Increasing Collaborative Communications in a Programming Course with Gamification: A Case Study

Antti Knutas, Jouni Ikonen, Uolevi Nikula, Jari Porras

Abstract: *In this case study we present an approach for using gamification elements to increase online student collaboration. In the study a gamified online discussion system was added to an introduction to programming course, with the aim of motivating the students to help each other. The actions in the discussion systems were analyzed and compared with user profiles and a student survey. The system had a positive impact on the course, increasing student collaboration, reduced response times and made course communications 88% more efficient by reducing email traffic.*

Key words: *Computer supported collaborative learning, CSCL, gamification, programming education, social network analysis, CS1.*

INTRODUCTION

The use of computer supported collaborative learning (CSCL) tools is increasingly common in lower and higher education settings, with new applications still coming up. They commonly address some part of the learning equation and are either directed by the course script or are aimed at independent learning. Examples of such systems are discussion systems (e.g. CoFFEE), knowledge construction tools (e.g. Fle3), knowledge bases (e.g. Knowledge Forum) and courseware systems like Moodle that support collaborative add-ons. As the learning becomes more independent in university settings, it is sometimes difficult to motivate the students to participate in the use of these systems. The motivation remains an issue despite the fact that the use of these systems has been shown to increase learning outcomes and is beneficial to the students.

There are already existing gamification designs applied to learning systems and collaborative learning [1, 15, 19]. However, the gamification aspects and design are often related to learning goals or individual course exercises. Our proposal is to arrange the gamification model around rewarding student collaboration, like helping solve posted problems or collaborating on difficult or additional tasks across groups, instead of tying the rewards to achieving the learning goals. Published theory on gamification [9] indicates that this can be more effective than using the ordinary course goals as reward goals, because the course grade can already be perceived as a reward in the context of the course.

Our hypothesis is that this model of gamification, when applied to a CSCL systems, provides an initial extrinsic motivation for students to start using the system, giving them time to realize the educational benefits to their studies and subsequently gaining the element of internal motivation. A secondary goal is to show that the gamification design elements can add to the level of engagement the system provides, which increases the frequency of the use of the system and makes the course communications more efficient.

We tested this approach in a case study where a gamified, collaborative discussion and peer support system was applied in an introductory programming course. The course lasted for a single semester (14 weeks), had 249 participating students and four assistants in addition to the lecturer. The course had each week 2 hours of lectures, 2 hours of exercises and exercise assignments that were evaluated by automated systems and course assistants.

Pre-print –version; Please cite the published paper available at
http://dl.acm.org/citation.cfm?id=2659620
doi>10.1145/2659532.2659620

To summarize, the research questions in this case study are:

1. Can computer science students be encouraged with gamification systems to collaborate online?
2. What kind of impact does using a gamified, collaborative system have on an introductory programming course?
3. Does increased collaboration improve course outcomes or communication efficiency?

In order to achieve our research goals we used a mixed methods approach. The social interactions were first evaluated with social network analysis tools and statistical methods and then interviews and surveys were used to gain additional context to the interactions.

In the following sections we describe the state of the art of gamification in CSCL, present our research setup and study results, discuss about implications and finally present the conclusion.

STATE OF THE ART IN THE UTILIZATION OF GAMIFICATION IN CSCL

Gamification, at its core, is the use of game design elements in a non-game environment [6]. However, effective gamification is about using these game elements along three important principles, in order to satisfy users' three innate needs for intrinsic motivation [9], which were originally adapted by Deterding [6] and Schell [17] from Deci and Ryan's [5] self-determination theory. The three principles are [9]:

- **Relatedness:** The universal need to interact and be connected with others.
- **Competence:** The universal need to be effective and master a problem in a given environment.
- **Autonomy**: The universal need to control one's own life.

These elements have been shown to be satisfied by gamification elements by Rigby and Ryan [14], where they also demonstrate the connection between the self-determination theory and gamification.

Gamification is an upcoming method in learning, with ongoing research in its use as motivation or engagement method [2, 8, 18], for fostering collaboration [12, 15, 20, 21] or engaging by competition [7]. It has also been used as an engagement method in the increasingly popular Massive Online Open Courses (MOOCs) [16, 22]. However, the successful application to gamification methods is not necessarily a straightforward affair, with the application of those methods sometimes negatively affecting the course [3].

Little research has been conducted on the impact of gamification on collaboration behavior patterns and course communications. Most of the previous studies on the field of gamification in education concentrate on measuring individual student course outcomes. However, some studies in the field indicate that gamification methods are successful in fostering collaboration and this collaboration can positively affect course outcomes.

The success through applying gamification on collaboration is especially evident in studies by Moccozet et al. [12] and Dubois and Tamburelli [7], where collaboration was rewarded or the course participants were able to publish their competence and compare the results to their peers. The elements of success in these studies are the fact that they connect the users' achievements to a *meaningful community* who share some of the user's *personal goals*. Additionally, by providing variance the approaches in these studies allow the user to retain their *personal autonomy*, by allowing the users to choose how exactly to achieve their goal.

RESEARCH METHOD

The research concentrated on the students' use of an asynchronous, gamified collaborative discussion system and its impacts on learning outcomes and collaborative behavioral patterns. During the course interaction data and user profile metrics were directly collected from the collaboration system and at the end of the course the participating students were asked to participate to a survey and course personnel was interviewed to gain additional context for the interaction data.

There were two different sources of data in the study, the collaboration system itself and surveys sent at the end of course, so there were two main analysis methods. The collaborative behavior of the students was analyzed with social network analysis and the survey results with statistical analysis. The next subsections go into more detail of how the data was collected, analyzed and which kind of results was obtained.

Research Setup

The study was conducted for the duration of a fourteen week long introduction to programming course that had 249 participating students, four assistant helping with the exercises and one lecturer ultimately responsible for the course material. Most of the participants were first year university students, with a minor amount of students being senior students attempting the course again. The course had weekly two-hour lectures, exercises of the same duration and weekly assignments that had to be returned through an online grading system. The grading depended on the return of the weekly exercises, one larger exercise project and a final exam. Additionally lecture or online activity was rewarded with activity bonus points.

The course has online support materials like a programming guide, lecture notes and video lectures. Also an IRC channel and a forum were in use in previous years, but they did not play a large role in course communications according to the interviews. This year an online asynchronous collaboration system with gamification elements was added to the course. This collaboration system (Q2A) was installed locally and accounts were created for students. The use of the system was taught on the introductory lecture of the course and the assistants also encouraged its use over questions by email, in order to have other participants to the course benefit from the discussion.

The discussion system's major feature is the possibility for participants to post questions or issues regarding the course and for others to participate in discussion. The somewhat novel element that separates this discussion system from other online forums is the aspect of gamification. The system recognizes and rewards people who constructively contribute with answers, comments or just ask good questions. Other users of the systems can upvote or downvote content of the system, further rewarding and encouraging other contributors. The users can also publicly show the points and achievement badges collected in the system.

All discussions and user profiles in the system were publicly visible. Interacting with other users required login and only course students and personnel had user accounts. All user actions in the discussion system were recorded through the duration of the course in addition to retaining visitor logs from the users who were not logged in. When recording the interactions into the log, the timestamp, the direction of the communication, the interactors and the type of interaction were stored. These were collated at the end of the course with user profiles for the social network analysis.

Surveys were sent to all course participants at the end of the course to gain more user insight into the system. They asked about which features of the system the student used, how many other users were of help, if other students or faculty helped him, which features of the system the student found useful and which kind of information sources the student used during the course. There was also the possibility to input text to give feedback about the system and its use in the course. Additionally course assistants from the current and previous years were interviewed regarding their work experiences.

Methods of Analysis

Two techniques that supplemented each other were used to analyze the datasets. The problem of analyzing classroom interaction data was approached with social network analysis (SNA). It is an interdisciplinary technique for the analysis of social networks, where social relationships are viewed in the terms of network theory [13]. These relationships can be mapped and visualized as graphs. There are also different mathematical tools available, which can for example be used to estimate the relative influence of the nodes [10]. This approach was further developed for use in computer supported collaborative learning systems by Martínez et al. [11], who also presented an example case of how to apply it in the same article.

In this case of each user was a mapped as a node in the graph, with lines of interaction mapped between the users. The graph is a directed one, meaning that the interactions always have a direction. The arrows were always drawn towards the source of information, so for example if a user answered a question, the arrow was drawn from the person getting advice to the person giving advice. Once the graph was complete, eigenvector centrality analysis was used on the graph, which is a vector-based measure of an individual's influence within a SNA graph [10]. In essence, the more central and the better connected the node is to other influential nodes, the more influential the node itself is.

After the social network analysis was completed the survey results and course assistant interviews were collated and analyzed statistically to find correlations with variables such as course grade and eigenvector centrality. Also, qualitative data from previous and this year's course assistant interviews were compared.

Study Results

The data collection resulted in three sets of data from system logs, user profiles, surveys and the correlational analysis between the two. The survey results concerned the usage times, most useful features, sources of help and most used features. Both users and non-users of the system from the course answered the survey.

In the survey 73 users replied, 61 of who had used the Q2A discussion system and 12 students who hadn't. On average the students answering the survey evaluated the usefulness of the discussion system to be 3.7 on a scale of one to five, with one being useless and five being essential. The users of the system evaluated the usefulness to 3.8, with non-users evaluating it to 3. When asked to evaluate the usefulness of the features, the users replied that finding existing answers and asking your own questions were the most useful. However, second most popular features that were accessed bi-weekly on average were voting on other users and checking the user's point and badge status.

On average users used the system weekly, with emphasis on finding useful message threads. The access frequency matches the weekly rhythm of the course, with new exercises and lectures published each week. When geographical access data was analyzed, it showed that 65% of the page loads were from the university area, with the rest being from nearby cities and small percent from abroad. A total of 88 questions were posted in the system during the course. 87% of these questions were answered and the average reply delay was 19.8 hours ($\sigma = 24.45$). Because the standard deviation is rather high, the average delay is misleading. 50% of the users' questions were answered within two hours and 80% had an answer the following day. 24% of the questions were submitted during working hours and 76% after working hours or on weekends.

The users of the system got help on average from three other students. Half as many users got help mainly from the course assistants. Additionally this and previous year's course assistants were asked to check their email archives and report the amount of programming-related emails they got from the students during the course. This year the amount of programming related questions over email dropped down from 1320 to 164 messages, which is a reduction of 88% in email traffic. The assistants also reported that students did not repeat the same common questions, unlike last year.

The statistical results match the social network analysis graph, which shows that active students form the core of the discussion system community. The graph can be seen in Figure 1, in which each node represents a student and relative size the student’s influence in the graph. Similarly line thickness between the nodes indicates more frequent communications. There are no arrows in the graph, but the flow of information and help curves always counterclockwise. For example, node 182 receives a lot of information from node 42, but sends less information in return.

In the graph the nodes 42, 137, 182 that form the tight core of community are all students. Most influential course assistants can be seen at the edges of the network as nodes 9, 19 and 275 where they add to the community, but do not lead it. Another notable feature in the graph are locally influential nodes at the edges of the network like nodes 103 or 155. These nodes are connected with the center of influence and relay information to their own leaf nodes.

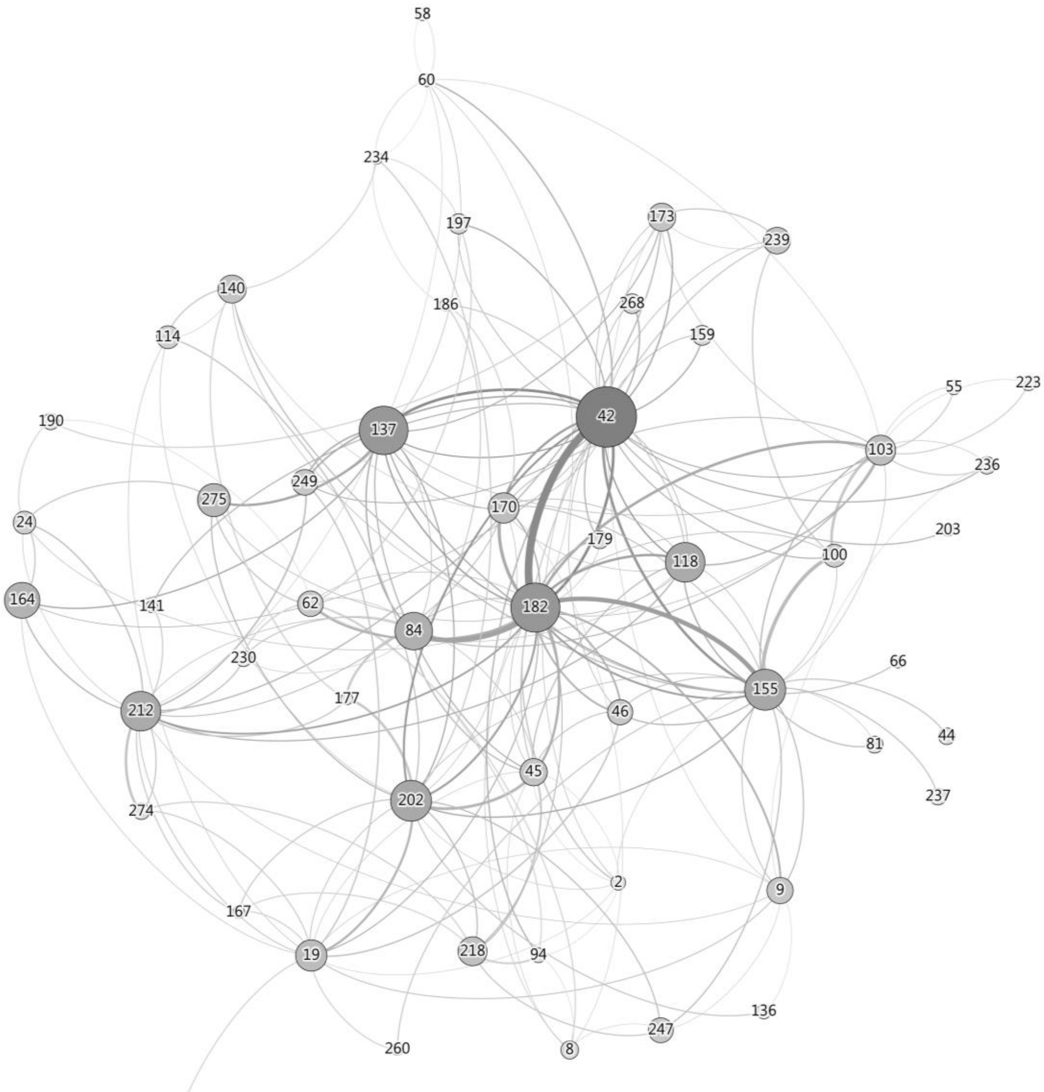

Figure 1. Social Network Graph of Online Collaboration

Different course variables were also subjected to correlation analysis. The data sources for the comparison were user profiles, student surveys and student course outcomes. The correlation analysis was done using Pearson’ product-moment correlation coefficient with Dancey and Reidy’s [4] scale for the strength of correlation (r-value).

First several variables from the user profiles were compared with final grades. Both the user's eigenvector centrality (the influence of a user in the discussion social network) and the points awarded by the gamification feature of the discussion system correlated weakly with final grades (r=0.29, p=0.028; r=0.25, p=0.059). This means that people central to the community and people who earned higher points from using the system were somewhat more likely to have a higher grade in the course.

Analyzing the survey results found other correlations with the student grades. Students who often voted on discussion content had a medium positive correlation (r=0.36, p=0.004), a medium-weak correlation between grades and a preference for answering questions (r=0.29, p=0.022) and a weak correlation between a preference for checking point or badge status and grades (r=0.29, p=0.03). This means that students who were more likely to moderate content, answer questions or were interested their system-awarded points were somewhat more likely to have higher grades.

DISCUSSION

The discussion system was a success in the context of the course and achieved all goals regarding increasing collaboration and communication efficiency. It increased student collaboration, made course communications more efficient by 88% (with less repeated questions for course assistants) and improved question response times, especially during off-duty hours.

Previously the students had to wait for the course personnel to arrive to work and process the evening's or the weekend's emails. The worst case delay could be as long as 68 hours. With the help of the discussion system several students could collaborate on the problem, get help within hours and search if similar problems had already been solved. The approach allows the assistants to see which problems cannot be solved by the students alone and *gives the assistants more time to concentrate on the most difficult issues that come up*. It also has an additional benefit of leaving a record of problems online, so that the lecturer can address the most difficult issues in upcoming lectures.

The social network analysis shows that actively contributing students formed the core of the discussion community, with course assistants adding to the conversations. This core of the community had higher grades, most points in the discussion system and was also active in peer review by commenting and upvoting according to student profiling and the correlation between profile variables. The students who had high grades were also interested in the points awarded by the system from positive activity. The structure of the social network and this correlation of attributes suggests that *highly performing students can be encouraged to contribute their expertise using gamification features*.

The results of being able to encourage beneficial student behavior using gamification features has similar results with two earlier studies in adding gamification elements to software engineering education. Moccozet et al. [12] rewarded collaboration with positive outcomes and Dubois and Tamburelli [7] enabled the course participants to publish their competence and compare the results to their peers with positive outcomes. The collaborative discussion system in this course similarly leveraged the critical gamification features of *allowing users to publish their achievements*, *connecting the users' achievements to a meaningful community* and *allowing the users to retain their personal autonomy* [9]. These gamification approaches were realized using a public leaderboard to display points, fostering a community around the discussion system that recognizes the user's expertise and allowing each individual user to choose how and how often to participate.

The major limitation for the study is the scale. While the results are very promising for a higher education programming course, a single case study in one environment is still too small for generalization. This study showed a correlation between certain user profile types and course success, but this does not prove causality. With more case studies and comparison groups it would be interesting to see if there is a causality between increased use of the system and increased grades, or if successful students are simply more likely to use the system. Also, the gamification system itself was still basic and could consider more variables. For example, the speed of reply is one important factor and the fastest reply could be rewarded.

CONCLUSION

In this case study we investigated the impact of a gamified online collaboration system on collaborative behavior and communications efficiency. We used the system in an introductory programming course with the goal of using gamification elements to encourage students to collaborate online. The case was a success, with the system adding a beneficial element of online collaboration and peer support to the course. The gamification elements of the system were a likely factor in encouraging skilled students to participate and contribute to the online community.

The discussion system increased student collaboration, course communication efficiency and reduced response times, especially during off-duty hours. The survey results show that skilled students liked the gamification features and this suggests that the elements of gamification encouraged them to contribute and answer more questions. This increased student collaboration and the reduced time spent on answering basic questions allowed the course assistants to concentrate on most difficult student issues.

The main limitation of the study is that it covers only one case, which does not allow the results to be generalized. A beneficial direction for future research would be conducting a multiple case study with comparison groups, which would allow the generalization of results and the comparative measurement of impact on course outcomes. This more extensive approach would also help to find the causality in the correlation between system activity and higher grades. Do more highly graded students seek out the goals set by the gamification system or do students following gamification goals earn higher grades?

REFERENCES

[1] Backlund, P. and Hendrix, M. 2013. Educational Games-Are They Worth the Effort? a Literature Survey of the Effectiveness of Serious Games. *5th International Conference on on Games and Virtual Worlds for Serious Applications* (2013), 1–8.

[2] Barata, G. et al. 2013. So Fun It Hurts–Gamifying an Engineering Course. *Foundations of Augmented Cognition*. Springer. 639–648.

[3] Berkling, K. and Thomas, C. 2013. Gamification of a Software Engineering course and a detailed analysis of the factors that lead to it's failure. *Interactive Collaborative Learning (ICL), 2013 International Conference on* (2013), 525–530.

[4] Dancey, C.P. and Reidy, J. 2007. *Statistics without maths for psychology*. Pearson Education.

[5] Deci, E.L. and Ryan, R.M. 1985. *Intrinsic motivation and self-determination in human behavior*. Plenum, New York.

[6] Deterding, S. et al. 2011. From game design elements to gamefulness: defining gamification. *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (2011), 9–15.

[7] Dubois, D.J. and Tamburrelli, G. 2013. Understanding gamification mechanisms for software development. *Proceedings of the 2013 9th Joint Meeting on Foundations of Software Engineering* (2013), 659–662.

[8] Glover, I. 2013. Play As You Learn: Gamification as a Technique for Motivating Learners. *World Conference on Educational Multimedia, Hypermedia and Telecommunications* (2013), 1999–2008.

[9] Groh, F. 2012. Gamification: State of the art definition and utilization. *Proceedings of the 4th seminar on Research Trends in Media Informatics* (2012), 39–46.

[10] Knoke, D. et al. 2008. *Social network analysis*. Sage Publications Los Angeles, CA.

[11] Martínez, A. et al. 2003. Combining qualitative evaluation and social network analysis for the study of classroom social interactions. *Computers & Education*. 41, 4 (Dec. 2003), 353.

[12] Moccozet, L. et al. 2013. Gamification-based assessment of group work. *Interactive Collaborative Learning (ICL), 2013 International Conference on* (2013), 171–179.

[13] Otte, E. and Rousseau, R. 2002. Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science*. 28, 6 (Dec. 2002), 441–453.

[14] Rigby, S. and Ryan, R. 2011. *Glued to games: How video games draw us in and hold us spellbound*. ABC-CLIO.

[15] Romero, M. et al. 2012. Learning through playing for or against each other? Promoting collaborative learning in digital game based learning. *LEARNING*. 5, (2012), 15–2012.

[16] Romero, M. and Usart, M. 2013. Serious Games Integration in an Entrepreneurship Massive Online Open Course (MOOC). *Serious Games Development and Applications*. Springer. 212–225.

[17] Schell, J. 2011. The Pleasure Revolution: Why Games Will Lead the Way.

[18] Sheth, S.K. et al. 2012. Increasing Student Engagement in Software Engineering with Gamification. (2012).

[19] Simões, J. et al. 2012. A social gamification framework for a K-6 learning platform. *Computers in Human Behavior*. (2012).

[20] Singer, L. and Schneider, K. 2012. It was a bit of a race: Gamification of version control. *2012 2nd International Workshop on Games and Software Engineering (GAS)* (Jun. 2012), 5–8.

[21] Singer, L. and Schneider, K. 2011. Supporting the cooperation of end-user programmers through social development environments. *Proceedings of the 2nd international workshop on Web 2.0 for software engineering* (2011), 13–18.

[22] Tan, C.T. 2013. Towards a MOOC game. *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death* (2013), 30.

ABOUT THE AUTHORS

Antti Knutas, M.Sc., Lappeenranta University of Technology, Phone: +358-0294-462-111, E-mail: antti.knutas@lut.fi.

Associate Professor Jouni Ikonen, D.Sc., Lappeenranta University of Technology, Phone: +358-0294-462-111, E-mail: jouni.ikonen@lut.fi.

Associate Professor Uolevi Nikula, D.Sc., Lappeenranta University of Technology, Phone: +358-0294-462-111, E-mail: uolevi.nikula@lut.fi.

Professor Jari Porras, D.Sc., Lappeenranta University of Technology, Phone: +358-0294-462-111, E-mail: jari.porras@lut.fi.