Structuring Flipped Classes with Lightweight Teams and Gamification

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ABSTRACT

We present a new approach to help make computer science classes both more social and more effective: “lightweight teams”. Lightweight teams are class teams in which the team members have little or no direct impact on each other’s final grades, yet where there is a significant component of peer teaching, peer learning and long-term socialization built into the curriculum. We explain how lightweight teams have been used in a CS1 class at our institution, and how this approach, combined with a flipped class approach and gamification, has led to high levels of student engagement, despite the difficulty of the material and the frustration that is common to those first learning to program.

Categories and Subject Descriptors

K.3.2 [Computer Science Education]

General Terms

Education

Keywords

lightweight teams, flipped classes, gamification, computing education, cooperative learning, team-based learning, CS1

1. INTRODUCTION

Students who self-select into computing disciplines are often considered to be less socially adept than average, or possibly just more introverted. While this stereotype is not true of all computing students, we do know that first-year students in all areas of study experience social anxiety when they arrive at university [6]. For students entering computing disciplines without a significant computing background (i.e. those without a CS AP course), this social anxiety coincides with the year when they learn the most basic computer science programming and problem solving concepts. Learning how to solve problems through programming is notori-

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ously hard [13], and correlates with a high attrition rate in the first year computer science classes [26].

We have developed an approach to help address this issue of social anxiety paired with the difficulty of learning programming: the use of lightweight teams. In this paper, we define what we mean by lightweight teams and describe how we have used this approach in a new CS1 course, building on the trifecta of best practices (media computation, peer instruction and pair programming) shown by Porter and Simon to have significant impacts on learning in CS1 [21]. We extend beyond this trifecta by using a flipped classroom approach along with lightweight teams and gamification elements. Lightweight teams and gamification provide the structure and motivation for in-class activities required by flipped classrooms. This new CS1 course has been taught twice with an enrollment of 92 and 65 students in the Fall 2013 and Spring 2014 semesters, respectively. We report on our experiences as the teaching team as well as on survey responses from students taking these courses.

1.1 Lightweight Teams Defined

We define lightweight teams as teams of students who work together in a class, but where the work done as a team has minimal direct impact on a student’s final grade. Thus, there is no large, high-stakes team project worth a large percentage of the final grade. Similarly, the teams don’t complete any assignments or exams together. The team’s work effort is focused on low-stakes activities and the team sits together for the whole semester in assigned seating in the classroom. Working on activities together throughout the semester gives the students a chance to get to know each other, become comfortable, and learn from one another.

1.2 Hypotheses

While we have not collected enough long-term data at this point to make any strong claims about the effectiveness of lightweight teams and gamification in combination with a flipped class structure, we do have some hypotheses about this combined approach. In general, we are interested in determining whether this combined approach encourages student learning, increases engagement in course-related activities, and increases feelings of community.

We posit the following hypotheses:

- H1.** Lightweight teams enhance the student’s ability to learn the course material.
- H2.** Lightweight teams make the course more engaging for students.

- H3.** Gamification elements (stamps, tokens and the leaderboard) encourage students to work harder.
- H4.** Gamification elements make the course more engaging for students.
- H5.** Students become socially integrated with their peers.

2. BACKGROUND

While we don't generally think of college as a lonely place, it can be lonely for freshman who have not yet made friends. Our work draws heavily on the idea of cultivating communities of learners [15], because there is significant evidence that students become more engaged in their activities when they are part of such groups. These ideas are also supported by the work of Rogoff on the cognitive benefits that accrue from an apprenticeship model of learning [22]. Increased engagement is likely to have positive impacts on learning, as engagement is a key factor in helping students increase their self-efficacy and improve their performance [19].

We were also inspired by the practices that have flourished in many classrooms based on Michaelsen's team-based learning approach [18]. In this approach, teams of students are strongly dependent on one another to work together to produce final outcomes that are graded. While this approach makes sense in upper year courses where students have the skills to complete more complex projects, it seems less useful in an introductory computing course. However, belonging to a group or a team can have significant positive benefits both in the current context, and for sustained success in college [1]. We wanted a way to leverage the increased engagement that comes with team social interaction and the cognitive benefits that come from apprenticeship learning. However, we also know that high-stakes group work tends to lead to high amounts of stress for many students. Students commonly complain about group work, typically because one or more team-members are not doing their fair share of the work. *Lightweight teams are designed to leverage the benefits associated with team-based learning and apprenticeship learning, but to remove the stress associated with high-stakes group projects.*

Gamification is the use of game mechanics and elements in non-game settings [16] in order to engage participants and have them perform desired patterns of behavior to reach established goals [9]. Typical gamification elements include point systems, badges, levels and challenges. Gamification has been applied to entire courses in game design [23]. We are beginning to see evidence that gamification contributes to learning in CS1 [3, 20, 8]. McGonigal argues that games promote learning and help people to socialize [17]. While gamification holds promise for increasing motivation and engagement, we are particularly interested in how it combines with lightweight teams, because a course designer can employ both individual and team-based gamification elements.

There has been significant research on the flipped or inverted classroom model [24, 25, 11, 14, 5]. In this model, content delivery occurs outside of the classroom, and in-class time is devoted to active learning activities. This approach means that instructors, through interaction with students in class, can determine where students have developed misconceptions. This is in direct opposition to the traditional 'sage on the stage' model which creates a social barrier between the instructor and the students. Recent research has shown that the flipped model can have a positive impact in CS1 classes [10]. The challenge associated with the flipped

class approach is developing in class activities. We believe lightweight teams and gamification provide structure and motivation for in-class activities.

3. FLIPPED MEDIA COMPUTATION

At our institution, we recently created a separate, additional track for introductory programming that runs in parallel to the traditional programming courses and is open to both majors in the CS and IS tracks and to non-majors. The first class in the new track is ITIS 1212: Introduction to Media Computation and meets twice weekly, Wednesday lab and Friday workshop. This course extends the media computation approach (for Java) [7] to a flipped class setting. Thus, students read the textbook, enter textbook programs, watch videos about programming concepts, and take a short online quiz before they come to the programming lab. The Wednesday lab meets in two smaller sections where students work through programming exercises with a same-gender peer, and lab partners change every two weeks. The last weekly activity is a 3-1/2 hour Friday workshop where we use the lightweight teams.

3.1 Lightweight Teams in ITIS 1212

Team Creation and Seating

Prior to the first class of the semester, we use Moodle's auto-grouping function to generate random teams with approximately five students per team. We then make minor adjustments so that female students are on a team with at least one other female. On the first day of class, we ask team members to choose a name for their team.

To encourage teamwork, we believe it is important that students sit together with their team every week, so we create a seating plan based on the classroom layout. While this seems strange to the students, we think that for many students there is anxiety about where to sit in class. Lightweight teams means that students don't have to choose where to sit, who to sit with, or even wonder if anyone will choose to sit next to them. We observed that over the semesters, students came in and began immediately talking with their team-mates and while this chat was often purely social, they sometimes used this time to discuss class work. This is quite unlike traditional large freshmen courses, which, in our experience, tend to be quite quiet before the start of class.

Peer Instruction Clicker Quizzes

We typically open the Friday workshop sessions by asking the students if they have questions about course content, and if they do, we spend 5 or 10 minutes answering questions. We then conduct the clicker quizzes¹, which are multiple choice quizzes run using a modified peer instruction method [2]. We project a question on screen and encourage students to talk with their team-mates *before* answering. Each student has their own clicker and is free to enter the answer they think is correct. We evaluate the responses to each question before continuing; if we feel that not enough people are getting the right answer, we ask students to 'find someone with a different answer and convince them that you are right'. This leads to teams debating with other teams, so the discussion can become quite loud. This means that not only are students talking with and getting to know the

¹<http://www.turningtechnologies.com/higher-education>

people on their own team, they are often getting to know the people on other teams as well.

Our clicker quizzes typically contain 15-20 challenging questions and will take 90-120 minutes to complete, depending on how much discussion is generated. Because questions and answers about Java code can be lengthy, we often distribute hardcopies for teams to share, promoting discussion. We also design non-trivial questions that really challenge the students, often requiring them to get out a pen and paper and work through a section of code to predict output or understand how something works. Finally, we use multiple similar questions that repeatedly test a concept, giving students a chance to cement their understanding. Because we have also entered the team rosters and team names into the clicker quiz software, we are able to display live team stats during the clicker quiz, showing which teams have earned the most points so far, generating competition and excitement.

The clicker quizzes are worth a total of 10% of each student's final grade. So, in the end, they are not a significant portion of a student's grade. However, feedback from students indicate that these team-based quizzes are one of the most useful parts of the course in terms of testing and developing their understanding of core programming concepts.

Other Peer Instruction Activities

While the clicker quiz often takes up more than half of the Friday workshop sessions, there is usually about an hour left. Some weeks this hour is devoted to one of the five tests (which are taken individually, not as a team). When we aren't giving tests, students engage with their team on other hands-on activities. These include paper problem solving activities, where students are asked to write pseudocode to solve a problem, or Parson's Problems [4], where they are given lines of pseudocode that need to be put in the correct order to solve a problem. For these activities, we sometimes ask teams to trade solutions and then do peer grading or peer critiquing of the other team's solution.

3.2 Gamification in ITIS 1212

To complement lightweight teams, we employed three simple gamification strategies to motivate and engage students.

Figure 1: Stamps available to be earned.

Stamps

We used the Moodle stamp collection module to give students stamps for small achievements that indicate extra engagement (Figure 1 shows a subset of the stamps available). The students could collect as many stamps as they wanted, and for every 10 stamps they collected, they would earn a 1% increase in their final grade. Stamps were given for activities such as answering forum questions, completing programming lab bonuses, implementing paper problem solutions from workshop, or completing Problett tutorials [12].

Team Leaderboard		
Current leaderboard, as of April 10, 2014:		
Rank	Team	Badges
1 (1)	Super Smash Bros (F)	48 (0)
2 (2)	Team Live Bad-Ass (N)	47 (0)
3 (3)	JailBreakers (J)	45 (0)
4 (4)	Cardiac Cats (E)	40 (0)
5 (5)	Dandrick Princes (K)	37 (0)

Figure 2: Partial screen-shot of the team leaderboard on Moodle, showing the total stamps earned by members of each team.

Leaderboard

While stamps were collected individually by students, we wanted students to encourage each other to participate more fully. To do this, we implemented a team leaderboard on Moodle which was updated weekly to reflect the number of stamps collectively earned by each of the teams. The board showed changes from previous weeks as well as total stamps earned. The top three teams at the end of the semester were awarded special prizes. Thus, the stamps and the leaderboard turned the course into a tournament.

Figure 3: The 3D printed media computation token.

Question Tokens

We designed and 3D-printed special 'media computation' tokens (see Figure 3), that we gave out to students during the labs. Each student got one token per week and their goal was to hold on to their token and turn it in to their team during the Friday workshop. If a five person team could hand in a full set of five tokens, they would all earn stamps. However, if a student wanted to ask a question of a Professor or TA during the lab, they would have to turn their token in if we determined that they should have known the answer from their weekly preparation. This was designed to encourage students to fully prepare for class, to learn to solve programming problems on their own, and to get help from each other and from online sources.

4. RESULTS

We collected anonymous survey information from our ITIS 1212 students in both semesters, to get their perspectives on these pedagogical approaches. The surveys were conducted twice per semester (as "early feedback" and "late feedback") and consisted of 44 and 50 questions, respectively; they were conducted during the Fall 2013 (N=45 and 45, response rates of 52%) and Spring 2014 (N=59 and 44, response rates of 94% and 70%) semesters. Our response rates were higher in Spring because we gave students time to complete the surveys in class. The surveys consisted of agreement statements on a 5-point Likert scale (1= strongly disagree, 3 = neutral, 5 = strongly agree). Table 1 presents the responses

Table 1: Survey Results: Average scores from ITIS 1212, Fall 2013 and Spring 2014 semesters.

ID	Agreement Statement (Scale is 1-5: 1 Strongly Disagree, 3 Neutral, 5 Strongly Agree)	Fall 2013 Early	Fall 2013 Late	Spring 2014 Early	Spring 2014 Late	Average
Flipped	The flipped structure of this class is working well for me (I am learning a lot).	3.17	3.76	3.76	4.05	3.69
Team-1	Working with my team members to answer clicker questions helps me to learn.	4.54	4.38	4.52	4.60	4.51
Team-2	The team aspect of the course makes the course overall more engaging.	4.11	3.96	4.22	4.28	4.14
Team-3	I like being part of a team and sitting with my team each week.	4.28	4.44	4.26	4.48	4.37
Stamp-1	Stamps provide a good incentive to get me to put more effort into this course.	3.26	3.07	4.00	3.75	3.52
Stamp-2	The leaderboard on Moodle showing which team has the most stamps adds to my desire to earn more stamps.	3.47	3.04	3.75	3.37	3.41
Stamp-3	The addition of 1% to my final grade for every 10 stamps earned adds to my desire to earn more stamps.		3.53		3.91	3.72
Token-1	The use of tokens makes me try hard to figure out the lab with my partner.	3.54	3.07	3.72	3.37	3.38
Token-2	The tokens are fun and cool.	2.65	2.80	3.56	3.36	3.02
Token-3	Because of the tokens I am becoming a more self-reliant learner.	2.85	2.86	3.47	3.09	3.03
Token-4	The potential loss of a token has discouraged me from asking for help, even when I really need it.		3.93		3.30	3.72
Overall	Because of this course, I am likely to take another programming course.		3.89		3.95	3.92

related to the flipped class, lightweight teams and gamification elements.

Flipping the media computation curriculum is seen as positive in early feedback, but receives higher scores in later feedback, indicating a change in attitude over the semester. The scores across most questions, including the flipped class, are higher in the Spring offering, likely because of a few refinements made after the initial offering. The results for Team-1, Team-2 and Team-3 show that students think very positively about lightweight teams, not only for enhancing their learning experience and engaging in the workshop, but also for the social/community benefits. In the Overall question, students responded positively regarding their likelihood to take another programming course, a question that was only on the late semester feedback survey.

We compared average scores between representative survey questions (see Table 1) Team-1, Team-2, Stamp-1, Stamp-2, and Token-1, for each of the four surveys and for all respondents. Results for Team-1 are significantly higher than Team-2 ($p<.05$), Stamp-1 and Stamp-2 ($p<.001$), and Token-1 ($p<.001$). Team-2 results are significantly higher than Stamp-1 ($p<.02$)², Stamp-2 ($p<.02$), and Token-1 ($p<.02$). The gamification elements such as the stamps, tokens and the leaderboard received positive ratings, but not as positive as the team elements. In general, stamps and leaderboard average scores were higher than scores related to tokens, however, there were no significant differences found in comparisons between Stamp-1, Stamp-2, and Token-1.

We also analyzed differences in average scores due to gender (male, female) and major (computing, other/undeclared) for each of the four surveys and across all survey questions, paying particular attention to questions related to lightweight teams and gamification. In both Fall 2013 surveys, we found one survey question (Stamp-2, $p<.05$) where females scored significantly higher than males; none of these were found to have significant differences in the Spring 2014 surveys. So at least for the Fall 2013 semester, it appeared that female students

were more excited about the stamp competition than male students. An interesting hypothesis we could posit in the future would be that while females may not be motivated by individual competition, they may strongly want their team to excel. We were looking for response consistency to assess differences in gender and major across all four surveys, especially across both semesters. We found only one instance of this consistency: the Team-3 question, where the other/undeclared majors scored significantly higher than the computing majors ($p<.05$) in the Fall 2013 and Spring 2014 semesters. In other words, non-computing majors liked being part of a team more than computing majors. Anecdotally, in the early Fall 2013 survey, other/undeclared majors scored significantly higher than the computing majors ($p<.05$) in the Team-1 question which might help explain why other/undeclared majors liked being part of a team, i.e., it helps them to learn. In both Spring 2014 surveys, we found that computing majors scored significantly higher than other/undeclared majors in this question: "I try all the required programming exercises from the book before each Moodle quiz and lab."; this would perhaps indicate that the computing majors learned more on their own than in a team setting.

Students had the opportunity to give us open-ended feedback through the surveys. The vast majority of this feedback was positive, and much of it relates to the lightweight teams. For example, one student commented: "Being able to work with people is the highlight of this course." And yet another simply stated that the best part of the course was "the bond of friends". One student summed up the Friday workshop: "I really enjoyed going to workshop. Going through a clicker quiz with a team made it easier to learn the material." Multiple students made positive comments about taking clicker quizzes as a team and how valuable that was to them. The students were also very positive about the flipped class style, with one student commenting: "This course was excellent. The unconventional style hit the same subject in so many different angles that helped me a lot." Another student noted: "At first, I did not like the flipped classroom idea, but now I find it isn't that bad if you do the work." There were two students who expressed

²Team-2 vs Stamp-1 difference was not significant in the Spring 2014 Early survey.

strongly negative opinions about the flipped class structure, one of them advising: “Go back to a traditional class set up. We pay to be taught and this is not what we got.”

Post-Course Performance

Of the 92 students who enrolled in our first semester ITIS 1212 class, 56 students went on to take ITCS 1213 in Spring 2014, an object-oriented Java course offered in the CS track within our college. The other 198 students enrolled in this follow-on course took ITCS 1212 as the pre-requisite course. ITCS 1212 has three significant differences from ITIS 1212: it is not flipped, there are no teams or gamification, and the programming language taught is procedural C++. Our ITIS 1212 graduates fared well in ITCS 1213, earning a class GPA of 3.06 (std.dev. of 0.9), compared to students from the traditional intro class (ITCS 1212), who earned a class GPA of 2.66 (std.dev. of 1.17). Compared to the other ITCS 1213 students, our ITIS 1212 students had higher percentages of A's and B's and lower percentages of C's, D's, and F's at the end of the semester (see Figure 4). Comparing the average ITCS 1213 final grades, students from ITIS 1212 course scored higher than ITCS 1212 students (84.19, st.dev. of 9.02 vs. 80.28, st.dev. of 12.5, $p < 0.3$). It is unclear which factors (flipped class structure, lightweight teams and gamification, knowledge of Java) led to our students performing better in ITCS 1213. Regardless, the high performance of our students in the follow-on course suggests that the learning outcomes from our ITIS 1212 class are positive.

Figure 4: Histogram of performance of our ITIS 1212 students (blue) in the ITCS 1213 course, compared to students from ITCS 1212 (red).

5. DISCUSSION

Based on the results shown in Table 1, and the significant differences between lightweight team and gamification results, hypotheses H1 and H2 related to lightweight teams are accepted; hypotheses H3 and H4 related to gamification scored lower and are considered marginally accepted for this analysis. Based on the number of friends made, we accept H5. Our interpretation of these results are that (1) lightweight teams exert a strong positive influence on students' ability to learn, engage in the course, and establish a sense of community, and (2) gamification elements (stamps, leaderboard, tokens) also exert positive influence on the student's work ethic and self-reliance, however, the use of these elements needs further refinement. In particular, we are concerned with the results of the Token-4 question because we don't want students to withhold their questions when they

really need help. On a positive note, the average score for the Token-4 question dropped significantly ($p < .02$) between Fall 2013 and Spring 2014 indicating that students were, in fact, spending the token to get help; our intent is to continue to monitor this concern.

The instructional team observed friendships form over both semesters of this course. We observed sets of these students hanging out outside of class and coming to office hours as a group. Students who started the semester without knowing anyone in the class left at the end of the semester with a set of new friends. We describe the phenomenon of lightweight teams as 'handing freshman students four friends on a platter'. Figure 5 displays one of the most exciting results from this class: 62% of respondents in Fall 2013 and 55% of respondents in Spring 2014 reported making 5 or more new friends as a result of taking ITIS 1212. This suggests that not only did students make friends on their teams but across teams. We believe that these students making so many new friends will have positive impacts on program and institutional retention because we have helped them become connected to their student community.

Figure 5: Histogram showing the number of new friends each respondent reported making as a result of taking ITIS 1212 in Fall 2013 or Spring 2014.

We paid considerable attention to gender issues in our pedagogical design because we wanted this first programming class to be a positive and confidence-building experience for our female students. We had gendered pairs for pair programming in the lab because of our experiences seeing 'guys take over' in the lab when they are partnered with a female for programming activities. In survey questions about this practice, the female respondents ($n=17$ in late Fall 2013) and ($n=7$ in late Spring 2014) were generally in agreement that gendered pairs was a good policy, although there were a few detractors. We observed that this practice ensured that everyone was able to fully participate in labs.

Our workshop sessions were held in standard lecture halls containing rows of tables with chairs attached. These rooms are definitely not optimally designed for lightweight teams. In designing the seating plan, we did not sit teams along a row, as that would make collaboration difficult. Rather we put two team members in one row and the other three team members directly behind them or in front of them. Because the chairs could swivel, we found that students could turn around and talk to each other as needed. Rooms with round tables for each team would enhance the interaction, but traditional lecture halls can be made to work.

6. CONCLUSIONS AND FUTURE WORK

We have presented our initial experience with using lightweight teams and gamification elements within a flipped class structure to enhance the trifecta of best practices for CS1 [21]. Lightweight teams are designed to address students' social needs without the stress associated with high-stakes team projects and the gamification elements are designed to increase engagement and provide a coalescing goal for teams. Our initial results suggest that this combination of elements provides the needed activity structure for a fully flipped classroom and leads to positive experiences for students and high overall engagement; it would be interesting, in the future, to assess the benefits of each component individually. Our results indicate that students (1) strongly agree with the lightweight teaming aspect of this course, and (2) made numerous friends (5+) in this course as a direct result of lightweight teaming. We will continue to track our students to see how they fare as they progress through our undergraduate programs. It is our expectation that the social aspects of lightweight teams will lead to students feeling more embedded in the College community and will have positive impacts on long-term program retention.

In the future we are interested in investigating how lightweight teams and gamification scale to larger class sizes. In addition, we plan to explore how lightweight teams might enable more social learning experiences in massively open online classes (MOOCs) and other online educational settings where learning can be a lonely experience.

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