Gamification of a Software Engineering Course

and a detailed analysis of the factors that lead to it's failure

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***Abstract*—This paper describes the setup for a gamified classroom for the subject of Software Engineering. A series of papers have resulted from this work: "Understanding Student Motivation" at CSEDU 2013 [1] and "Bridging the Motivation Gap", an IGIP SPEED Young Scientist award paper here at ICL 2013 [2]. The intention behind gamifying the course was to increase student engagement and motivation by allowing for independent learning with flexible speed and choice of emphasis. Daniel Pink's [3] motivational theory, which is also found in gamification factors, outlines that autonomy, mastery and purpose lead to these goals. The adopted approach also deals nicely with the vast differences regarding background knowledge and the spread of interest of each of the students. During the latter part of the course a student survey was conducted. Out of 90 students, 59 answered. As a general rule, students did not receive the gamification ideas in a positive light. We examine what went wrong regarding the gamification factors and propose changes for the next iteration of the course.**

Keywords: motivation, e-learning, blended learning, gamification, software engineering, education

I. Introduction

This paper describes the gamification of a Software Engineering course offered during the second of three years towards earning a Bachelor Degree. The Cooperative State University of Baden Württemberg is based on a quarter system, where students earn salaries and combine work and study in alternating semesters. While at University, they sit in the same room for at least 5 hours a day, listening to frontal lectures in cohorts of about 30 students. This passive monotony leads to little engagement from the student body during class time. To improve engagement, the five hours of Software Engineering class were redesigned. The vast differences regarding background knowledge and the spread of interest was also addressed with the redesign. In order to achieve the goal of engagement, fundamental ideas, shown to be successful motivators in the area of gamification, were included.

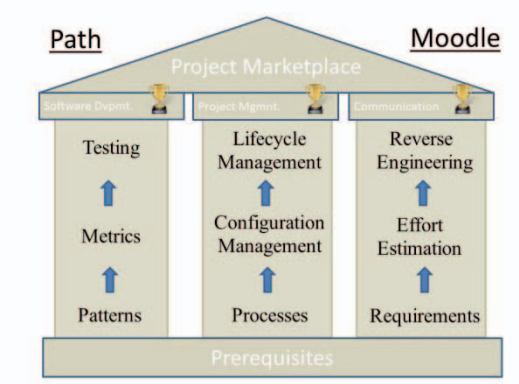
During the latter part of the course a student survey was conducted. Out of 90 students, 59 answered. As a general rule, students did not receive the gamification ideas in a positive light. A detailed analysis of motivational factors for this student body was previously published [1]. In this paper, we examine what went wrong regarding the gamification factors and propose changes for the next iteration of the course in order to be more successful in reaching the goal of having self-motivated, engaged learners. More detail about the redesign can be found in [2].

II. Theoretical Background

A. Content of Software Engineering

Topics covered in this Software Engineering course are structured into three pillars of three topics each: Software development (Design Patterns, Metrics, Testing), Communication (Requirements Specification, Effort Estimation, Reverse Engineering) and Project Management (Processes, Configuration Management, Lifecycle Management) and culminates in a project-based experience. This approach gives students enough time to learn all aspects of Software Engineering before applying the collective know-how in a project. The chosen topics are typical for Software Engineering courses as evident also in the current course books like Ian Summerville's Software Engineering [4].

Fig. 1. Topics sorted by Categories: Software Development, Project Management, and Communication.

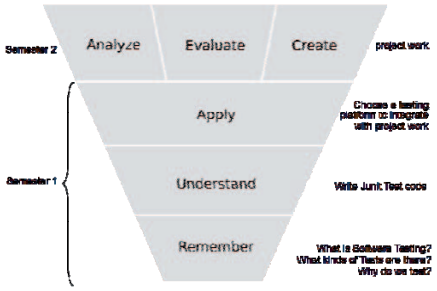


B. Pedagogy

Each of the topics above was further structured internally into cognitive levels according to Bloom's taxonomy, building towards higher level thinking skills. This approach has been used effectively in Computer Science in the past [5, 6]. At the knowledge level, students can arrange for a theoretical lecture on demand in the order depicted in Figure two in any of the three columns. In the lecture, terminology, facts, principles and theories are presented. An online exam with essay questions

tests understanding of the principles taught in the lecture. These exams can be repeated until mastery, with asynchronous feedback from the lecturer. They are the preparation for the theoretical exam at the end of the first semester.

Fig. 2. Bloom's taxonomy and the distribution of levels across semesters.



At the next two levels, work is done on the new concept to understand and apply it. For the example of software testing, as depicted in Figure 2, the lecture explains what the different types of software tests are, when they are performed and what they cover. At the next level, students then implement several unit tests for a given suggested code. At this point there is a clear answer to the problem to be solved. Finally, they choose a testing framework like *JUnit* for later use in their projects. This is an open problem as the students have their individual work environment into which they need to integrate a testing framework that may not be the same for all. For example testing for Android, Java or PHP clearly requires different tools, none of these are explicitly taught. The student has to independently find tutorials and make tool choices based on the theoretical foundation acquired in advance. In this point this particular course strays far from conventional courses the students attend where tools are prescribed and demonstrated in class, sometimes even provided preinstalled.

Apart from Bloom's Taxonomy and providing more high-level thinking problems than in years before of teaching this course, another key difference to the regular classroom was the timing. All material was provided online. There were nine frontal lectures for each of the topics. Unlike previous teachings, this time, any lecture was available to any student each week providing that they went in the order of the pillars from bottom to top, choosing the pillars in any order. Homework was exactly the same as in previous courses, preparatory quizzes were also identical. However, this time, the quizzes were given online and personal feedback was given to student answers. They were then allowed to retake the exam until they obtained full points. These are characteristics of gaming that will be explained next. Students determined their own speed through the material. Neither attendance nor speed of progress was enforced.

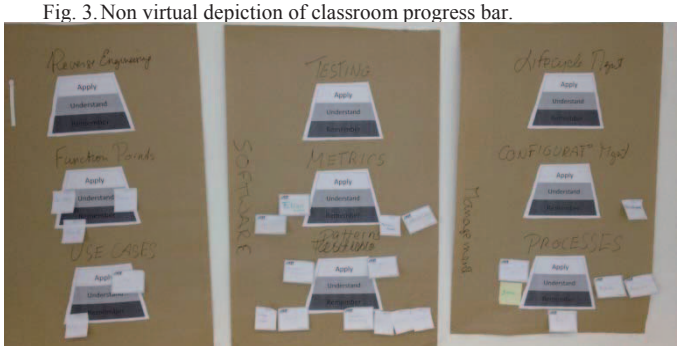
C. *Gamification*

Gamification is a controversial topic that has become ubiquitous in the business world since 2010 when the term was coined by the gamification community [7, 8].

One idea behind gamification is to understand which mechanics keep gamers motivated to come back to play and apply those constructs to non-game environments with the goal of encouraging similar engagement. Since these have been shown to work [9, 10, 11], some typical game mechanics and processes were chosen from the literature and incorporated into a web-app for the course.

According to positive psychology's theories about motivation [3, 12-16], humans are motivated to work on cognitively difficult tasks when they are granted **autonomy, purpose** and **mastery**. The course content was provided along a clear path with options of order and speed (autonomy) and a clear and rewarding goal (purpose) at the end. Along the way, students took exams that could be repeated (mastery) to validate understanding of the material and chart their own progress towards projects and exam preparation (purpose). Detailed analysis of game mechanics and the integration of motivation into the visible elements of a game was provided by Amy Jo Kim at Google Tech Talk, in 2009 [17]. Her analysis is taken into account in the design of the course. The various offerings cater to different personas, a progress bar is provided, leaderboards are shown, there are rewards for collaboration and acts of support among students are honored. An example of such a progress bar is shown in Figure 3 below. Three areas of study are shown with three subtopics each. The pyramid shows Bloom's levels within each topic. Post-it notes are students' names, indicating their location of study. Implementation of each of the game mechanics used will be explained in the next section.

Fig. 3. Non virtual depiction of classroom progress bar.



III. IMPLEMENTATION

Through a student project, co-author of this paper, an online interactive tool was provided to support the learning path with gamification aspects providing collaboration opportunities and keeping track of progress.

TABLE I. GAME MECHANICS AND DYNAMICS

Game Dynamics	Game Mechanics
~~Reward~~ Status Achievements Competition Altruism	Points Levels, Paths and Progress Challenges Immediate Feedback Leaderboards ~~Gifts & Sharing~~
Processes: Interaction with other people Clear path and progress bars Autonomy, Purpose, Mastery	

The application was built using the Vaadin framework, which is easy to work with and generates whole web applications in Java with little knowledge of HTML, CSS or JavaScript. While Vaadin was practical for the student who had to work under extreme time constraints, a Vaadin application can look like a desktop application, limiting the esthetic user experience. The finished platform implements some of the gamification components taken from the previously listed literature as shown in Table 1. Their integration will be described next.

A. Paths and Purpose

After logging in, the student chooses which of the three areas of study (see II.A) to start with (clear path and autonomy of choice). The goal is to complete two out of three subject areas in order to build enough knowledge to create a team and start a project (purpose). This kind of autonomy in moving through material at the students' chosen speed is possible due to the long lecture times given for each course. Since the class meets five hours each week and a lot of the work following the lecture is done independently, the lecturer can take the time to give presentations to smaller groups as they are ready for the material and are asking for the lecture. This simple act of having to ask for a lecture on a particular topic is a form of engagement that comes across to the lecturer, seeing students that are more active in asking questions in the smaller setting than in a full classroom.

The gamification platform is intended to support the students in visualizing where they are in the content, see their progress and find other students who are working in the same area or reward other students' with recognition for helping them. Figure 1 depicts the main screen that shows three topic areas, a classroom and a marketplace for advertising and joining projects.

Fig. 4. Main screen for "gamified" display of class content.

Additionally, students can view their class mates' progress in the classroom and send them messages (collaboration, competition, peer pressure). Levels are unlocked progressively with the goal of reaching the marketplace that is unlocked for those students who have completed two subject areas and are therefore ready to start forming teams and realizing their own project ideas.

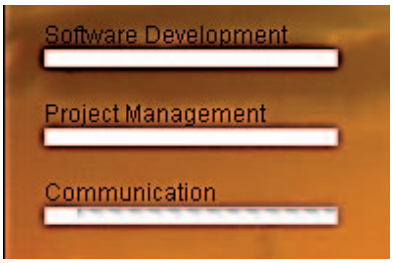
Students can see study areas on the map (the current level is highlighted in red) and can view their task by clicking on a location. At every location, one can see other students who are in the "room" or have mastered the material. Thus, a student can find peers to collaborate with. This "view" is augmented with the wall depiction as shown in Figure 3.

Fig. 5. Learning goals for a particular level with a "todo" checklicst.

B. Autonomy, Levels, and Progress Bar

In each learning area, students can see their tasks at their current level as shown in Figure 2. Once the student marks a level as completed, the next level (according to Bloom's taxonomy as explained in II.B) becomes unlocked.

Fig. 6. Progress bar visible from Profile page showing accomplishments of levels in each of the three areas of study.



C. Points and Heroes

With each completed level, students are earning points. To achieve a level, students can ask for help from other students who can gain points by helping. To support this functionality, a student can see who is currently working on the task and who has already completed in order to know who to ask for help. When completing a task the student can give credit to another student who has given support, thus granting recognition. That person's effort is then rewarded with points via the system. Such helper/experience points (XP) are displayed in a student profile (hero, altruism).

D. Peers, Interaction and Collaboration

In the classroom, students can see each other's profile and send their class mates messages. After successfully completing two study areas, students can post projects in the market place or apply for positions in existing projects, thereby forming teams for increasing long-term collaboration.

E. Personas

Various personas are taken into account during the design. Three main types can be distinguished based on the student author's experience over three years in the classroom.

The applied type: The applied type does not appreciate too much theoretical content.

Therefore, sections for applying learned knowledge is important for every topic. For this persona the autonomy that is provided by the platform to increase the time spent on the applied sections may come in handy.

The grade optimizer: The grade optimizing persona wants a good grade with the least possible workload.

The section "Remember" is most relevant for the exam and can be emphasized over application of the material in order to obtain the feeling of efficiency. In addition, the online exams provide lecture feedback and supports mastery.

The inquirer: The inquirer prefers content that is relevant for the job.

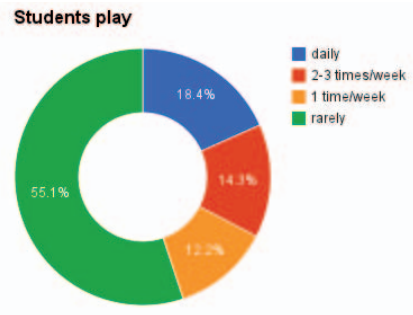
The autonomy provided by the platform, allows this persona to choose two out of three areas of study that are most closely related to interests at work at Mastery level. In addition, more time can be spent on the practical aspects of the course work if so desired since the speed of working through the material is individualized.

IV. Evaluation of Feedback

Feedback was collected through a built-in form within the application. The two co-authors of this work, a student and the lecturer, were in constant contact with students to gather feedback concerning the platform. Such feedback could then be applied to improving the platform as the course was progressing.

Feedback regarding the methodology of the course was done through a rather long survey, including a section about the gamification aspects. This survey resulted in quantitative and qualitative feedback from 59 out of the 90 participants. While the CSEDU paper focused on the motivational aspects of the results, this paper will emphasize the results concerning the gamification aspect and feedback concerning the platform that was employed. Several misconceptions regarding student view of gamification thus became apparent.

Fig. 7. Classroom gamer statistics.



A. Students are not gamers

First, students were asked about their attitude towards gaming. Despite general statistics about gamers [18], which states that 58% of Americans are gamers, this statistic does not seem to be replicated in these German University classrooms. The survey shows that only 18% of the students game daily while over half, 55%, play games less than once a week.

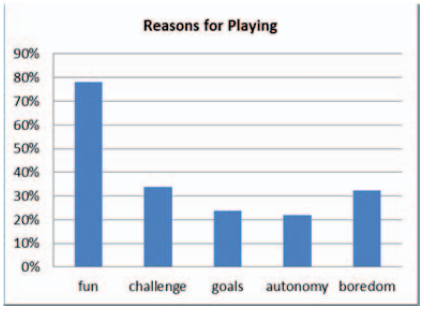
B. Few students play for "hard fun"

Students were then asked why they enjoy playing games. In the general literature the belief is that there is something called hard fun, which assumes that challenges and autonomy are part of what makes people want to play.

According to a study done by Nicole Lazzaro [19], there are four main categories of reasons to play: "Hard fun" (opportunities for challenge, strategy and problem solving), "easy fun" (intrigue and curiosity), "altered states" (internal pleasant sensations) or the "people factor" (social experience). "Hard Fun" frequently generates emotions and experiences of frustration, and "Fiero" (pride) and comes closest to what a gamified classroom could potentially achieve. Flow [20], the feeling of immersion and energized focus is the result of good balance between the perceived challenges and the student's perceived skill so that the task at hand is just right and lets the student concentrate actively with maximal motivation. Flow can be reached in the "hard fun" region of gaming where challenge is part of the fun factor.

In the questionnaire, a question asked whether students played for fun. To qualify further, students could also choose reasons like challenge and goals, these are the key contributors to hard fun. Autonomy, as a key important characteristic for gamers according to the mentioned literature was also listed as a possible response, where students could check all that apply. Around 70% or more of students explicitly did not think of challenge, autonomy or goal seeking as part of why they play games.

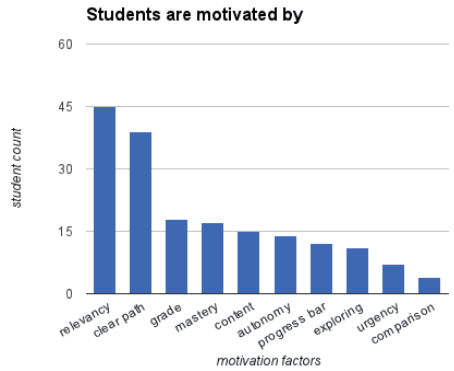
Fig. 8. Classroom gamer statistics.



The result from the survey suggests that the benefits of a game environment for the classroom are not evident to the students and would indicate a mismatch of expectations when using the nomenclature of gamification in context of the classroom. The very high value of rare gamers in combination with the high value of easy fun gamers suggests a connotation of gaming as a waste of time in such an outcome-focused environment as a University. The critical view of gamification is also reflected

by some freeform comments such as: “don’t focus that much on gamification stuff, not every [computer scientist] […] is a gamer!” or even more negative comments e.g. “don’t use this gamification …, it’s annoying and prevents students from learning”.

Fig. 9. Motivation factors for students

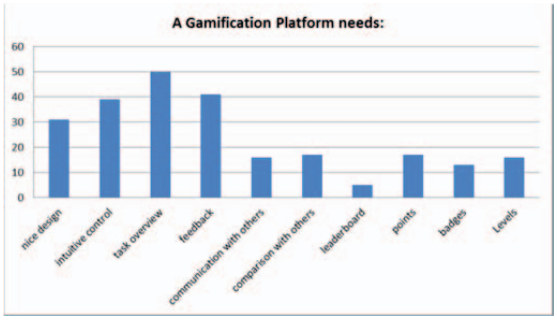


C. Games are not efficient – students are

Figure 9 shows motivational factors for students that clearly indicate that studying for the exam requires relevant material and a clear idea of what is going to be on the exam. Under such circumstances autonomy is not efficient enough, hence the lack of points given to those other factors. Autonomy also seems to make it superfluous to have a teacher or to even attend the class.

Looking at Figure 10, which shows what students are looking for in a gamified platform, it becomes more evident why the task overview is so important. In fact the only game aspects that are relevant are an intuitive control so that the tasks can be found efficiently and quickly. Looking at these results, none of the gamification elements would have been necessary or even made a difference to the students.

Fig. 10. What a gamification platform needs according to students



D. Students are not ready for this idea

The overall feedback concerning the platform had no clear consensus. The idea is ok (23%), with some changes useful (32%), only useful with significant changes (20%), and useless (25%). In a qualitative feedback round, students were asked for free comments about the gamification platform. There was relatively little feedback and the positive and negative views are balanced. As the case may be, gamification elements were not mentioned and not relevant in the feedback. Most of the remarks concern the ease of finding the information necessary to prepare for the exam.

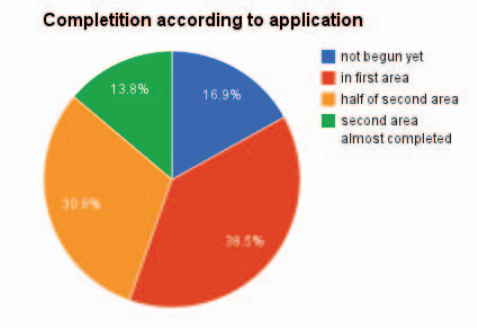
TABLE II. QUALITATIVE FEEDBACK FOR PLATFORM

Positive Perception	Negative Perception
Overview of current status (12)	Not useful (15)
Know what to do	I don’t care
Access to materials	I don’t know
New concept	I didn’t use it (3)
To-do list	Learned that normal classroom isn’t so bad
Learned to learn in another way	Platform is missing essential functionality
More motivated to reach the other levels	
More fun than usual (2)	

E. Self-regulation and planning are not self-evident skills

What is especially interesting is that towards the end of the semester, the pie chart in Figure 11 shows that only 13% of the students were moving towards finishing the necessary material for the exam that was coming up. The rest of the students were still in the middle or at the very beginning of the material. Even if perhaps a number of students were not using the platform, it was still evident from the classroom that there were students that were very far ahead of the time plan while others clearly did not know how to schedule their time effectively, or were not willing to do so.

Fig. 11. Course completion towards the end of the semester



V. DISCUSSION: CHANGE MANAGEMENT FOR INSTRUCTION TO LEARNING PRADIGM

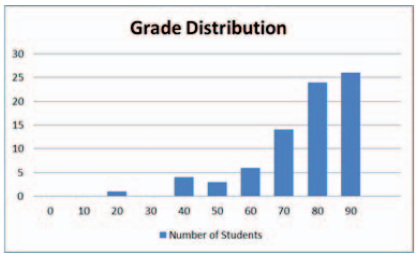
Part of the problem with the gamification platform was probably its lack of esthetic appeal that a professional platform would have brought. Nonetheless it was fully functional in aspects that could have easily been of interest, like the progress bar or finding which people had already mastered a particular level. Similarly, getting extra points and public recognition for helping others was fully functional and not utilized at all. There is still a strong culture of formal, traditional schooling. 12 years of working for grades in the environment of a classroom does not lead to growth in certain skills that are now very important at the college level and beyond. Tony Wagner [21] has been writing about how education has to change: Move away from individual achievement, stop penalizing mistakes because it

fosters risk aversion, stop catering to consumers and ask students to create, nurture inquisitiveness over grades. Knowledge today is free with Khan Academy and MOOCs, it is these thinking skills that will define the students' future. The problem is the change in teaching style is not seen as a relief by the student but rather as very painful and frustrating and no longer perceived as teaching but rather as an effort to self-teach, which is not why they came to university.

The learning paradigm described by J.Tagg [22] requires a rethinking of the teacher's role. Related blog writings about this shift from teacher-centered classroom to the student-centered classroom often focus on the shift in the teacher and the classroom layout. But given this experience, it seems that the shift is not such a welcome change to the comfortable student experience as expected.

Students did not seem to be ready for autonomy, mastery was not perceived to be relevant and the purpose of starting project work as well as good preparation for the exam seemed unattainable to the students. Gamification was viewed as unnecessary hindrance towards studying for the exams and self-regulation and the ability to schedule the material across the semester was lacking despite a number of proposed schedules that were suggested by the lecturer but not enforced. Even attending lecture was not enforced. This was not welcomed by all students, who were looking for that kind of structure. Much needs to be done in terms of creating a course that manages this kind of change in stages and creates a clear understanding of what this new environment entails and how it effects their transition from school to the work environment.

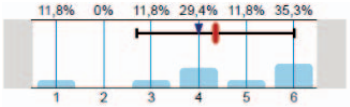
Fig. 12. Achievement in terms of student grades



VI. Conclusion

For the outcome oriented reader, grades may also be an important measurement of the course success. It is difficult to compare grades across groups as the test given to this class had more high-level questions than had been possible in previous years. However, looking at Fig. 12, the typical two-hump distribution that has been usual in past years has practically vanished.

Fig. 13. Student grading of teacher's pedagogical approach



In contrast, Figure 13 shows the student grading of the teaching style. Here, 1 is the best grade and 6 is the worst grade.

This was the first time gamification was tested in the classroom. Given the learning from this course, the most important changes will be to use gamification elements without naming them explicitly and to introduce change from traditional style classroom to learning environment very slowly. More details will be available in [2] at this conference.

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