a lecture hall.
- The level to which the teams are challenged should be carefully considered. The optimum level of expectation placed on the team will lead to a strong sense of interdependence among the team members. If the goals are not challenging enough, the true value of working as a team will be lost.

Summary

In this work we presented a case study in the use of teaming to reduce the negative outcomes of large engineering classes. The teaming process was implemented as a modification of the scrum methodology, which is largely used in the software development industry. The results from surveys taken during the case study suggest that teaming leads to a more positive student experience, a greater sense of belonging and engagement, and increases class attendance rates. Further investigation is required to evaluate how the teams are organized and the overall impact on how well course concepts are absorbed. These topics will be pursued in forthcoming studies.

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