Creating Software Engineering Student Interaction Profiles for Discovering Gamification Approaches to Improve Collaboration

Antti Knutas, Jouni Ikonen, Dario Maggiorini, Laura Ripamonti, Jari Porras

Abstract: *Benefits of collaborative learning are established and gamification methods have been used to motivate students towards achieving course goals in educational settings. However, different users prefer different game elements and rewarding approaches. We present an evidence-based method and a case study where interaction analysis and k-means clustering is used to create gamification preference profiles. These profiles can be used with an agent-based simulation to evaluate how computer supported collaboration system users react to the gamification elements and how the collaboration dynamics change.*

Key words: *Collaborative learning, interaction analysis, profiling, k-means clustering, gamification.*

INTRODUCTION

Collaborative learning, or the cooperative activity of students working together towards a specific learning goal with the teacher as a facilitator [1], [2], is becoming increasingly important topic in education [3]. This collaborative approach to education has been shown to develop critical thinking, deepen the level of understanding and increase the shared understanding of the material [4], [5]. Computer-supported collaborative learning (CSCL) extends and facilitates this cooperation by using electronic communication tools [6]. CSCL has several benefits, including wider participation for knowledge building, and improved student productivity and satisfaction [7].

Computer supported collaboration is also essential in software engineering education, because working and efficiently collaborating teams is at the basis of software engineering industry [8]. The impact of collaboration has been studied in both physical classrooms [9] and in online environments [10] with positive course outcomes. However, the people who benefit most from this collaboration do not always interact [11].

In recent studies it has been shown that students can be guided towards educational goals like collaboration by using gamification [12], which is defined by Groh [13] as the application of game-like elements to non-game environments. Approaches that use some elements of gamification [13] have been shown to increase student collaboration [14] and the motivation towards achieving course goals in educational settings [15].

Although we instinctively recognize that games and fun are tightly related, both concept and their interrelation are quite slippery to define [16]–[19]. The investigation of these issues has led neuroscientists and cognitive psychologists to examine how playing a game and learning are connected [20], [21]. The basic observation is that humans have always used games as playgrounds for learning and exercising safely specific skills. During this process, human brain secretes endorphins (which makes a game an enthralling and fun activity), is highly focused on recognizing recurring patterns in problems, and on creating appropriate neural routines to deal with them. Once the pattern is fully caught by the player, the game becomes boring, but the skill has been accurately acquired. In a certain sense, we could say that “Fun is the emotional response to learning” [22] and that the first and main reason for a (video) game to exist is to provide fun to its players [23], that is achieved not only through alluring game mechanics, but also by providing an environment that fosters immersivity [24], [25].

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Our proposed solution is to use an evidence-based method for deciding which elements of gamification to apply and how to apply them. In this method we build collaborative behavior profiles for students by using interaction analysis, Belbin's teamwork profiles [26] and Bartle's player profiles [27]. These profiles and the collected profiles of interactions can be used to model how different students react to gamification elements and the available goals.

In this paper we detail our profiling method and present a case study where we profile the collaborative behavior patterns of students who participated in a software engineering course. We also present our plan of how to use these profiles in an agent-based simulation, with an ultimate goal of using these simulations to find gamification approaches that improve collaboration in CSCL environments.

Specifically, our research questions in this study are:

1. What kind of collaborative interactions are present on a collaborative software engineering course?
2. Do these interactions have repetitive patterns that can be used for profiling?
3. Which team worker roles and gameplay styles the profiled students prefer?
4. How can these profiles be used in an agent-based simulation to find gamification approaches that improve collaboration in CSCL environments?

In the next section we review previous approaches to interaction analysis. In the section research method we detail our research setup, methods of analysis and research results. In the discussion section we consider the implication of these results, how these results can be applied to an agent-based CSCL simulation and present plans for future work. The paper finishes with the conclusion section.

INTERACTION ANALYSIS IN SOFTWARE ENGINEERING EDUCATION

The problem of analyzing classroom interactions into quantitative data has been commonly approached with interaction analysis in educational and pedagogical sciences and it inspects how people communicate with each other [28]. More specifically, interaction analysis is an interdisciplinary method for investigation of interactions of human beings [28].

The adoption of teamwork roles in CSCL software engineering education has been studied by Vivian et al. [29] and in this study they also introducing an approach for coding collaborative interactions in CSCL using team collaboration analysis roles defined by Dickinson and McIntyre [30]. Interaction analysis has also been used to examine student collaboration behavior by identifying common interaction patterns with k-means clustering and correlation analysis [31].

RESEARCH METHOD

In this study we observed 17 students over a five day long intensive format and collaborative software engineering course. The course had 10 hours of lecturing and 40 to 64 hours (depending on the student team) of collaborative teamwork around a set task. The topic for the course was to develop a new mobile or tablet application before Friday's deadline and the students had no other courses concurrently. The students spent their time in the same computer classroom, with each student team sitting at their own table group.

All student interactions that occurred in the classroom were recorded. The video and audio recordings were combined into multi-angle and surround sound videos that allowed the researchers reviewing the video to hear several concurrent interactions. This resulted in 40 hours of video, from which 3366 interactions were recorded for analysis. To gain additional information about preferred teamwork roles, the students were interviewed and were asked to fill surveys about their teamwork methods. All 17 students participated in the interviews and 15 students participated in the surveys.

The collected data was processed using interaction analysis, which produced a data table with timestamps, interaction initiator, interaction target, and interaction context like goal coordination or seeking help. The interview and survey results were used to gain teamwork preference profiles and these were combined with statistical and network analysis of student interactions. This resulted in combined profiles which contains Belbin teamwork inventory profiles [26], Bartle's gaming profiles [27], and interaction frequency distribution by action and target. The analysis results that is based on this data is presented in the following subsections.

Methods of Analysis

The main source of data for statistical and network analysis was interaction analysis based on the classroom interactions. The interactions were classified by using team communication methods defined by Dickinson & McIntyre [30] and further defined for use in CSCL by Vivian et al. [29]. These categories were originally meant for intra-team communications, but were adapted for all collaborative communications in this study.

To summarize, these interaction types are: *Team leadership*, which involves providing direction, structure and support for other team members. *Team orientation*, which refers to attitudes that members have towards one another and the team task. Social, non-professional communications were included under this category. *Monitoring*, which is observing other team members' performance or activities. *Coordination*, which involves process reporting and goal setting. Profession or learning related *communications*, which involves the exchange of information in a prescribed manner and by using proper terminology. Additional behaviors introduced by Vivian et al. [29] were also used: *Seeking*, *receiving* or *giving feedback* about performance and seeking help (*seeker*) or receiving help (*supporter*).

The list of analyzed interactions were collated, resulting in a frequency distribution of interactions by type and by interaction target for each person. These lists give individual communication profiles between the students, but it is not immediately apparent from these individual profiles if there are repeating patterns in the student interactions. To find these patterns k-means clustering was used, which is a statistical analysis method for automatically partitioning a dataset into a specified amount of groups [32].

In order to gain further insight of which kind of teamwork and gameplay the students would prefer, two different profiling methods were applied: Belbin's team work inventory [26] and Bartle's [27] classification of player types. Belbin's team role inventory divides the participants to three major categories (action, people, cerebral) and each of the major categories into three subcategories. Bartle's player type classification divides the player types into two separate axis: Whether the player prefers to act or interact, and whether the player prefers to interact with other players with the world. Players who act towards other players are called *clubs*, players who act towards the world are named *diamonds*. Players who interact with the world are named *spades* and players who interact with other players are *hearts*.

Analysis Results

3366 interactions were analyzed based on the student communication interactions, of which 81.79% were internal team interactions and 18.21% were to communications to outside the team (external). The most common internal interaction type was communication (42.93%) and the most common external interaction type was team orientation (7.90%).

K-means clustering analysis with Pearson's correlation coefficient as a distance measure resulted in four clusters of student profiles that share same communication behaviors. The average silhouette coefficient for the resulting clusters is 0.64, which means that the data points group well and the clusters are mostly distinct from each other [32]. These clusters are detailed in the Table 1, which lists the clusters CL1 to CL4, their members and the most commonly occurring profiles in these clusters. Individual team members are first labelled by their group alphabet and then their number within the group.

Table 1. Student Profile Clusters

Cluster ID (Nodes)	Belbin Profiles	Bartle Profiles	Most Common Internal Actions	Most Common External Actions	Members
CL1 (A4, B4)	Resource Investigator; Coordinator	Heart; Club	Communication (33.05%); Team Orientation (8.91%); Coordination (8.05%)	Communication (19.54%); Team Orientation (9.48%); Monitoring (7.66%)	2
CL2 (A1, A3, C1, D1, D2)	Coordinator; Resource Investigator; Team Worker	Heart; Club; Spade	Communication (32.26%); Monitoring (16.04%); Team Orientation (13.18%)	Team Orientation (11.61%); Monitoring (7.37%)	5
CL3 (A2, B3, D5)	Implementor; Monitor Evaluator; Resource Investigator	Diamond; Club	Communication (41.74%); Supporter (12.26%); Team Leadership (11.72%)	Communication (7.64%); Team Orientation (4.44%)	3
CL4 (B1, B2, C2, C3, C4, D3, D4)	Complete Finisher; Implementor; Plant; Team Worker	Diamond; Spade	Communication (54.65%); Team Orientation (10.77%); Coordination (7.62%)	Team Orientation (6.01%)	7

At a first glance the most common internal (int.) and external (ext.) actions in these profile clusters appear similar. However, when one looks at the distribution of all tasks, presented in the Figure 1, the specialties and differences in the clusters become more apparent. In the figure actions are sorted to internal team actions and external actions to other teams, with a bar in each category representing a cluster's activity in that category. The most active profile cluster in each category is additionally pointed out by its label. For example, only the Cluster CL3 exhibits leadership behaviors (*supporter* and *team leadership*) while the Cluster CL2 has most observation (*monitoring*) and social (*team orientation*) behaviors. Other immediately notable features are Cluster CL1 having most external professional communications (*communication*) to other teams while Cluster CL4 concentrates mostly on internal communications, except for external team orientation.

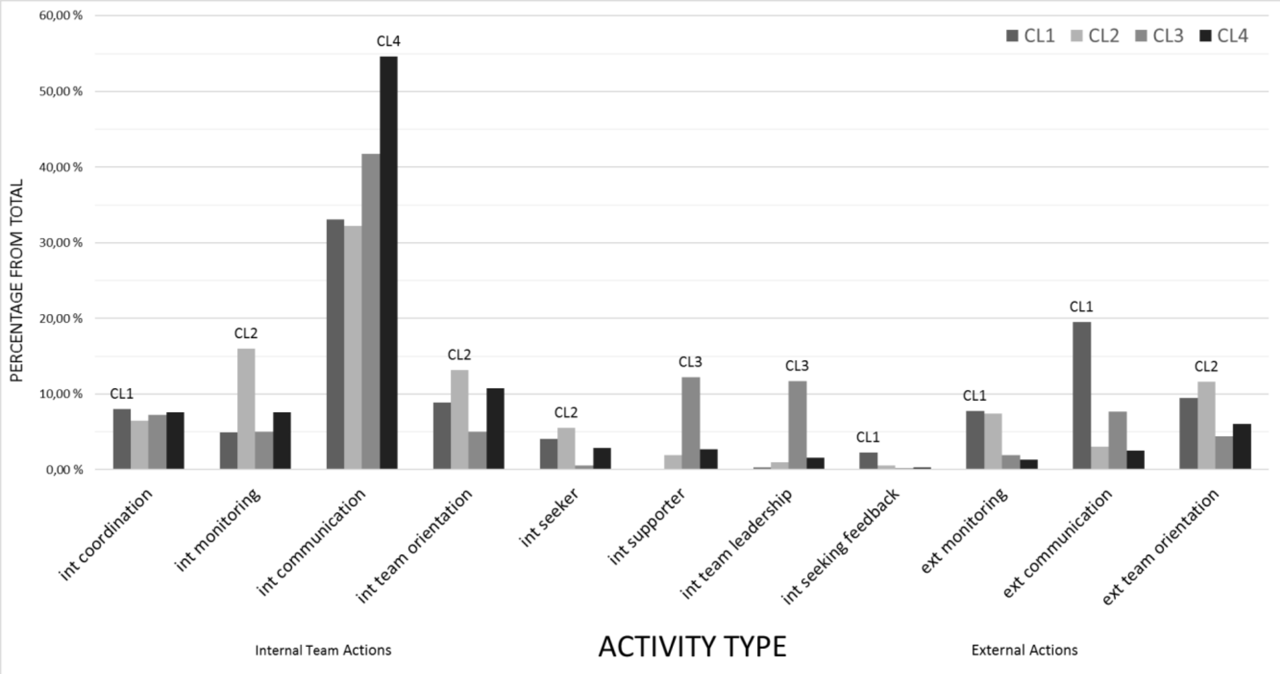

Figure 1. Profile Cluster Interaction Types

Discussion on Detected Profile Clusters

The most distinct profile types are in the Cluster CL3. These students identify themselves people who get things done (*implementor*), or critical, logical thinkers (*monitor evaluator*). However, in practice they exhibited most leadership and supporting actions. They also listened least to feedback and got least help. In short, these people could be characterized as people who want to get things done and have seized the opportunity to lead people towards practical goals. Their weakness is getting little input and advice from others. Their team could benefit from an approach where they are are encouraged to include others in project planning, resulting in more diversity in decision-making.

The second most distinct cluster is the Cluster CL2. These team members identify themselves as seekers of new information (*resource investigator*) or team organizers (*coordinator*). However, their Bartle profile *hearts* is more matching. They socialize and passively watch other students work instead of actively contributing. If these types of students could be encouraged to contribute the ideas and solutions they have observed, it would increase the flow of new ideas back to the team.

Clusters CL1 and CL4 concentrated most on professional communications, which essentially means that they mostly communicated about software engineering tasks at hand. The difference between these clusters are that the members of the first cluster also collaborated with other team members and members of the latter cluster concentrated almost solely on working with their own team members. This is also reflected in the survey answers. The more collaborative Cluster CL1 members identify themselves as more social or coordinator type of team workers, while the members of the Cluster CL4 are more goal-oriented.

DISCUSSION AND FUTURE WORK

Four distinct profile clusters were detected based on directly observed student interaction patterns. In many of the cases the students' Belbin and Bartle preferences match the observed actions, despite being based on the students' subjective views. In many gamification approaches abstract points or achievement levels are used as rewards [13], but game design can go beyond that. According to Bartle [27] there are four major player types that enjoy different activities and also different kinds of rewards in online or multiplayer games. For example, for an explorer (*spade*) type of player providing more areas to explore can be a better reward than showing a counter of explored areas.

This mirroring is of great interest and importance in the gamification process. In fact, the core idea of our research is to borrow approaches, methodologies and techniques from the field of (video) game design to create – and test – an engaging learning environment, able to foster cooperation among students, to promote positive behaviors and to impact on their overall learning performances. As a matter of facts, beside the "traditional" way to convey teaching, learning patterns have changed radically [33]: new generations are experiencing new forms of computer and video game entertainment and this has shaped their preferences and abilities, while offering an enormous potential for their learning [34]. The usefulness of games as learning tools is a well-known phenomenon, especially in the first years of our life [35]–[37], and it is demonstrated that games are able to guarantee high learning effectiveness in quite short time [23], [38], [39].

To exploit positive traits of games, we are planning to combine in different ways the building blocks used by game designers [25] to design and deploy one – or more – "gamified" learning environment(s) for students. The learning environment(s) will be built according to the following guidelines:

- The "game" should be alluring for different types of Bartle's player at the same time.
- We must take care that the "pattern" learned by the students-players will enforce their willingness to collaborate and their teamwork skills, independently from their Bartle type.

Once the gamified learning environment is in place, we are planning to run several activities to collect data in order to dis/prove our thesis. In particular, on one hand we will run experiments with small groups of real students in the area of Computer Science, both in Finland and in Italy. As a side effect, this will offer us the possibility to verify to what extent their cultural background has an impact on the perception of the playing experience. Moreover, we will develop and test a model mimicking the relationships among the students in the learning environment. This will be the basis to build a large-scale simulation to verify the effects on the composition of the student population (in terms of Bartle's types) deriving from variations into the structure of the gamified learning environment. The simulation will be run both from the perspective of achieving a higher degree of satisfaction for students and from that of providing leverages to the teachers, useful for affecting students behaviors (see e.g. Maggiorini, Nigro et al. [40] for similar approaches).

CONCLUSION

In this case study we studied software engineering student collaboration behavior, collated them into profile clusters with the k-means algorithm and found common behaviors among them. We also found possible points of improvement in the profile clusters' behavior and presented ways of how to address them with gamification methods. The profile clusters presented in the study can be used in an agent-based simulation to test gamification approaches described in the previous section, discussion.

The presented profiles combined with the simulation approach allow modeling how approaches and design techniques from the field of game design can be applied to gamified collaborative learning. These approaches and their usefulness as learning tools is well-known, but this far there has not been a systematic approach to create a modeling framework for gamification elements in collaborative learning settings.

The study results cannot be generalized yet because of the limited sample size, but the analysis method itself can be applied to other interaction studies [29], [31] with the steps detailed in this paper to gain additional and comparative profile material for the proposed simulation. Additionally, we present a plan for designing and implementing a gamified collaboration system, which can be used to test and validate the model.

REFERENCES

[1] Alaoutinen, S. et al. 2012. Experiences of learning styles in an intensive collaborative course. *International Journal of Technology and Design Education*. 22, 1 (2012), 25–49.

[2] Bartle, R.A. 2004. *Designing virtual worlds*. New Riders.

[3] Belbin, R.M. 2010. *Team roles at work*. Routledge.

[4] Bruffee, K.A. 1995. Sharing Our Toys: Cooperative Learning Versus Collaborative Learning. *Change: The Magazine of Higher Learning*. 27, 1 (1995), 12–18.

[5] Caillois, R. 1961. *Man, play, and games*. The Free Press.

[6] Coccoli, M. et al. 2011. Computer Supported Collaborative Learning in software engineering. *2011 IEEE Global Engineering Education Conference (EDUCON)* (2011), 990–995.

[7] Crawford, C. 2003. *Chris Crawford on game design*. New Riders.

[8] Csikszentmihalyi, M. 1991. *Flow: The Psychology of Optimal Experience*. New Riders.

[9] Dewiyanti, S. et al. 2007. Students' experiences with collaborative learning in asynchronous Computer-Supported Collaborative Learning environments. *Computers in Human Behavior*. 23, 1 (Jan. 2007), 496–514.

[10] Dickinson, T.L. and McIntyre, R.M. 1997. A conceptual framework for teamwork measurement. *Team performance assessment and measurement*. (1997), 19–43.

[11] Dillenbourg, P. 1999. *Collaborative-learning: Cognitive and computational approaches*. Elsevier.

[12] Dillenbourg, P. 1999. What do you mean by collaborative learning? *Collaborative-learning: Cognitive and computational approaches.* (1999), 1–19.

[13] Din, F.S. and Calao, J. 2001. The Effects of Playing Educational Video Games on Kindergarten Achievement. *Child Study Journal*. 31, 2 (2001), 95–102.

[14] Fullerton, T. 2008. *Game design workshop: a playcentric approach to creating innovative games*. CRC Press.

[15] 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.

[16] Gokhale, A.A. 1995. Collaborative Learning Enhances Critical Thinking. *Journal of Technology Education*. 7, 1 (1995).

[17] 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.

[18] Huizinga, J. 1950. Homo ludens. (Boston, 1950).

[19] Johnson, D.W. and Johnson, R.T. 1999. Making cooperative learning work. *Theory Into Practice*. 38, 2 (1999), 67–73.

[20] Johnson, S. 2004. *Mind wide open: Your brain and the neuroscience of everyday life*. Simon and Schuster.

[21] Jordan, B. and Henderson, A. 1995. Interaction analysis: Foundations and practice. *The journal of the learning sciences*. 4, 1 (1995), 39–103.

[22] Juul, J. 2003. The game, the player, the world: looking for a heart of gameness. *DIGRA Conf.* (2003).

[23] Kauffman, L. and Rousseeuw, P.J. 1990. Finding groups in data. *An introduction to cluster analysis. New York: John Willey & Sons*. (1990).

[24] Knutas, A. et al. 2013. Communication Patterns in Collaborative Software Engineering Courses: A Case for Computer-supported Collaboration. *Proceedings of the 13th Koli Calling International Conference on Computing Education Research* (2013), 169–177.

[25] Koster, R. 2005. *Theory of fun for game design*. Paraglyph Press.
[26] Maggiorini, D. et al. 2013. Resources Optimization in (Video) Games: A Novel Approach to Teach Applied Mathematics? *Learning and Intelligent Optimization*. Springer. 189–195.
[27] Maggiorini, D. et al. 2012. The Perfect Looting System: Looking for a Phoenix? *IEEE Conference on Computational Intelligence and Games* (2012), 371–378.
[28] Miller, G.A. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological review*. 63, 2 (1956), 81.
[29] Moccozet, L. et al. 2013. Gamification-based assessment of group work. *Interactive Collaborative Learning (ICL), 2013 International Conference on* (2013), 171–179.
[30] Okamoto, T. 2004. Collaborative technology and new e-pedagogy. *IEEE International Conference on Advanced Learning Technologies, 2004. Proceedings* (Sep. 2004), 1046 – 1047.
[31] Prensky, M. 2006. *Don't Bother Me, Mom, I'm Learning!: How Computer and Video Games are Preparing Your Kids for 21st Century Success and how You Can Help!* Paragon House New York.
[32] Resta, P. and Laferrière, T. 2007. Technology in support of collaborative learning. *Educational Psychology Review*. 19, 1 (2007), 65–83.
[33] Ritterfeld, U. and Weber, R. 2006. Video games for entertainment and education. *Playing Video Games. Motives, Responses, and Consequences. Mahwah, NJ: Lawrence Erlbaum Associates*. (2006), 399–413.
[34] Salen, K. and Zimmerman, E. 2005. Game design and meaningful play. *Handbook of computer game studies*. (2005), 59–79.
[35] Serçe, F.C. et al. 2011. Online collaboration: Collaborative behavior patterns and factors affecting globally distributed team performance. *Computers in Human Behavior*. 27, 1 (Jan. 2011), 490–503.
[36] Sheth, S.K. et al. 2012. Increasing Student Engagement in Software Engineering with Gamification. (2012).
[37] Squire, K. and Jenkins, H. 2003. Harnessing the power of games in education. *Insight*. 3, 1 (2003), 5–33.
[38] Susi, T. et al. 2007. Serious games: An overview. (2007).
[39] Vivian, R. et al. 2013. Analysing Computer Science Students' Teamwork Role Adoption in an Online Self-organised Teamwork Activity. *Proceedings of the 13th Koli Calling International Conference on Computing Education Research* (2013), 105–114.
[40] Zyda, M. 2005. From visual simulation to virtual reality to games. *Computer*. 38, 9 (2005), 25–32.

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REFERENCES

[1] K. A. Bruffee, "Sharing Our Toys: Cooperative Learning Versus Collaborative Learning," *Change Mag. High. Learn.*, vol. 27, no. 1, pp. 12–18, 1995.
[2] P. Dillenbourg, "What do you mean by collaborative learning?," *Collab.-Learn. Cogn. Comput. Approaches*, pp. 1–19, 1999.
[3] T. Okamoto, "Collaborative technology and new e-pedagogy," in *IEEE International Conference on Advanced Learning Technologies, 2004. Proceedings*, 2004, pp. 1046 – 1047.
[4] A. A. Gokhale, "Collaborative Learning Enhances Critical Thinking," *J. Technol. Educ.*, vol. 7, no. 1, 1995.
[5] D. W. Johnson and R. T. Johnson, "Making cooperative learning work," *Theory Pract.*, vol. 38, no. 2, pp. 67–73, 1999.
[6] P. Dillenbourg, "Collaborative-learning: Cognitive and computational approaches," Elsevier, 1999.
[7] P. Resta and T. Laferrière, "Technology in support of collaborative learning," *Educ. Psychol. Rev.*, vol. 19, no. 1, pp. 65–83, 2007.
[8] M. Coccoli, L. Stanganelli, and P. Maresca, "Computer Supported Collaborative Learning in software engineering," in *2011 IEEE Global Engineering Education Conference (EDUCON)*, 2011, pp. 990–995.
[9] S. Alaoutinen, K. Heikkinen, and J. Porras, "Experiences of learning styles in an intensive collaborative course," *Int. J. Technol. Des. Educ.*, vol. 22, no. 1, pp. 25–49, 2012.
[10] S. Dewiyanti, S. Brand-Gruwel, W. Jochems, and N. J. Broers, "Students' experiences with collaborative learning in asynchronous Computer-Supported Collaborative Learning environments," *Comput. Hum. Behav.*, vol. 23, no. 1, pp. 496–514, Jan. 2007.
[11] A. Knutas, J. Ikonen, and J. Porras, "Communication Patterns in Collaborative Software Engineering Courses: A Case for Computer-supported Collaboration," in *Proceedings of the 13th Koli Calling International Conference on Computing Education Research*, 2013, pp. 169–177.
[12] I. Glover, "Play As You Learn: Gamification as a Technique for Motivating Learners," in *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, 2013, vol. 2013, pp. 1999–2008.
[13] F. Groh, "Gamification: State of the art definition and utilization," in *Proceedings of the 4th seminar on Research Trends in Media Informatics*, 2012, pp. 39–46.
[14] L. Moccozet, C. Tardy, W. Opprecht, and M. Léonard, "Gamification-based assessment of group work," in *Interactive Collaborative Learning (ICL), 2013 International Conference on*, 2013, pp. 171–179.
[15] S. K. Sheth, J. S. Bell, and G. E. Kaiser, "Increasing Student Engagement in Software Engineering with Gamification," 2012.
[16] R. Caillois, *Man, play, and games*. Gelncoe, New York: The Free Press, 1961.
[17] J. Huizinga, "Homo ludens," Boston, 1950.
[18] J. Juul, "The game, the player, the world: looking for a heart of gameness.," in *DIGRA Conf.*, 2003.
[19] K. Salen and E. Zimmerman, "Game design and meaningful play," *Handb. Comput. Game Stud.*, pp. 59–79, 2005.
[20] G. A. Miller, "The magical number seven, plus or minus two: some limits on our capacity for processing information.," *Psychol. Rev.*, vol. 63, no. 2, p. 81, 1956.
[21] S. Johnson, *Mind wide open: Your brain and the neuroscience of everyday life*. Simon and Schuster, 2004.
[22] C. Crawford, *Chris Crawford on game design*. New Riders, 2003.

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[23] R. Koster, *Theory of fun for game design*. Paraglyph Press, 2005.

[24] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*. New Riders, 1991.

[25] T. Fullerton, *Game design workshop: a playcentric approach to creating innovative games*. CRC Press, 2008.

[26] R. M. Belbin, *Team roles at work*. Routledge, 2010.

[27] R. A. Bartle, *Designing virtual worlds*. New Riders, 2004.

[28] B. Jordan and A. Henderson, "Interaction analysis: Foundations and practice," *J. Learn. Sci.*, vol. 4, no. 1, pp. 39–103, 1995.

[29] R. Vivian, K. Falkner, and N. Falkner, "Analysing Computer Science Students' Teamwork Role Adoption in an Online Self-organised Teamwork Activity," in *Proceedings of the 13th Koli Calling International Conference on Computing Education Research*, 2013, pp. 105–114.

[30] T. L. Dickinson and R. M. McIntyre, "A conceptual framework for teamwork measurement," *Team Perform. Assess. Meas.*, pp. 19–43, 1997.

[31] F. C. Serçe, K. Swigger, F. N. Alpaslan, R. Brazile, G. Dafoulas, and V. Lopez, "Online collaboration: Collaborative behavior patterns and factors affecting globally distributed team performance," *Comput. Hum. Behav.*, vol. 27, no. 1, pp. 490–503, Jan. 2011.

[32] L. Kauffman and P. J. Rousseeuw, "Finding groups in data," *Introd. Clust. Anal. N. Y. John Willey Sons*, 1990.

[33] M. Zyda, "From visual simulation to virtual reality to games," *Computer*, vol. 38, no. 9, pp. 25–32, 2005.

[34] M. Prensky, *Don't Bother Me, Mom, I'm Learning!: How Computer and Video Games are Preparing Your Kids for 21st Century Success and how You Can Help!*. Paragon House New York, 2006.

[35] F. S. Din and J. Calao, "The Effects of Playing Educational Video Games on Kindergarten Achievement.," *Child Study J.*, vol. 31, no. 2, pp. 95–102, 2001.

[36] U. Ritterfeld and R. Weber, "Video games for entertainment and education," *Play. Video Games Motiv. Responses Consequences Mahwah NJ Lawrence Erlbaum Assoc.*, pp. 399–413, 2006.

[37] D. Maggiorini, S. Previti, L. A. Ripamonti, and M. Trubian, "Resources Optimization in (Video) Games: A Novel Approach to Teach Applied Mathematics?," in *Learning and Intelligent Optimization*, Springer, 2013, pp. 189–195.

[38] K. Squire and H. Jenkins, "Harnessing the power of games in education," *Insight*, vol. 3, no. 1, pp. 5–33, 2003.

[39] T. Susi, M. Johannesson, and P. Backlund, "Serious games: An overview," 2007.

[40] D. Maggiorini, A. Nigro, L. A. Ripamonti, and M. Trubian, "The Perfect Looting System: Looking for a Phoenix?," in *IEEE Conference on Computational Intelligence and Games*, 2012, pp. 371–378.

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