The impact of opt-in gamification on students' grades in a software design course

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ABSTRACT

An achievement-driven methodology strives to give students more control of their learning with enough flexibility to engage them in deeper learning.

We observed in the course Advanced Software Design, which uses the achievement-driven methodology, that students fail to get high grades, which may hamper deeper learning. To motivate students to pursue and get higher grades we added gamification elements to the course.

To measure the success of our gamification implementation, students filled out a questionaire rating the enjoyment and motivation produced by the game. We built a statistical regression model where enjoyment and motivation explain 55% of the variation in grades. However, only the relationship between motivation and grade is significant, which implies that notivation drives the overall effect of the model. The results suggest that the more the students were motivated by the game, the higher their grades on the course (and vice versa). This implies that if gamification indeed motivates students, then it makes them go beyond what is expected.

CCS CONCEPTS

• **Applied computing** → **Education**; • **Social and professional topics** → *Software engineering education*; • **Software and its engineering** → *Unified Modeling Language (UML)*;

KEYWORDS

gamification, education, software design, UML

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1 INTRODUCTION

The course *Advanced Software Design* is built around the achievement-driven learning methodology [30] (more details in Section 2). This methodology gives students more control of their learning with enough flexibility to engage them in deeper learning [5]. Yet, year after year, although the course *Advanced Software Design* has increased in the number of students, we observed that students do not pursue higher grades. In this course, a higher grade implies the possibility of deeper learning, as students need to justify the design choices of the software-under-construction and they cannot just memorise solutions (Section 2 explains more details).

To motivate students to pursue higher grades and deeper learning, we designed a new opt-in game on top of the achievement-driven learning methodology, adding gaming elements such as leaderboard, cards and points. To answer whether the enjoyment and motivation provided by the game has an effect on grades we built a regression model that explains 55% of the variation in grades.

The paper makes the following contributions:

- Gamification of the achievement-driven learning method
- Evidence that students motivated by the game get higher grades
- Implementation experience.

2 THEORY

2.1 Achievement-driven learning methodology

The learning outcomes specified to help students succeed with their courses [4] are often necessarily at a high level, for instance to allow course content to change more fluidly, and thus arguably do not help students as much as they should. Five to ten goals might be specified for a course, but this does not tell a student what needs to be done to earn a specific grade. Indeed, often the learning outcomes can only be fully understood by someone who has completed the course.

To make these learning outcomes more achievable, comprehensible and accessible, Tobias Wrigstad and Elias Castegren [30] developed a new assessment technique, called *achievement-driven learning*, based on a more fine-grained collection of achievements, which taken together encompass the course's learning outcomes, but are more achievable when taken individually. The list of achievements makes more explicit what a student needs to master in order to pass the course, but also to achieve higher grades. In a sense, achievement-driven learning refines constructive alignment to the micro level and provides a means for linking learning outcomes with assessment activities—it aims to hit a sweet spot in the constructive alignment design space.

In achievement-driven learning, students are presented with a number of achievements (21 in Advanced Software Design) that need to be satisfactorily demonstrated to achieve each grade. Achievements are divided into 3 groups (3, 4, 5)[1], and students need to

[1] In many courses at Uppsala University, grades are given from a 4-point scale, U (fail), 3 (pass), 4 (pass with distinction), and 5 (pass with excellence).

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demonstrate all 3s to get a 3, all 3s and 4s to get a 4 and all achievements to get a 5. Demonstration of achievements involves a dialogue with a teaching assistant, which creates a reason to interact with knowledgable assistants beyond the usual correction of assignments and troubleshooting, and feedback comes naturally. Feedback, of course, enhances learning quality [17].

Achievement-driven learning adopts aspects of mastery learning [6]. Students are required to master all achievements specified for each given grade, and achievements must be retried until the teaching assistant is satisfied. This gives students freedom to fail, but also ensures that students passing the course do actually satisfy the learning outcomes—in contrast, grading schemes in which students only need to obtain a certain number of points do not guarantee coverage of the learning outcomes.

Typically, there are far too many achievements to demonstrate all individually during the time available (certainly, to obtain higher grades). To counter this, achievement-driven learning encourages students to see the relationship between multiple achievements, and to group and demonstrate them coherently together. Not only does this reduce their workload, it forces students to search for the connections between topics. Achievements can often be grouped vertically: level 5 achievements on a certain topic often encompass level 3 and level 4 achievements on the same topic—the quality of learning being demonstrated is the key difference. Achievements can also be grouped horizontally: a single presentation can be used to demonstrate achievements addressing different topics, assuming that students establish the relationship between the topics within their presentation. In a sense, achievement-driven learning forces students to solve a puzzle in order to optimise their time—similar to ideas underlying gamification [20]—and as a result they are compelled to explore the connections between concepts. The idea of vertical combinations of achievements is compatible with the requirement of the Bologna Process that greater *quality* of work **not** greater *quantity* earns higher grades [7].

Achievement-driven learning has a lot in common with self-regulatory learning, which sees successful learners as able to plan, set goals, organise, self-monitor, and self-evaluate [32], then the teaching assistant can stop the demonstration. Students are not only forced to plan, but they need to evaluate whether their plan will be good enough—although having a demonstration 'failed' does not directly affect a student's grade, only a finite number of opportunities to demonstrate are available. In general students need to reflect on their learning as a whole, and cannot simply hope to get by without engaging with the material. Students are forced to determine their own learning trajectory. Indeed, students are free to choose the most appropriate form of examination, avoiding examination formats that do not match the task at hand (e.g., a written exam for a software design process). Achievement-driven learning puts more responsibility on students for their own education, while providing more freedom in how they embrace the subject. To clarify for the student what she actually can do, thereby building both self-awareness and self-confidence, more so that an standard collection of learning outcomes, and flexibility motivates students to engage in deeper learning [5].

Achievement-driven learning is similar to Clark's approach based on Student Observable Behaviours (SOBs) [8]. SOBs are similar to achievements and software exists to support both schemes. A major difference is that achievement-driven learning compels students to combine achievements and understand the relationship between topics.

The achievement list is presented to students at the start of the course and it is made clear which ones need to be completed in order to get each grade (3, 4, 5). In this respect an achievement list resembles a grading criteria, and literature on the impact of good grading criteria on learning [23] is arguably applicable to achievement-driven learning. A key difference is the combination of achievement that students must explore to construct their own demonstrations.

2.2 Gamification

Gamification refers to the use of game elements in non-gaming environments [13]. Gamification in education is not a new idea [14, 18, 28] and courses that use gamification elements do not put the emphasis on the game, rather it uses the game as a motivational and driving factor. Thus, the most important benefit is its potential to increase students' motivation and engagement [26, 28]. There are two types of gamification: reward-based and meaningful [2]. Reward-based uses badges, leaderboards and achievements – external elements – as a way of measuring progress; meaningful gamification strategies try to find a connection with the participant – intrinsic motivation. From the psychological point of view, these match with extrinsic and intrinsic motivational factors [12, Ryan and Deci [24],Ryan and Deci [25]]. Motivation is *extrinsic* if an individual is motivated by external factors, e.g. recognition after completion of a task and *intrinsic* if an individual experiences joy when performing a task . The use of gamification in the learning process can trigger both extrinsic and intrinsic motivation, which could induce deep learning and higher grades.

Therefore we derive the following hypothesis:

H Motivation and enjoyment from gamification increases grades.

3 BACKGROUND

Advanced Software Design is a masters-level course taught in the Department of Information Technology at Uppsala University. The course covers topics such as object-oriented analysis and design, domain modelling, software architecture, class and object modelling, behavioural modelling, design patterns, GRASP principles, design evaluation, and design improvement/refactoring. The course does not involve any programming, and instead uses UML, text, and oral presentation as the means for recording and communicating designs. Students taking the course are expected to have a solid background in programming, in particular in object-oriented programming. The course offers 8–10 interactive lectures describing the material and a course-long project. Students form teams on their own (of 4 members and they are encouraged to diversify the team's skill set) and work together on the achievements. Teams get a fixed teacher assistant (TA) for the duration of the course. Each team has a weekly, thirty-minute-long meeting and feedback sessions with a TA. During the meetings team members are evaluated individually, i.e. some team members may pass an achievement while others will have to try again in the next meeting. The assessment scheme

Achievement Grade	Points
3	50
4	100

Figure 1: Number of points of each achievement. Students get *floor(points/100)* cards per meeting.

Category	Name	Overview
Attacks	Thief	Steal 20 points from leading team
	Master Thief	Steal 20 points from two teams
	Destroyer	Reduce 50 points of chosen team
	Longinus Spear	Impale up-to 3 teams, steal 20 points from each team
Shields	Safe pockets	Protection against Thieves
	Safe box	Protection against (Master) Thieves
	Self preservation	Protection against Destroyer
Others	Death note	Forbids chosen team from making a move
	Sell out	System buys card for 30 points

Figure 2: Cards available in the game.

for the project is based on achievement-driven learning [30], as described in Section Section 2.1. There is a total of 21 achievements[2]: 11 achievements of level 3, 9 achievements of level 4 and a single individual achievement of level 5. There is no exam.

4 METHODOLOGY

4.1 The Game

We developed a game of top of the achievement-driven learning methodology. This game uses points, leaderboards and cards and is played at a meta-level, i.e. the game is not related to the software design process but rather it uses the achievements passed by teams during the meetings as its internal structure, e.g. to give cards to a team so that they can use them to perform some special action in the game such as stealing points from other team. *Students earn points by passing achievements and by playing the game, but points won or lost in the game do not influence the number of achievements passed or the final grade.*

Students form teams and teams are place randomly in mini-competitions (made up of 4 teams) that are course-wide; the team with most points wins. Each achievement has a fixed number of points, linked to its level (Figure 1): students who pass achievements of level 3 get 50 points, students who pass achievements of level 4 get 100 points. Teams demonstrate their knowledge to the TA and gain the total sum of the points in the achievements that they successfully pass each week. The more points a team gets, the more cards a team can draw; teams draw *floor(number of points/100)* cards per meeting (cards are randomly drawn from an online number generator). Cards allow teams to attack to each other (subtracting points), steal points (subtract-and-gain points), block teams from using cards and even raise their own score (Figures 2 and 6). Each card has a priority number, which is randomly generated when students get a card, and this number establishes the order in which the cards are applied, within each round of the competition. Cards with higher priority number will be played before cards with a lower number. This system removes the advantage that some teams may get by scheduling meetings early in the week since the priority number is randomly generated.

Teams may decide to keep cards and use them all in the last meeting of the game or they may decide to play them as they come. Ultimately, the strategy is in their own hands.

Each week the TAs have meetings with the teams, who prove their knowledge presenting achievements and the teams get the corresponding points and cards. Teams tell TAs which cards they would like to use and the TAs collect this information (cards and their priorities). Based on this information, the TAs make up a story timeline of what happens when they applied the cards (based on their priorities), always trying to be funny and unpredictable as well as to encourage students when they put effort and performed well.

For example, the team *Yin Yang* passed at least 2 achievements of level 3 in week 46 (granting them a card) and they got a *Thief* card with a high priority number. They decided to use it that week, which led to the following comment in the story timeline:

> Yin Yang are sneaky and steal from (team) Number One, 20 points (using a Thief card). Number One is still on the lead, but not by far. This is going to be a tough competition.

An example of encouragement words to keep them motivated:

> Team Number One got 100 points again. They seem to have found the sweet spot to tick off achievements!

The story timeline shows the classification before and after the application of cards.

4.2 Gaming design

The game is optional and does not link the game to the final grade (avoids creation of parallel assessment routes [15]). If the students decide to not participate, the course takes place as in previous years. From the beginning, we told students that they have nothing to lose and they should try the game.

The main idea was to foster competition, motivation, engagement and higher grades with the introduction of the gaming elements (points, a leaderboard and cards). As mentioned before, students form teams placed randomly in mini-competitions; the use of mini-competitions serves to keep teams always close to each other, preventing a team being put in a far-from-the-top position, which can be discouraging [19].

To make the game appealing, we added the card system and we release new cards each week, to prevent stagnation. The introduction of cards and leaderboard for the mini-competition introduces extrinsic motivation [31].

To counteract the fact that students have meetings at different times during the week, the game is not played in real time, but

[2]Link to the the overview, achievement goals and requirements: https://goo.gl/CNLLLg

cards are played at the end of each week based on a random priority assigned to the cards, as explained in Section Section 4.1.

Finally, we created a story timeline, so that students know why they get different points from the ones collected during the meetings (due to attacks, shields, etc).

In terms of platform, we used Google Spreadsheets[3] with three tabs:

Leaderboard: contains the leaderboard and the rules
Timeline: contains the timeline for each mini-competition
Cards: contains the number of cards, which ones have been just released and clear explanation

The main reason for using Google Spreadsheets was that it is simple to use, platform agnostic (no need to commit to any platform) and let us connect Google Analytics to gain further insights.

5 EVALUATION: QUESTIONNAIRE AND VARIABLE MEASUREMENT

As part of evaluating the gamification methodology students were asked to answer two questions about their experience with the game. First, we asked to which extent they enjoyed the game, which became our independent variable "Enjoy". Students answered on a Likert scale from 1 ("Not at all") to 5 ("Loved it"). Second, students reported on a Likert scale from 1 ("I didn't bother") to 5 ("I tried to get as many as possible") to which degree the game competition motivated them to get more cards, which became our independent variable "Motivation".

Our dependent variable "Grade" was computed from 2 to 5, 2 being suspended, 3 being pass, 4 being pass with distinction, and 5 being pass with excellence. The boxes "Enjoy", "Grade" and "Motivation" (Fig. 3) show the distribution and frequency of responses for our 3 variables.

Questionnaire responses were anonymous within teams, meaning that we could not identify individual responses or names within teams, except for 3 individuals who got different grades than their team members and were personally asked whether they wanted to share their answer for data matching purposes.

6 RESULTS AND DISCUSSION

Statistical analyses were performed using R version 3.5.0.

71 students answered the questionnaire providing 71 observations without missing data. Table 1 shows descriptive statistics of our 3 variables, including means, standards deviations, skewness and kurtosis scores. The Pearson correlation matrix in Table 2 shows that both "Motivation" and "Enjoyment" are positively correlated with our dependent variable "Grades". The correlation between the two independent variables is below 0.90, meaning that we do not seem to have issues with multicollinearity. The scatterplot matrix (Figure 3) confirms furthermore that the relationships between our 3 variables are linear. For example, the upper right box shows a linear correlation between "Motivation" on the x-axis and "Enjoyment" on the y-axis.

Results of our linear regression analysis (Table 3) show that "Enjoyment" and "Motivation" explain 55% of the variance in students' grades. The critical cutoff value of the F-distribution at a 5% significance level is 3.13. Since our F-value of 41.39 is larger than 3.13, we can conclude that our model fits the data well. However, only the relationship between "Motivation" and "Grade" is significant (t-value 3.20, $p<0.01$), which implies that "Motivation" drives the overall effect of the model. The relationship between "Enjoyment"

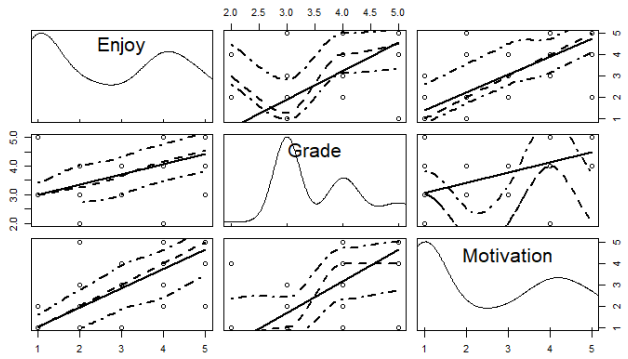

Figure 3: Scatterplot matrix

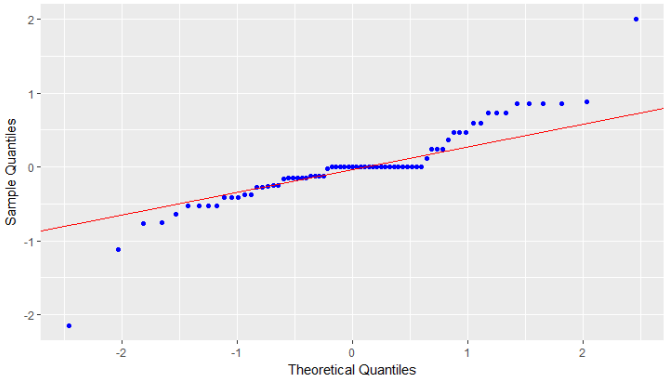

Figure 4: Normal QQ plot

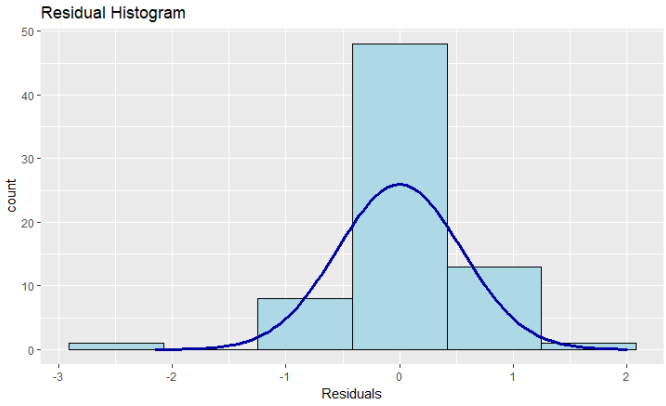

Figure 5: Residual histogram

[3]https://goo.gl/iZLS5p

	vars	n	mean	sd	median	trimmed	min	max	range	skew	kurtosis	se
Enjoyment	1	71	2.79	1.57	3	2.74	1	5	4	0.10	-1.60	0.19
Motivation	2	71	2.65	1.64	2	2.56	1	5	4	0.22	-1.67	0.19
Grade	3	71	3.65	0.81	3	3.60	2	5	3	0.39	-0.91	0.10

Table 1: Descriptive statistics. *sd* stands for *standard deviation* and *se* for *standard error*

	Enjoyment	Motivation	Grade
Enjoyment	1.0000000	0.8659292	0.6927165
Motivation	0.8659292	1.0000000	0.7313952
Grade	0.6927165	0.7313952	1.0000000

Table 2: Pearson correlation

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.61479	0.13519	19.342	< 2e-16 ***
Enjoyment	0.12307	0.08442	1.458	0.14949
Motivation	0.26054	0.08067	3.230	0.00191 **
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 0.5535 on 68 degrees of freedom Multiple R-squared: 0.549, Adjusted R-squared: 0.5358 F-statistic: 41.39 on 2 and 68 DF, p-value: 1.741e-12				

Table 3: Regression analysis

	W	p-value
Residuals	0.89516	2.223e-05

Table 4: Shapiro-Wilk normality test

and "Grade" is not significant. The results suggest that the more the students were motivated by the game, the higher their grades on the course (and vice versa). Consequently, our hypothesis is partially confirmed.

Tests for normality indicate that our residuals deviate from a normal distribution (Shapiro-Wilk test: p-value < 0.05, Table 4 and residual QQ plot, Figure 4). However, the residual histogram shows that the distribution looks symmetric and bell-shaped (Figure 5). The impact of non-normality depends on both distribution and sample size [16]. According to [16], small sample sizes below 50 observations might be problematic, while larger sample sizes increasingly cancel out violations against normality. Given that our sample size is 71, we believe that results from our regressions are still accurate despite non-normality of the residuals.

7 IMPLEMENTATION EXPERIENCE

In this section we discuss our experience when using gamification elements in the course Advanced Software Design, focusing on:

- Time to create a game
- Designing a game for maintainability
- Educational laws and games
- Gamers need help
- Implementation.

Category	Name	Overview
Wisdom	Mini-turn (retired)	Get 15 min extra feedback
	Extra turn (not available)	Get 15 min extra to tick off achievements
	E-Deadline (not available)	Get 24h to re-submit after feedback from TA
Others	Eavesdrop	Show hand (cards) of all teams

Figure 6: Problematic cards. Cards retired from the game are marked as *retired*. Cards that were in the released schedule but never went live are marked as *not available*.

Time to create a game. Creating a fair game is no easy task and requires *plenty* of time. Fairness means that the best team should win. You should plan with enough time to come up and design your gaming elements. In our setting, gaming elements are cards and points, whether to play in real time or using a priority system and its consequences, among other things. Do not underestimate the time that it takes to write unambiguous game rules and ask for feedback on the wording. From our experience, we were a diverse group of TAs (one Spanish, one Chinese and one Vietnamese) and the game rules were more understandable after a common discussion.

Designing a game for maintainability. We wanted to create an engaging game that, together with the course, could be maintained by two TAs working full time (120 h for the duration of the course, 10 weeks) and one TA working a maximum of 60 h. To do this, teams should *not* be able to get too many cards per week or the game would not be maintainable. The non-maintainability comes from playing actions (using cards), which need a story and to keep track of the order in which each action is taken. For this reason, we tested playing a few hands and we settled on *floor(number of points/100)* cards per meeting (Figure 1). Writing the story timeline and keeping the scores up-to-date per action takes at least two hours per mini-competition and we had 5 mini-competitions. Each TA was responsible for writing their teams story timeline. Overall, our feeling is that the gamification of the achievement-driven methodology is very TA intensive, although manageable if well planned.

Educational laws and games. Regarding the cards and their utility, we had more cards than the ones that were available (Figure 2 and 6). Wisdom cards were particularly problematic (Figure 6): the card *Mini-turn* had to be retired after the second week due to its potential unfair treatment to students, i.e. some students could receive more feedback than others. (This is not allowed under the Swedish Educational Law.) Based on the same principle, cards *Extra turn* and *E-deadline* were going to be released later on but never

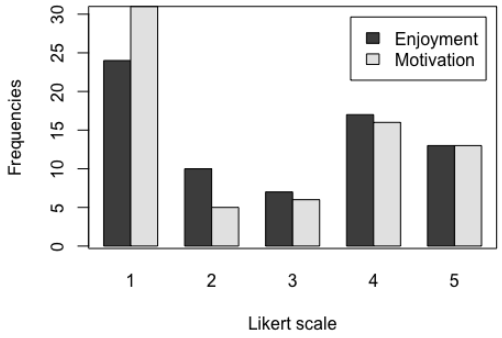

Figure 7: Histogram showing students enjoyment and motivation by the game. Numbers from 1–5 represent the Likert degree (1 lowest, 5 maximum).

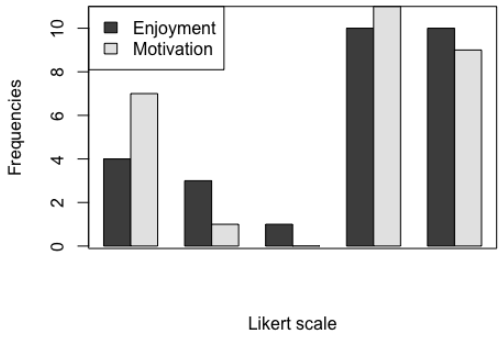

Figure 9: Histogram showing students enjoyment and motivation by the game, with support from TA. Numbers from 1–5 indicate the degree (1 lowest, 5 maximum)

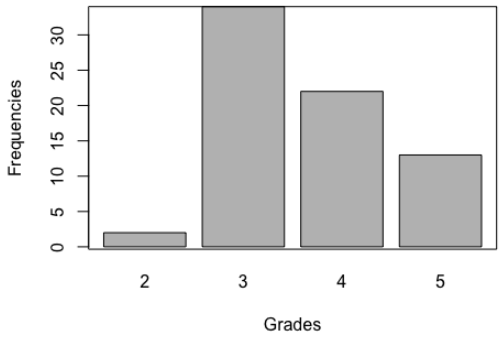

Figure 8: Histogram showing students grades

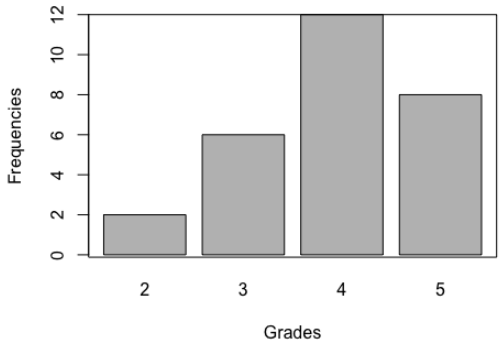

Figure 10: Histogram showing students grades when the TA provides support during the game

saw the day of light. One needs to be careful when designing and implementing a game and know the educational laws of the country in which the course takes place.

Gamers need help. One thing to improve was to be consistent in how we encourage and support students to play the game. TAs were instructed to encourage students to play the game. One TA added 10 extra minutes per group meeting to provide support to students by answering questions regarding the game, cards and leaderboard score. The result was that most of his students were engaged, highly motivated by the game and they got better grades (overall result in Figure 7 and the overall grades in Figure 8; subset of students with support from the TA in Figure 9 and their grades in Figure 10).

The other TAs did not add these 10 extra minutes to their meetings and, when students asked questions regarding the rules and cards, they referred the students to the online documentation. These students did not participate in the game that much and some teams thought that the achievement-driven learning methodology was already too complex to add a game on top of.

Implementation. During the game competition we observed that fostering competition makes students go beyond what is expected to lead the classification; something that was also discovered in a previous study [28].

Summary. Creating a game takes time and we recommend not to take this lightly [21]. In the integration of your game and course, always think about the effort that the gamification elements entail, i.e. adding game elements that are easy to integrate with your course and that you can maintain. The game should be easy to understand, or students will not make the effort to play. Finally, make sure that the game satisfies the educational laws of your country (check them!).

8 LIMITATIONS AND THREATS TO VALIDITY

A limitation of the study is related to the use of cross-sectional data, as we cannot claim causality of the effects of gamification. However, given that students filled out questionnaires before they knew their grades helps us to infer that motivation most likely affected grades, and not that better grades made students more motivated. Regarding construct validity, another limitation might have been the use of one-item measures for our independent variables.

Another threat to validity refers to the achievement-driven methodology applied to a software design course: TAs were trained to evaluate software designs and welcomed to talk to the main lecturer in case of doubts regarding designs. However, whether team members pass or fail an achievement is completely subjective to the TA's opinion. Regarding the encouragement and support from the TAs (to students) to play the game, the TAs come from different cultures and the way they provide encouragement and support may be differently shown. This could affect the validity of the subsection *Gamers need help* (Section 7).

9 RELATED WORK

In our case, the steps to the gamification of the course closely follow the suggested guidelines by De Paz [10]. Points of departure were related to issues outside of our control, such as, gathering team members and knowing your players. In the former, the TAs have the knowledge but we lack experience (consistency between TAs, Section 7). In the latter, the course takes Swedes and international students and students come from different backgrounds, which made difficult finding a unifying game that could satisfy them all.

The achievement-driven learning [30] uses gamification to force students to solve a puzzle in order to optimise their time. This work extends achievement-driven learning, introducing explicit gaming elements to foster competition, engagement and the possibility of deeper learning.

Gamification of computer science courses that add gaming elements often use points, leaderboards and badges and report on higher engagement from students [1, 9, 22, 27, 29]. Instead, our work uses similar gaming elements although we measure whether gamification elements induce higher grades.

The gamification of a course does not always succeed, even when one adds leaderboards, points and other gaming elements, as noted by K. Berkling et al [3]. In this paper, we report mixed feelings from students (Figure 7), where we found two extremes, students who loved the game and students who didn't like it. However, we found that adding 10 extra minutes to discuss the game mechanics can have a huge impact on the motivation, enjoyment of the game and students' grades (Figures 9 and 10, Section 7).

We report our implementation experience, something that de Sousa Borges argues is often forgotten [11]. In this regard, our experience coincides with O'Donovan's work [22], that is, the creation of a game takes time. O'Donovan's report that the gamification of a course can incur in high (monetary) costs, as they hired a programmer and designer to create a game. In our setting, we used a platform-free software, i.e. the free Google Excel Sheet.

10 CONCLUSION

We have added gaming elements to the *Advanced Software Design* course, based on the achievement-driven learning methodology [30], to motivate students to get higher grades. The gaming elements provide enjoyment and motivational factors. We have built a regression model where enjoyment and motivation explain 55% of the variation in grades, whereby motivation drives the overall effect of the model, meaning that students who were motivated by the game also got higher grades. The link between enjoyment and grades, however, was insignificant. A future research direction could be to further explore the motivational factors that drive higher grades. Are students motivated intrinsically or extrinsically by opt-in gamification elements? What is it that drives motivation when it comes to gamification? If enjoyment, which was insignificant in our model, is indeed an intrinsic motivational factor, as suggested by [25], our results suggest that intrinsic motivational factors may be less likely to influence students' grades after all. Our results provide a hint that extrinsic motivational factors in form of achievements may be more important in students' motivation. However, future research is needed to corroborate those suggestions.

Finally, we report on the implementation of the game and remark that adding 10 extra minutes per meeting can potentially have a positive effect on students enjoyment, motivation of the game and thus, higher grades.

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