Proceedings of the 52nd Hawaii International Conference on System Sciences | 2019

Increasing Knowledge Retention through Gamified Workshops: Findings from a Longitudinal Study and Identification of Moderating Variables

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Abstract

Apathetic and poorly motivated students require educators to redesign their educational measures in order to create inspiring learning environments. One such educational measure is gamification, a new tool for active learning to improve students' motivation, with the ultimate goal of increasing knowledge retention. In this paper we investigate the effects of gamification on short- and long-term knowledge gains. Moreover, the moderating effects of gender and school type are scrutinized. We conducted a longitudinal study with 384 students using three assessments at different times and compared the results from gamified and non-gamified workshops. Our findings indicate that gamification is an effective tool to increase students' knowledge retention in the short term, but not necessarily in the long term. There was no significant effect of gender, but we found some preliminary evidence that school type might have a moderating effect on knowledge retention.

1. Introduction

Previously, researchers have lamented that "the challenge of teaching has increased when faced with increasingly apathetic students and diverse learning styles" (p.101) [54]. In particular, the so-called generation Y, referring to people who were born between 1980 and 2000, is hard to motivate with traditional teaching methods. Despite continuous efforts by education professionals to select novel and innovate teaching methods, many students perceive traditional schooling as boring and ineffective [24] and prefer engaging and interactive learning activities [46] [35].

In 1995, [14] found that traditional teaching does not foster students' capability to solve problems autonomously or transfer learning content to new situations. Educators have consequently identified a need for novel teaching methods which tackle the challenge of efficient knowledge transfer, student engagement, and transferability of the course contents. Furthermore, they should also equip students with problem solving skills. Experiential learning is considered as a potential solution to address students' motivational problems and to increase students' problem solving skills by increasing their level of involvement [14] [24][39].

Games and gamified activities represent a form of experiential learning and constitute an alternative to traditional forms of learning. Gamification is a promising approach to fostering intrinsic motivation [16], making learning more engaging [48] and increasing students' knowledge retention [1][27][39]. By applying game design elements in non-game contexts [8] [37] [49], gamification takes advantage of the growing popularity of playing games in different settings [45]. Previous studies have shown that the educational use of games and game elements triggers students' active learning processes, which subsequently improves their knowledge retention [21].

In recent years, gamification has been frequently applied to create highly motivating learning environments that help to overcome the lack of student interest and to increase students' knowledge retention levels [11]. However, rigorous empirical research on the effectiveness of gamification in educational environments and its impact on knowledge retention is still scarce [11] [18] [27]. This especially pertains to the question of whether gamification has the potential to positively influence students' knowledge retention. Moreover, the potential moderating effects of gender and school type are often neglected.

In this paper, we examine the potential of gamification to make education more appealing and effective. In particular, we strive to answer the question of whether students are better able to recall course content after participating in gamified workshops as opposed to their traditional counterparts. To this end, an experiment was conducted comparing the knowledge retention performance of two groups of workshop participants,

URI: https://hdl.handle.net/10125/59586
ISBN: 978-0-9981331-2-6

as well as examining the moderating effects of gender and school type.

The remainder of the paper is organized as follows. First, the existing literature on the application and effects of gamification in education is reviewed. Next, we briefly outline our hypotheses, describe the methodology, and present the results. Finally, the paper ends with a discussion, several limitations, as well as some concluding thoughts.

2. Gamification and Education

The term "gamification" was first used in 2008, but only gained widespread adoption in academia and the industry from the year 2010 onwards [45]. Gamification is defined as *"the use of game-design elements in any non-game system context to achieve one or more of the following: intrinsic and extrinsic user motivation, facilitated information processing, better goal achievement, and behavioral changes" [49]*.

Popular game design elements—so-called motivational affordances—include, for example, points, badges, leaderboards, competition, immediate feedback, and time constraints [9][28][49]. The concept of gamification substantially differs from playing games. Whereas the former employs specific game elements in contexts which are otherwise unrelated to play, the latter describes full-fledged games for all kinds of purposes (e.g., education) [11].

Positive effects of gamification have been identified in fields such as diverse as health [42][44], crowdsourcing [30], and technology adoption [48]. Additionally, the concept has been previously applied for educational purposes [21][27][38]. A review paper conducting a systematic mapping study of empirical papers on gamification found that most published studies had been conducted in the context of education [17].

Previous research shows mixed, but predominantly positive effects of gamification on cognitive and behavioral outcomes. Gamification supports learning processes and offers great potential to improve students' motivation as well as to enhance engagement [15]. According to [43] (p. 347) the aim of gamification in education is to "extract the game elements that make good games enjoyable and fun to play, adapt them and use those elements in the teaching processes. […] Learning must not be a boring activity while gaming is fun. Learning can be fun if students learn as if they were playing a game." In order to achieve this, game elements need to be deployed in such a way that students are able to retain the learned content and apply the learning experience outside the game context [29]. One approach to gamifying the teaching experience is to include elements of games that have been part of the students' lives since early childhood [2].

Additionally, gamification has been shown able to increase students' engagement as well as extrinsic and intrinsic motivation [1]. This has important implications for motivational research, since students that are intrinsically motivated tend to have a higher level of in-class participation and achieve better results [6].

Existing empirical studies on gamification in education focus mainly on engagement and motivation as outcomes for learners [34]. Although gamified teaching techniques have been shown to be suitable in areas such as the military, retail organizations, computer service providers and manufacturing organizations [21], little research has been conducted on gamification and knowledge retention [1][27]. Research specifically addressing the question of whether gamification can lead to increased knowledge retention remains scarce to this day. A notable exception is an empirical study with more than 100 participants which found that gamification has a positive impact on students' knowledge retention [1].

In addition, research on the effects of gamification applied in a workshop setting is fairly new. A notable exception, [20], compared gamified workshops with non-gamified ones in terms of their capacity to generate innovation. The results indicate a higher capability for self-learning in the gamified group.

3. Hypotheses

A sustained increase in knowledge is the main goal of all educational measures. It is therefore highly desirable that the substantive content is fully understood and retained by the students for as long as possible after the educational event [13][32]. In this paper "short term" refers to the period of about 20 minutes immediately following the workshops and "long term" refers to the point in time two weeks after the workshops [13].

The forgetting curve [13] has been the subject of intense scholarly discussions regarding the measurement of knowledge retention [32]. It postulates a 100% recall immediately after a learning event and indicates that memory retention corresponds to about 58% of the total content after 20 minutes, which corresponds to the second assessment in our study. After two weeks the retention rate is predicted to be about 25% [13][32]. By providing an

indication of students' ability to recall content over time, the learning curve provides a benchmark in the learning literature against which to assess actual observations.

Gamification is frequently applied in marketing and education with the aim of encouraging specific behaviors and increasing engagement and motivation. It has previously been used for teaching purposes to help educators broaden the variety of teaching methods to motivate students [19][38]. Gamification is intended to engage students in an interactive setting, leading to better memorization [5][16][21] [38].

A literature review and a systematic mapping study on gamification in education identified a positive impact in the majority of studies [11]. A particular finding was higher levels of student engagement and motivation in gamified settings. Gamified teaching resulted in active participation, more project engagement, increased attendance, and a higher proportion of students passing the course.

An experiment comparing a non-gamified and a gamified group found that gamification led to positive results including an increase in class participation and course success [10]. Moreover, students evaluated the gamified course better than its non-gamified counterpart.

Summarizing the findings from previous research, we postulate that gamification is a suitable tool for enriching exhausting full-day workshops since students face a huge amount of learning content and need to stay concentrated and focused over an extended period of time. More specifically, we hypothesize that students in the gamified group are able to retain knowledge better than students in the non-gamified group.

H_1: In the short term the gamified group achieves better knowledge scores than the non-gamified group

H_2: In the long term the gamified group achieves better knowledge scores than the non-gamified group

The study of gender differences in cognitive functioning and knowledge gains has a long tradition, with partially conflicting results. [7], for example, emphasize the need for the design and use of gender-specific didactics to better meet the different learning requirements of female and male students. [51] show that female students have a higher study-oriented learning culture than male students, which positively influences knowledge accumulation. Several studies suggest that female students perform better in terms of knowledge gains than their male counterparts [22][36][51]. Gender-specific performance, however, seems to depend on subject matter: while males outperform females on tasks of visuospatial ability and mathematical reasoning, females show better results in tests involving memory and language use [12][26]. [25] conclude that male students are more sensitive to resources that create a learning-oriented environment and that these resources can facilitate their commitment in learning. [23] find that female students appreciate the social benefits arising from gamification more than males. Since there is no conclusive evidence of the moderating effect of gender on memory retention through gamification, we hypothesize:

H_3: Male and female students perform equally

Previous research has found significant differences in students' learning orientation by school type. Students attending vocational schools achieve lower scores than students attending other school types, which might be caused by the learning environment [22][51]. Compared to students engaged in higher education, vocational students spend less time on theoretical learning and instead focus on advancing their practical abilities. A self-selection process may also play a role, since better grades are needed for entry into higher educational programs than vocational schools [3]. It is therefore hypothesized:

H_4: Higher educational students outperform vocational school students in terms of knowledge retention

4. Methodology

We used an experimental design in order to investigate whether significant differences in knowledge retention exist between students who participated in a gamified full-day workshop and students who were not exposed to gamification during their workshop participation. The questionnaire used to measure students' knowledge—Table 4 in the appendix—featured questions of varying complexity, and was developed in close cooperation with the industry to ensure its practical applicability. The scales were pre-tested in three workshops with a total of 131 students to ensure their understandability and validity.

Our pilot study further showed that the separation of students coming from the same class into different testing groups led to social interaction threats and resentful demoralization [50]. In order to achieve a high level of internal validity in this study, it was

essential that students and teachers did not know that there was another group which received an alternative treatment [50]. Classes as a whole were therefore randomly assigned to either the non-gamified or the gamified group.

To ensure comparability in terms of educational levels, all participants were recruited from the second year of tertiary educational programs at Austrian institutions (i.e., vocational schools and higher educational institutions). A substantial number of students attend these school types at a later career stage, which explains the broad age range of the sample.

The study included a gamified and a non-gamified workshop group. Measurements were taken at three points in time using identical questions: immediately before (observation 1: O1), 20 minutes after (O2), and two weeks after (O3) the workshops.

The aim of the workshops was to train logistics students on sustainable transport by combining theoretical and practical knowledge. The gamified and non-gamified workshops had the same duration, identical learning goals and educational material. Both workshops were organized as full-day events lasting from 9:45 am until 3:45 pm. The instructors of the workshops stayed the same in order to eliminate any moderating impact by the instructor.

The program and the interactive tasks were also identical in both workshops. Whereas the gamified workshops included multiple motivational affordances (e.g., competition, leaderboards, badges, time constraints, storytelling, immediate feedback, rewards, clear goals, social interaction) [49], the non-gamified workshops did not include any game elements. For example, the students had to do the same calculations in each group, but only received points for correct solutions in the gamified workshops. Students in the gamified group also received bonus points for accomplishing each task, such as finding the correct solution in a simulation game. All tasks were embedded in a "story" (i.e., a case) to use the motivational advantages of storytelling as a game element [21]. Competition between the gamified groups was encouraged by leaderboards. Grouping students into teams served to reduce the negative effects of competition at an individual level and to support social interaction [40][41]. The detailed gamified and non-gamified workshop programs can be found in the appendix in Table 5. Table 6 details the game elements that were used during the gamified workshop. Some elements, such as leaderboards, immediate feedback, clear goals, competition and cooperation, were used throughout the whole day, while others (i.e., time constraints, storytelling, rewards) were only applied in specific sessions.

5. Results

In total, 384 students participated in the study, with 261 assigned to the gamified group and 123 to the non-gamified group. The latter simultaneously served as a control group in our experimental design, since their "treatment" resembles common teaching practices in educational settings. The students were slightly older in the non-gamified group (m = 23.88, sd = 9.47) than in the gamified group (m = 18.73, sd = 4.15). Gender distribution in the total sample was balanced with 194 female and 190 male students. In the non-gamified group, 73 students were from vocational schools and 50 students from higher educational institutions. Due to large class sizes in higher educational institutions, it was not feasible to include these students in the gamified workshops, which required more interaction than the non-gamified events.

A Mann-Whitney U test showed that knowledge levels did not differ significantly between the gamified and the non-gamified group prior to the workshops (p = .39, U = 7,383). Additionally, we found that the age difference had no significant effect on the level of prior knowledge. The demographics are shown in Table 1.

Table 1: Demographics

	Gamified	**Non-gamified**	**Total**
Age	m = 18.73 (sd = 4.15)	m = 23.88 (sd = 9.47)	m = 20.38 (sd = 6.79)
Gender			
male	161	29	190
female	100	94	194
School type			
vocational	261	73	334
higher education		50	50

In the following sections we use several non-parametric tests for hypothesis testing in order to accommodate the properties of our data (e.g., distributions, skewness, ordinal level of measurement, unequal sample sizes). In order to verify the robustness of our findings we also applied parametric tests and obtained identical results. The latter are not reported in this paper due to lack of space.

Table 2 shows the descriptive results of the knowledge measurements for vocational school students only. Since not all students completed the

assessments, the total numbers do not fully correspond to the number of all workshop participants in Table 1.

We conducted the first analysis with vocational students only in order to avoid a distorting effect of the school type and to account for our relatively small sample of higher educational students.

The maximum score attainable for the knowledge questions was 11. We found that the mean score in the first assessment was quite low (m = 3.59, sd = 1.55), which confirmed the novelty of the topic for both groups. The scores improved substantially immediately after the workshops (m = 6.74, sd = 2.90). As expected, knowledge levels had declined after two weeks (m = 5.33, sd = 2.08), but the scores were still significantly better than those of the initial assessment. The comparison between the gamified and the non-gamified group showed that the values in the gamified group increased from 3.62 (sd = 1.48) in O1 to 7.10 (sd = 2.19) in O2 and decreased to 5.39 (sd = 2.13) in O3. In contrast, the scores in the non-gamified group were 3.47 (sd = 1.77) in O1, 5.49 (sd = 2.17) in O2 and 4.97 (sd = 1.77) in O3.

To test whether the knowledge improvements between O1 – O2 (short term) and O1 – O3 (long term) were significant, we used a dependent samples Wilcoxon signed-rank test. The results show a significant difference between O1 and O2 ($Z = -1.97$, $p<.01$) and between O1 and O3 ($Z = -9.13$, $p<.01$) for the gamified group. Similarly, the results for the non-gamified group were significant ($Z = -6.38$, $p<.01$ for O1 to O2 and $Z = -3.50$, $p<.01$ for O1 to O3).

Table 2: Knowledge mean values and standard deviations across groups (max = 11)

	Gamified mean, sd, no	Non-gamified mean, sd, no	Total mean, sd, no
O1	3.62 (1.48), 240	3.47 (1.77), 66	3.59 (1.55), 306
O2	7.10 (2.19), 234	5.49 (2.17), 68	6.74 (2.9), 302
O3	5.39 (2.13), 207	4.97 (1.77), 37	5.33 (2.08), 244
m	5.37	5.24	5.30

In order to test H_1 and H_2, which postulate a significant positive effect of gamification in the short and long term, we used a non-parametric independent samples Mann-Whitney U test. This test showed that the scores in the first assessment were not significantly different between the gamified and non-gamified group ($U = 7{,}883$, $p = .390$). In the second assessment, the gamified group outperformed the non-gamified group, corroborating H_1 ($U = 4{,}583$, $p < .01$). In the third assessment, the mean value in the gamified group (m = 5.39) was higher than that in the non-gamified group (m = 4.97), but no significant difference between the groups was found ($U = 3{,}357$, $p = .114$, H_2 rejected).

A frequency analysis revealed that 69.7% of the students in the gamified group achieved more than six points out of eleven in assessment 2, as opposed to 35.5% of the non-gamified group. 9.9% of the gamified group achieved ten or eleven points, as opposed to 1.5% in the non-gamified group. In O3, no student of the non-gamified group achieved nine or more points whereas 6.4% of the students from the gamified group achieved nine or more points. 29.5% of the gamified and 24.3 % of the non-gamified group achieved more than six points in O3.

Figure 1 illustrates the effect of the gamified and non-gamified workshops and shows that both workshops clearly outperform the benchmark from the forgetting curve postulating that after two weeks the retention rate will hover around 25% [13] [32].

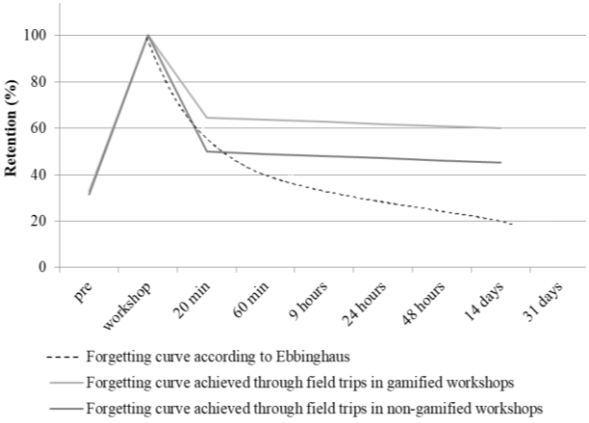

Figure 1: The impact of gamification on knowledge retention

In order to test for significant differences between genders we used a non-parametric independent samples Mann-Whitney U test. We found no significant differences in any of the three assessments, thereby corroborating H_3. In the first assessment, the male students slightly outperformed the female students, but the results were not significant (gamified: $U = 6{,}320$, $p = .292$; non-gamified: $U = 314.50$, $p = .624$). In the second assessment the male students had higher scores in the gamified group while the female students had higher scores in the non-gamified group, but, again, the results were not significant (gamified: $U = 5{,}813$, $p = .148$; non-gamified: $U = 366$, $p = .909$). As was predicted by [13], the amount of memorized knowledge had decreased after two weeks for both groups, with no significant gender effect (gamified:

U = 5,620, p = .300, non-gamified: U = 518, p = .409). The results are summarized in Table 3.

Table 3: Knowledge across genders

	Gamified mean		Non-gamified mean	
	female	male	female	male
O1	3.51	3.68	3.43	3.62
O2	6.88	7.25	5.51	5.39
O3	5.58	5.26	5.15	4.50

Finally, we analyzed the differences between school types in the non-gamified workshop to explore whether school type might qualify as a potential moderator in future research. In the first assessment (O1), no significant difference was found between higher educational and vocational school students (U = 6,660, p = .20). However, immediately after the workshops (O2, U = 4,888, p < .01) and two weeks later (O3, U = 3,197, p < .01), students from higher educational schools exhibited a significantly better performance than those from vocational schools. The results are supported by previous empirical studies, determining that higher educational school students have different learning orientations than vocational school students [51]. Thus, H_4 is supported.

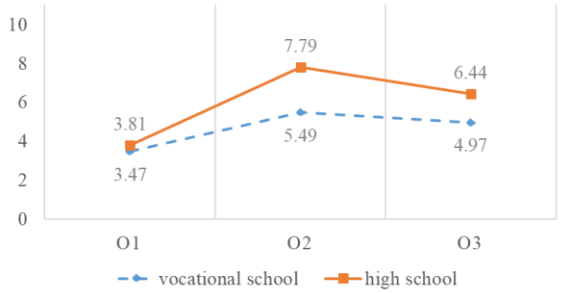

Figure 2: Knowledge retention between school types

6. Discussion, Limitations & Conclusion

In this study, we investigate whether the use of game elements in educational workshops leads to improved knowledge retention. Furthermore, we tested gender and school type as potential moderating variables.

We compared a gamified with a non-gamified group, both of which attended workshops with identical content, but which featured different designs. Prior to the workshops, no significant knowledge differences were found based on gender or school type. However, several differences emerged in the second and third assessment, both between and within the groups.

We found that both the gamified and non-gamified workshops led to a significant increase in short-term and long-term knowledge. Student knowledge had increased substantially directly after the events and remained at a significantly higher level after two weeks as compared to the initial state.

When it comes to comparing the gamified and the non-gamified group, the former outperformed the latter in the short term, indicating that gamification can be suitable to improve short-term memory retention. A descriptive frequency analysis indicates that the participants of the gamified workshops were also slightly better at recalling knowledge in the long-term (i.e., after two weeks), but no statistically significant effect was found.

No significant differences were found between male and female students in any of the comparisons, even though the female students had slightly higher scores in the long term than the male students.

Finally, our experiment showed that higher educational school students achieved better knowledge retention than vocational school students. This effect was predicted by existing literature and previous empirical studies [3]. However, since the school types were only compared within the non-gamified group, with no data being available for the gamified group, further research is needed to investigate if the results also hold when educational measures are gamified.

It is important to mention that we treated gamification in this study as a collection of game elements and did not investigate the specific underlying mechanisms that explain its effects on knowledge retention. For example, [31] argue that gamification can trigger emotions which in turn exert positive effects on knowledge retention.

As a practical implication, we strongly encourage educators to incorporate game elements into their teaching routine in order to foster students' knowledge retention levels. When designing gamified workshops, the didactical methods for covering content have to be chosen carefully with consideration of the demographics of the target group. According to flow theory [4], for example, information and learning aims must be adapted to the age and educational background of the participants with the goal of achieving an adequate level of difficulty that is neither too easy nor too hard.

This study has several limitations. We randomly assigned classes, rather than individuals, to the gamified and non-gamified groups, since our pre-test showed that the division of existing groupings

influences student behavior and produces social threats to the study's validity [50].

Furthermore, this study was conducted in Austria and various cultural differences might influence the results [47]. Moreover, as the focus of the workshops was specifically to create awareness for sustainable transportation, further research is needed to investigate whether the application of gamification to workshops also improves knowledge retention in other areas.

Additionally, the composition of the gamified and non-gamified samples was not equal because of class-wise assignment. Due to organizational reasons, students from higher educational schools were only included in the non-gamified workshops and therefore our hypothesis regarding the moderating effect of school type was only tested within the non-gamified setting.

The focus of this study was exclusively on knowledge gains pertaining to memorization skills. Other types of capabilities such as mathematics, language, or social skills were not measured. Also, different learning types or gaming types were not considered.

According to [33] and [41], individual game elements should be analyzed and not the gamification concept as a whole. Since the experiment was designed using gamified full-day workshops as whole, the investigation of isolated game elements could not be implemented. Finally, several of the measurement scale items were slightly modified from their original and demonstrated formats in order to fit the specific purposes of this study. We used several rounds of pretesting to ensure the content validity of the items, but further research is needed to assess the psychometric properties of our scales [53].

Our study reveals multiple opportunities for future research. We treat gamification as a black box, since we only consider gamification as input and knowledge retention as the educational output. Future studies may delve deeper and strive to find more detailed explanations. A possible approach would be to include and test the effect of gamification on hedonic outcomes as mediating factors. Additionally, it might be worthwhile to closely investigate the motivational and learning effects over a longer time period. Qualitative interviews can be used to get a better understanding of the underlying drivers.

Moreover, investigating differences between learning types (e.g., [55]) or gaming types is another promising direction for further research. The focus of our study was exclusively on knowledge gains depending on memorization skills. Other types of capabilities such as social skills or general intelligence were not measured. Further empirical research is needed to ensure the generalizability of the results and to better understand how knowledge acquisition using gamification differs from traditional learning techniques. We also suggest the thorough investigation of the effect of school type in a gamified setting.

Finally, the positive effects of gamification in education are not only limited to its ability to improve knowledge memorization, but also to enhance social and practical skills such as problem solving, collaboration, and communication. Thus, future research might also have a closer look at how gamification can facilitate social dynamics [29]. Finally, a strong theoretical background for gamification research, as is suggested in [49], will help to better integrate new research with previous findings and to create an incremental research agenda.

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Appendix

Table 4: Questionnaire

Question	Grading
Which is the largest European inland port in terms of total cargo volume? (single choice)	1 point for correct answer
What percentage of the modal split was used for inland waterway transport in Europe in 2014? (open question: 0-100%)	1 point for correct answer
Which of the following types of goods are appropriate for inland waterway transport? (multiple choice)	1 point = one answer correct 2 points = two answers correct; 3 points = all answers right (all scores = 3 points) 1 point deduction for every incorrect answer
What percentage of the potential cargo volume of the Danube are currently used for freight transport? (open question: 0-100%)	1 point for correct answer
Which of the following key characteristics describe the new logistics concept of 'synchromodality'? (multiple choice)	1 point = one answer correct 2 points = two answers correct; 3 points = all answers right (all scores = 3 points) 1 point deduction for every incorrect answer
What was the total cargo volume transported in 2014 in the European Union on inland waterways? (single choice)	1 point for correct answer
How many trucks are substituted by one common inland vessel of the Danube? (open question)	1 point for correct answer

Table 5: Schedules of the gamified & non-gamified workshops

Non-gamified Workshop		Gamified Workshop	
09:45-10:00	Assessment (O1)	09:45-10:00	Assessment (O1)
10:00-12:00	Traditional Lecture 'Inland Waterway Transport'	10:00-11:00	Interactive Lecture 'Inland Waterway Transport'
		11:00-11:30	Transport Calculation
		11:30-12:00	LEGO Simulation Game
12:00-12:15	Container Quiz	12:00-12:15	Container Quiz
12:15-13:00	Break	12:15-13:00	Break
13:00-13:30	Transport Calculation	13:00-14:00	Future Transport Ideas
13:30-14:00	Demonstration of Simulation game		Award Ceremony
14:00-15:00	Company Visit, Port visit	14:00-15:00	Company Visit, Visit of the Port
15:00-15:20	Break	15:00-15:20	Break
15:20-15:45	Assessment (O2)	15:00-15:45	Assessment (O2)

Table 6: Game elements in the gamified workshop

Gamified Workshop		Game Elements
10:00-11:00	Interactive Lecture	Time Constraint
11:00-11:30	Calculation	Time Constraint
11:30-12:00	LEGO Simulation Game	Storytelling Time Constraint
12:00-12:15	Container Quiz	Time Constraint
13:00-14:00	Future Transport Ideas Award Ceremony	Storytelling Time Constraint Rewards: Price & Badges
Whole day (in each exercise)		Leaderboard Immediate feedback Clear goals Competition & Cooperation