The Wear Out Effect of a Game-based Student Response System

ABSTRACT

The Bring Your Own Device (BYOD) wave and advancement in technical infrastructures and in learning technology opens for new ways of teaching in the classroom. The teachers' laptops connected to a video projector, access to wireless network and the students' smartphones, tablets or laptops can be utilized to enhance the interaction between the teacher and students, as well as boost the students' motivation, engagement and learning. The introduction of new learning technology in the classroom normally results in immediate enthusiasm and excitement both from the teacher and the students. However, the immediate positive effects might fade when the new learning technology has become familiar to the teacher and the students. This paper shows the results from investigating the wear off effect of using the game-based student response system *Kahoot!* in classroom teaching. More specifically, it compares the results from students using Kahoot! for the first time in a single motivational lecture vs. using Kahoot! in every lecture in a class for five months. The quasi-experiment focused on how the students' perception changed in relation to user-friendliness, engagement, motivation, classroom dynamics, concentration, and perceived learning. The results show a slight reduction in the students' motivation and engagement, but the only statistically significant wear out effect found was related to classroom dynamics. At large, the game-based student response system managed to boost students' engagement, motivation and learning after using it repeatedly for five months. The core factor to keep the students attention after heavy repeated usage was found to be the competitive nature of Kahoot!.

Keywords: Game-based Learning; Interactive learning environments; Student-Response Systems; Evaluation

1. INTRODUCTION

The Bring Your Own Device (BYOD) wave and advancement in technical infrastructure and in learning technology, opens for new ways of teaching in the classroom. In 2012, Gartner said that BYOD is the most radical shift in enterprise client computing since the introduction of the PC. A survey from 2013 showed that more than 85 percent of 500 educational institutions in UK and US (K12 to college/university) allowed some form of BYOD (Bradford-Networks 2013). The survey also showed that the devices were increasingly being integrated into the classroom and learning experience. The advancement of BYOD in schools provide a foundation to make the classrooms fully interactive – enabling students to interact with the teacher and learn subjects in new ways. The classical way of providing classroom interaction has been offered through student response systems (SRS) providing the students with handheld devices commonly called “clickers”, “key-pads”, “handsets” or “zappers” (Caldwell 2007). These devices have typically been devices that resemble a TV-remote where students can give their response to a question posed by the teacher or displayed on a large screen. As most students now have their own mobile digital devices, the clicker-devices have become obsolete. The main benefit from BYOD in schools is to remove the costs and effort to administrate and maintain special devices, as well providing interactive classroom tools that provide better a user experience. In this article we will use the term student response system (SRS) for these interactive classroom systems but note that other names are commonly used such as class response systems, audience response systems, personal response systems or electronic response systems.

James Paul Gee argues that well-designed video games are learning machines (Gee 2003). Further he argues that schools, workplaces and families can use games and game technologies to enhance learning. The idea is that when you learn through games, you are so engaged and motivated that you are learning even you are not aware of it. Games have been found to be beneficial for academic achievement, motivation and classroom dynamics in K-12 (Rosas, Nussbaum et al. 2003) as well as for higher education (Sharples 2000). Games can mainly be integrated in education in three ways (Wang 2011): *First*, traditional exercises or tasks be replaced by letting students play motivating games giving the teacher an opportunity to monitor the students progress in real time (Foss and Eikaas 2006, Ke 2008, Sindre, Nattvig et al. 2009). *Second*, game development can be used to learn other subjects like design patterns (Gestwicki and Sun 2008), literacy (Owston, Wideman et al. 2009), software architecture (Wang and Wu 2011), computer science (Distasio and Way 2007), and mathematics and physics (El-Nasr and Smith 2006). *Third*, games can be made an integrated part of a traditional classroom lecture to improve learning, motivation and engagement (Carver Jr, Howard et al. 1999, Carnevale 2005, Wang, Øfsdal et al. 2007, Wang, Øfsdal et al. 2008, Wu, Wang et al. 2011).

This paper focuses on the latter. Kahoot! is a game-based student response system that transforms temporarily a classroom into a game show. The teacher plays the role of a game show host and the students are the competitors. The teacher's computer connected to a large screen shows questions and possible answers, and the students give their answers as fast and correct as possible on their own digital devices. A distribution chart of how the students have answered is shown between questions. The chart is useful for the teacher to get feedback on how much the class knows about a topic and opens an opportunity to explain better the parts where students lack knowledge. Between each question, a scoreboard shows the nicknames and scores of the top five students, and at the end of the game a winner is announced. Kahoot! uses playful and colorful graphics and audio to increase the engagement. Based on observations and feedback from teachers using Kahoot!, the main difference between a game-based student response system (GSRS) and an classical student response system (SRS) is the energy and engagement the gamification creates.

Bringing game-technology to the classroom can pose some challenges. When Kurt Squire introduced Civilization III in his history class, many students complained about the game being too complex and difficult, and they did not understand why they should play a game in a history class in the first place (Squire 2005). For his students, it took some time before they actually understood that they learned something from the game. At the other end of the spectrum, introducing simple learning games can spark immediate enthusiasm that later fades away as the students have to repeat the same tasks over and over again. Boredom in computer learning environments is shown to be associated with poorer learning and problem behavior (Baker, D'Mello et al. 2010). Baker et al.'s study also found that frustration was less associated with poorer learning. This study shows how important it is that a GSRS keep students engaged, not only the first time it is introduced but also for repetitive usage over time. Tom Malone's theory of intrinsically motivating instruction lists three categories to make things fun to learn: *Challenge* (goals with uncertain outcomes), *Fantasy* (captivate through intrinsic or extrinsic fantasy), and *Curiosity* (sensor curiosity through graphics and sound, and cognitive curiosity where the player should solve something unsolved) (Malone 1980). The Kahoot! GSRS was designed with these categories in mind, where the *challenge* is to answer unknown questions and try to beat other players, the *fantasy* is to be part of a game show, and the *curiosity* is provided both through inviting graphics and audio as well as solving a cognitive puzzle (finding the correct answer and wait to see if it was correct or not). To compensate for simple game play, we designed Kahoot! to be a multiplayer game where students compete for the top of the scoreboard. From experiences trying out Kahoot! in single lectures, we knew that it engaged and motivated the students. However, our fear was that if the students were exposed to using Kahoot! frequently over time, they would become bored and the engagement, motivation and learning effect would drop drastically. In this article we present the results of a quasi-experiment where we investigate the wear out effect of a GSRS.

The rest of this article is organized as follows. Section 2 presents material and methods that include related work, a description of the game-based student response system Kahoot!, and the research goal, the research questions and the research approach. Section 3 presents the results from the quasi-experiment. Section 4 discusses the results found as well as the validity of the results. Section 5 concludes the article.

2. MATERIAL AND METHODS

This section presents related work, the game-based student response system Kahoot!, and the research questions and the research approach.

2.1 *Related work*

As far as we know, there are no other studies published that looks at the wear out effect of game-based learning tools. However, there are many studies that evaluate both student-response systems (SRS) as well as game-based learning which we will cover in this section. We will also describe some SRSs with similar features to Kahoot!.

Kahoot! distinguishes itself from other SRSs as it was designed as a game or rather a game-based platform. This is why we categorize Kahoot! as a Game-based SRS (GSRS). There are however other SRSes that provide games as a part of their platform. One SRS that shares many of the same characteristics as Kahoot! and is widely used, is Socrative (Coca and Slisko 2013). Socrative is also web-based and does not require any special equipment to be used. The core of Socrative is the ability to get feedback from the students in the form of multiple choice, true or false, or short text answers. Socrative provides a real-time formative assessment to collect data from the students through forms. Socrative also offer the game Space Race where teams of students answer questions to move their rocket as fast as possible across the screen. Another example of a learning environment that share some of the features of Kahoot is Quizlet (Gruenstein, McGraw et al. 2009). Quizlet is not a SRS, but a web-based learning tool where the students can study various topics through Flashcards, speller, tests and more, and it also provide also a Space Race game where the player can kill moving terms by answering the correct word and vice versa. Quizlet focuses on spelling words and giving the correct definitions for words. Poll Everywhere is a SRS that provides a system for collecting audience responses in real-time to multiple choice or open ended questions (Sellar 2011). Poll Everywhere does not provide any game features. iClicker is a SRS similar to Poll Everywhere, but the students can respond using both specialized iClicker remotes or web-based clients, as well as the tool can be integrated with learning management systems and presentation tools such as PowerPoint, KeyNote and Prezi (Lucas 2009). Another commonly used SRS is Learning Catalytics which makes it possible for students to give numerical, algebraic, textual or graphical responses (Schell, Lukoff et al. 2013). Learning Catalytics provides also support for grouping and performance assessment of students and is owned by the publisher Pearson. If we compare Kahoot! to all the systems above, the most obvious difference is that Kahoot! focuses 100% on engaging and motivating the students through a game experience where students compete. A few systems such as Socrative and Quizlet also provide games, but these are add-ons to the main-features. In this sense, Kahoot! is more similar to Buzz!: The Schools Quiz that was released on Sony PlayStation 2. Another difference is the social focus of Kahoot!. Kahoot! was designed to create a social experience in the classroom through the game show metaphor. Further, it is heavily integrated with social media, enabling both teachers and students to share their quizzes and experiences within the platform and on Facebook, Twitter, Pinterest, and Google+.

Prototypes of student-response systems have been around since the sixties (Judson 2002), and started to be used in biology and chemistry teaching in the early seventies (Bessler and Nisbet 1971, Casanova 1971). The need for SRSs grew as the size of classes grew. The initial experiments did not show any significant performance improvement among the students, but the feedback both from the teacher and were positive. Since the 1970s there have been published many studies on SRSs, and we will here highlight some of the results related to student engagement, motivation, classroom dynamics and learning. Jane E. Caldwell's literature study on SRSs found that both students and instructors have positive attitude to use SRSs, that clickers have a positive effect on student performance on exams, and that they create a more positive and active atmosphere in classrooms (Caldwell 2007). More specifically, students using SRSs were twice as likely to work on a problem presented during class (Cutts, Kennedy et al. 2004), student attendance rose to 80-90% (Burnstein and Lederman 2001), and about 88% of students either "frequently" or "always" enjoyed using the SRSs in class (Caldwell 2007). These results are in alignment with our own results and observations using Kahoot!. From our experience, close to 100% of the students in a class work on problems promoted by the GSRS, attendance is much higher when a GSRS is used compared to when it is not used, and 94% of the students want a GSRS to be used at least once a week in lectures. Caldwell's survey also shows that SRSs are used in a variety of classes ranging from 15 to more than 200 students, and that SRSs are used to teach any subject (e.g. nursing, communication, engineering, computer science, mathematics, chemistry, biology, philosophy, physics, and more). Finally, the survey summarizes some common uses of clicker questions found in the literature: to increase or manage interaction, to assess student preparation and ensure accountability, to find out more about students, for formative assessment, for quizzes or tests, to do practice problems, to guide thinking review or teach, to conduct experiment, to make lectures fun, to differentiate instruction, and to prompt discussions.

In a more recent literature review from 2009, Kay and LeSage summarize the benefits of SRSs into the three areas Classroom environment, Learning, and Assessment (Kay and LeSage 2009). The *classroom environment benefits* are listed to be higher attendance, more focused students in class, all students can participate anonymously, student can participate with peers more in the class to solve problems, and students are more engaged in class. The *learning benefits* are listed to be more student interaction with peers, students actively discuss misconceptions to build knowledge, instructions can be modified based on student feedback, increased learning performance, and improved quality of learning through better explanations, thinking about important concepts and resolving misconceptions. The *assessment benefits* can be decomposed into students and teacher getting regular feedback on understanding, assessment done to improve student understanding and quality of teaching, and students can compare their SRS responses to class responses. These findings strongly resonate with what we have observed, learned and found through experiments using our GSRS. In addition, our on-going research shows that GSRS compared to SRS results in higher engagement and motivation among the students. Kay and LeSage's literature review also lists the biggest challenges in using SRSs to be time to learn and set up the SRS technology, create effective SRS questions, adequate coverage of course material, and ability to respond to instantaneous student feedback. The technical challenge to learn how to use and set up the SRS technology has now been minimized in many of the new web-based SRS platforms. There are, however, still technical challenges related to web-browser incompatibility, unreliable wireless networks, access to wireless networks, and network security.

Game-based learning is a research field that has received increased attention in recent years. Traditionally digital learning games have been used to teach facts using multiple-choice questions, but games can also be used to teach skills, judgment, behaviors, theories, reasoning, process, procedures, creativity, language, systems, observation, and communication using various approaches (Prensky 2005). GSRSs like Kahoot! are typically used to drill facts, but they can also be used to train skills through solving problems, to do reasoning presenting cases where the students have to analyze to find the right answer, and for training judgment where the students have to respond to ethical or manage decisions. GSRSs can also be used to teach process, procedures, language, communication and creativity by assigning a task where students (usually in groups) study a topic, create a quiz on the topic, and then lead fellow students playing through the quiz. This approach gives the highest learning outcome of GSRS usage and is more flexible in what can be learned.

Compared to mainstream entertainment games, learning-oriented games more often have negative associations related to produced for few platforms (mostly Windows), simplistic games, single player and offline play, low production value, not typically marketed to users but rather to parents and teachers, and more focus on relevant for formal curriculum than being fun (Kirriemuir and McFarlane 2004). This is especially a problem if the learning games trying to reproduce mainstream digital games, ending up in games that are poor copies of better pure entertainment games that try to squeeze learning into an existing game concept. We have not faced this problem with Kahoot!. We believe the main reason is that a GSRS does not try to copy an existing game concept but offer a new game experience that fits well into the lecture setting. The game show fantasy which was the main inspiration when developing Kahoot! fits well into existing teacher and student roles in the classroom. Earning points and competing to be in the top five on the scoreboard makes the experience exiting and motivating. From a course evaluate where Kahoot! was used, the students said that Kahoot! is a much better alternative than other activities typically taking place in a classroom. Just being able to play a game during a lecture is regarding as a very welcome break from other learning activities. Average human attention span is no more than 20 minutes, and the use of SRSs can help restart the attention clock (Caldwell 2007). As GSRSs are more motivating and engaging than SRSs, they are the perfect tool for breaking up tedious lectures and enabling students to be receptive for new knowledge. Results from research in organizational learning show that variation in itself can improve the learning rate significantly (Schilling, Vidal et al. 2003).

Although we have not found any literature documenting the effect of use of GSRSs, there are several articles that have shown the positive effect of digital game-based learning. Papastergiou shows in a study where the effect of using a computer game for learning computer memory concepts was assessed, students using the game learned more and were more motivated compared to students using a similar but non-game teaching approach (Papastergiou 2009). The study showed that boys were more trilled with learning from a game, but both genders were more motivated and learned more from using the game compared to a non-game alternative. Kurt Squire reveals that bringing video games into the classroom not always results in improved student motivation and more learning even if commercial entertainment games are used (Squire 2005). His conclusion from introducing Civilization III in a history class was that students that do well in the classroom are more reluctant to view gaming as a legitimate learning tool. Ebner and Holzinger describe how they successfully used an online game tailored for teaching *structural concrete* at Master's level where the *minimum learning result* of playing the game was equal to that achieved with traditional methods (Ebner and Holzinger 2007). They also found that the "fun factor" of playing the educational game was very high. In an evaluation of a virtual reality educational game, Virvou et al. documented that such a game can be very motivating as well as retaining or improving the educational effects on students (Virvou, Katsionis et al. 2005). The most interesting result in this article was that the improved educational effectiveness from playing the game was particularly high for students who used to have poor performance in the domain. We have observed similar results with Kahoot!. Students that are typically shy and quiet in class who do perform well in the classroom have made it to the top of the scoreboard. These students have been able to show the class that they can do well even though they are not active in classroom in the traditional sense.

2.2 *Kahoot! – A Game-based Student Response System*

2.2.1 The Background of Kahoot!

Kahoot! is a game-based student response system (GSRS) being a result of the Lecture Quiz research project initiated in 2006 at the Norwegian University of Science and Technology (NTNU). The initial idea for Kahoot! was to create a platform where the teacher and the students in a classroom could interact through a competitive knowledge game using the existing infrastructure. The motivation was to engage students through transforming the classroom into a game show, where the teacher would be the game show host, and all the students could compete by earning points through answering correctly on various questions related to the current subject being taught. At the end of a game session, a winner would be announced. The concept is very similar to Buzz! on the PlayStation or Scene it! for the XBOX, with the distinction that the quizzes can be created by the teacher, and there is no limitation on the number of simultaneous players. The first version of Lecture Quiz was developed on the Java platform both for the teacher client (Java SE) and the student clients (JavaME). With the introduction of smart phones, we replaced JavaME with a HTML4 web-interface for the student clients (Wang, Øfsdal et al. 2007). It was hard to get teachers to use the Lecture Quiz prototype due to the requirement of installing Java as well as installing of a Java graphics library and the Lecture Quiz software. Another challenge was the cumbersome interface to create and edit quizzes. Apart from these technical issues, the Lecture Quiz platform produced promising results when being used in lectures in terms of improved student motivation, improved student engagement, and increased perceived learning (Wang, Øfsdal et al. 2008, Wu, Wang et al. 2011).

In fall 2012, the start-up company Mobitroll developed a commercial version of Lecture Quiz from ground up, which was named Kahoot!. Kahoot! was developed as a cloud-based service providing HTML5 web-interfaces removing the need to install software, making it much easier to integrate with social media, enabling easier maintenance and upgrade, and offering support for most digital devices.

2.2.2 Creation of Quizzes

The Kahoot! platform includes a web-based creator tool that let you create a quiz, a discussion or a survey through a simple step-by-step guided process. A question in a quiz can have two to four answers where one or more can be correct, it has a time limit for students to answer the question (from 5 to 120 seconds), a choice whether the students can earn points or not on the question, and an image or YouTube video to illustrate the question. Fig.1 shows the creation tool in Kahoot!

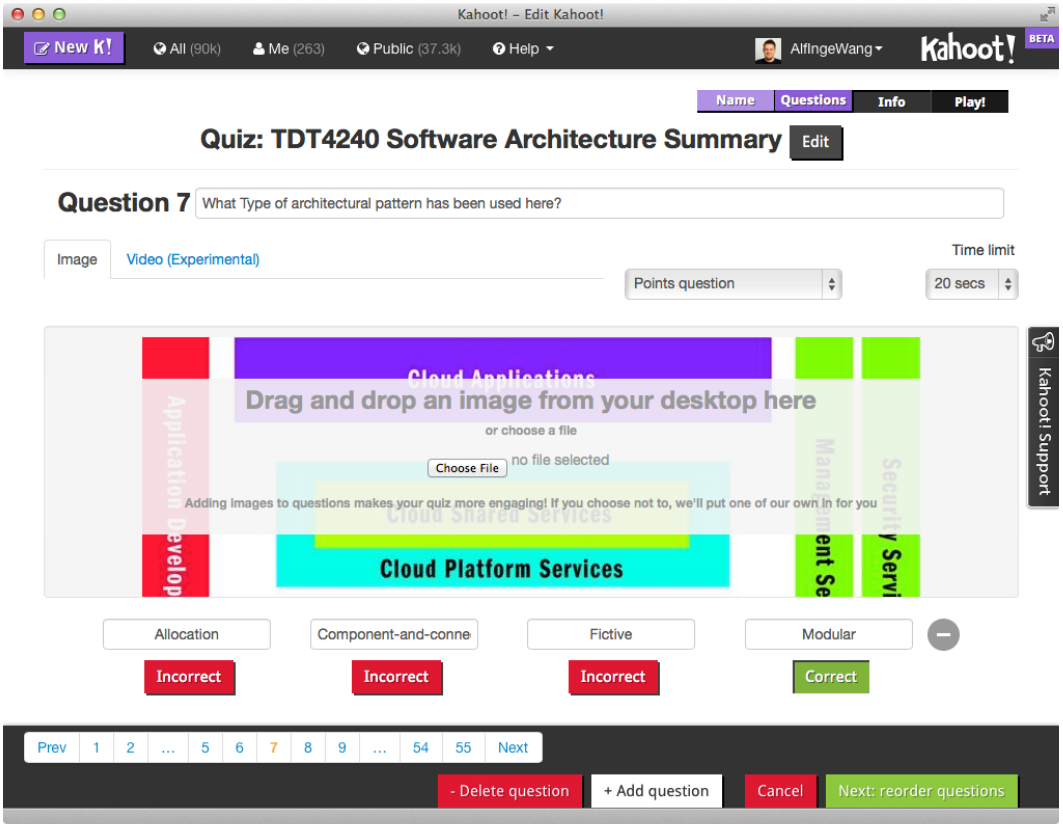

Fig. 1. The creation tool in Kahoot!

The creation tool also let the quiz creator re-organize the sequence of the questions, make it private or public, and add meta-information about the quiz such as language, primary audience, description, difficulty level, and tags.

Another important feature of Kahoot! is the ability to share quizzes with other teachers either directly within the tool or through Facebook, Twitter, Pinterest, Google+ or email. You do not have to create your own quizzes to use Kahoot!, as you can search and browse through a large number of public quizzes created by others. The functionality of duplicating existing quizzes makes it easy to use a public quiz as a starting point for your own modified quiz.

2.2.3 Play Kahoot! in the Classroom

To use Kahoot! in a classroom, the teacher has to launch Kahoot! in a web-browser on her or his laptop (or another digital device) which must be connected to a large screen. It is important that all the students are able to clearly see what is being displayed from the teacher's laptop. On the launch screen the students are asked to open the URL *kahoot.it* in a web-browser on their own devices. The students are not required to have an account to play Kahoot!. To enter the game, they must enter a game pin (a number) followed by a nickname. When playing the quiz, the question along with the answers are shown on the large screen, and the students click/press the same color and symbol as the answer they believe is the correct one. On the screen a timer will count down to zero as well as the number of students that have answered is shown. Fig. 2 shows how students give their answer in Kahoot!.

Fig. 2 Giving answers in Kahoot!

When the time to give answers is up, a distribution of the students' answers are shown on the large screen. At the same time, the students get individual feedback on how they have answered on their devices. The distribution of the students' answers gives the teacher feedback on the students understanding of the question, and open for a good opportunity to elaborate on the question and the answers. A scoreboard of the top 5 students with points and nicknames is shown between questions. Every student can also follow her or his own score and ranking on own device. To get a high score, the students have to answer correctly as well as fast. Music and sound effects are used in Kahoot! to create suspension and the atmosphere of a game show.

2.2.4 Uses of a Game-based Student Response System

Compared to a traditional student response system (SRS), a game-based student response system (GSRS) has more emphasis on engaging and motivating students. An SRS is a very useful tool for a teacher to collect data about the students' knowledge and about how much they have learned during a class. By gamifying the SRS experience, the students are likely to be more motivated and engaged during the quiz. There are several uses of GSRS.

A typical usage of a GSRS is to review important key points at the end of the lecture. This approach gives the teacher information about how much the students actually know about a topic after being taught, as well repeating the highlights of the lecture. An alternative approach is to play a quiz in the beginning of a lecture (to test the knowledge level), then teach the topic adjusted to the knowledge level of the class, and at the end of the lecture play the same quiz to see how much the students have learned. From a learning perspective, the best way of using a GSRS is to ask the students make their own quizzes. To be able to do this, the students have to study a topic, to find relevant questions, to come up with both correct and incorrect answers, and to create or find relevant illustrations. In practice, the students need to learn the topic very well to be able to create a good quiz. Further, the students can become leaders and teachers for the other students, by leading when playing through the quiz they have made. This is a typical blended learning or flipped classroom approach.

An SRS in general is a great tool for discovering feedback on weaknesses in lecture plans, to do anonymous polls before a discussion, to discover what topics should be taught, as well as doing surveys among the students to discover their attitude.

2.3 *Research Questions and Research approach*

The research goal of the evaluation presented in this article was to investigate the wear off effect of frequent use of a game-based student response system (GSRS) over a period of time. Specifically, we wanted to see how such use of a GSRS affected the classroom dynamics, the students' engagement and motivation, and the perceived learning. The research method used is based on the Goal, Question Metrics (GQM) approach (Basili 1992) where we first define a research goal (conceptual level), then define a set of research questions (operational level), and finally describe a set of metrics to answer the defined research questions (quantitative level). In our case, the metrics used to give answers to the research questions are a mixture of quantitative and qualitative data.

2.3.1 Research Goal and Research Questions

The research goal of this study was defined as the following using the GQL template:

The purpose of this study was to *evaluate the wear off effect of using a game-based student response* system from the point of view of *a student* in the context of *a lecture.*

The following research questions (RQs) were defined by decomposing the research goal:

— RQ1: *How is the classroom dynamics affected by short time vs. long time usage of a GSRS in the classroom?*

  This research question focuses on potential changes in the how the students behave and interact in the classroom as an effect of using a GSRS once vs. frequently over five months.

— RQ2: *How is the students' engagement affected by short time vs. long time usage of a GSRS in the classroom?*

  This research question investigates how the students' engagement changes from using a GSRS one time vs. using a GSRS frequently over five months.

— *RQ3: How is the students' motivation affected by short time vs. long time usage of a GSRS in the classroom?*

  This research question studies how the motivation of students changes from using a GSRS one time vs. using a GSRS frequently over five months.

— RQ4: *How is the students' perceived learning affected by the short time vs. long time of a GSRS in the classroom?*

  This research question focuses on the changes in how much students perceive they learn from using a GSRS the first time vs. using a GSRS frequently over five months.

— RQ5: *Do the students want to continue to use GSRS in lecture after frequent usage?*

  This research question focused on investigating whether the students wanted to continue using a GSRS after frequent usage, and potentially how often they would like to use a GSRS in lectures.

2.3.2 Data Sources and Metrics

Table I shows the data sources, the metrics and how the data are compared with respect to the five research questions from Section 2.3.1. We have used both qualitative and quantitative data for the evaluation. The same survey was used at the end of a single motivation lecture on game-based learning and at the end of the semester in a software architecture course. The survey consisted of eleven statements using Likert Scale reflecting the research questions RQ1-RQ4. The survey used at the end of the software architecture course included a question about how often the students wanted to use Kahoot! in other classes (RQ5). Data from the course evaluation of the software architecture was also used. This evaluation had three questions: What has been good, what has not been good, and what should be improved next semester?

Table I. Data Sources, Metrics, and Comparison Method

RQs	Data Sources	Metrics	Comparison Method
RQ1	Kahoot! Survey, Observation	3-level Likert Scale [Disagree, Neutral – Agree], Open questions, Observed interaction between students	Mann-Whitney Test, Percent-wise distribution
RQ2	Kahoot! Survey, Course evaluation, Observation	3-level Likert Scale [Disagree, Neutral – Agree], Open questions, Number of engaged students, Student comments	Mann-Whitney Test, Percent wise distribution
RQ3	Kahoot! Survey, Course evaluation, Observation	3-level Likert Scale [Disagree, Neutral – Agree], Open questions	Mann-Whitney Test, Percent wise distribution
RQ4	Kahoot! Survey, Course evaluation, Observation	3-level Likert Scale [Disagree, Neutral – Agree], Open questions	Mann-Whitney Test, Percent wise distribution
RQ5	Kahoot! Survey	4-level Likert Scale [Never, Once a month, Once a week, Every lecture], Open questions	Percent wise distribution

2.3.3 Quasi-experiment and Data Collection

Before we started to collect data for this quasi-experiment, we conducted a pre-test of the survey. The reason for this pre-test was to ensure that the questionnaire was understandable, and we wanted to investigate potential gender differences. The reason we wanted to test for gender differences on beforehand was that the two cases available to test Kahoot! (a motivational lecture and frequent usage in a university course) had very different gender characteristics. The pre-test was conducted on an earlier prototype of Kahoot! in 2012 that had the same characteristics as the version used in the quasi-experiment. The pre-test had a distribution of 37% female vs. 63% male students and a total of 126 subjects. The pre-test showed only minor variations between the two genders (on average 3% differences). Two statements had some what more noticeable differences: 1) Female students agreed to a larger degree (8% more) that it was easy to use a mobile device to play the game. 2) Female students agree to a larger degree (9% more) that they learned something from playing a GSRS!

To find the difference in effect of using the GSRS Kahoot! for the first time vs. using it frequently in a subject throughout a semester, we gathered data, we observed, and conducted a survey from two cases:

— A 45 minutes motivational lecture on game-based learning where Kahoot! was played at the end of the lecture to summarize the key points in the lecture. A total of 206 subjects answered the survey, all female students.

— A semester of the Software Architecture course, where Kahoot! was used in every lecture to summarize key points in the lectures. A total of 46 subjects answered the survey where 85% were male students and 15% were female students.

Both cases took place at the Norwegian University of Science and Technology spring 2013. An alterative approach would have been to conduct a survey at the first lecture of the software architecture course and the same survey at the end of the course. This was not done, as many of the students in the software architecture course had previous experiences with Kahoot!. In this evaluation, we wanted to look at the differences between using a GSRS for the very first time vs. using a GSRS for a whole semester. The first time new technology is used, it will always spark more enthusiasm and engagement. We wanted to see how much of this enthusiasm that would wear off after massive usage.

3. RESULTS

An overview of the descriptive statistics and the results from the Mann-Whitney Test is shown in Table II. The Mann-Whitney test was used, as it is a nonparametric test of the difference between the distributions of two independent samples. The Mann-Whitney test is well suited for our quasi-experiment as it is a test on ordinal data where the samples can be of different sizes. The table shows a comparison of the statements in the survey grouped according to Event (single lecture) and Semester (lectures for five months). The first statement in table is not related to any of the research questions, but was included to evaluate the usability of Kahoot!. The numbers show that both groups were in general happy about the usability of the tool. In textual feedback it was revealed that a couple students in the Semester group had some difficulty using their Windows 8 smart phones with Kahoot! and therefore disagreed on the ease of use.

Table II. Descriptive Statistics And Results From Mann-Whitney Test

STATEMENT	Group	Disagree	Neutral	Agree	Z	P
It was easy to use a mobile device to play the game	Event	0%	6%	94%	0.73	0.4754
	Semester	4%	9%	87%		
I communicated with other players while playing	Event	14%	19%	67%	3.62	**0.0003**
	Semester	28%	20%	52%		
It was fun to compete against others	Event	0%	5%	95%	1.14	0.2543
	Semester	9%	7%	85%		
It was fun to play together in the same room	Event	0%	1%	99%	3.62	**0.0003**
	Semester	0%	22%	78%		
I concentrate more when playing against other students	Event	3%	8%	89%	1.9	**0.0574**
	Semester	11%	17%	72%		
I was engaged while playing	Event	1%	3%	95%	0.63	0.5287
	Semester	2%	9%	89%		
I was emotionally engaged while playing	Event	13%	35%	52%	0.55	0.5823
	Semester	24%	24%	52%		
It was fun to play the game	Event	0%	5%	95%	0.6	0.5485
	Semester	2%	9%	89%		
I wish Kahoot! was used in other lectures	Event	3%	12%	85%	0.26	0.7949
	Semester	4%	13%	83%		
I am more positive towards topic after playing the game	Event	2%	33%	64%	1.02	0.3077
	Semester	9%	35%	57%		
I learned something from playing the game	Event	4%	22%	74%	-0.28	0.7795
	Semester	2%	22%	76%		

3.1 *Research Question 1: Classroom Dynamics*

The statements two to five in Table II are related to the classroom dynamics decomposed into interaction between students, enjoyment of competition, enjoyment of playing in the same room, and concentration when competing against others. Table II shows statistically significant differences for the two statements “I communicated with other players while playing” and “It was fun to play together in the same room”. Observations in the classroom from the two different groups (Event and Semester) confirm these differences. The difference can be explained by the different context of a single motivational lecture where nothing is at stake vs. a series of regular lectures ending up in a written examination. The textual feedback from students in the survey also revealed that the students in the software architecture class wanted to focus more on the subject in the quiz than communicate with other students. Despite the differences, the teacher of the software architecture class noticed a major change in the classroom when Kahoot! used. When playing quizzes, 100% of the students focused on what was going on in the front of the classroom (which was not the case for the rest of the lecture). The teacher also noticed that the students started to laugh and give positive comments during the quiz. Although there is a wear off effect in terms of classroom dynamics, there was a noticeable improvement in classroom dynamics even after repeated usage.

For the two remaining statements related to classroom dynamics (fun to play in same room and concentration while playing against other students), the numbers were lower for the Semester group compared to the Event group as expected, but the number for the Semester were still good numbers (85% agreed that it was fun to compete against others and 72% agreed that they concentrated more when playing against other students).

3.2 *Research Question 2: Student Engagement*

The statements six and seven in Table II are related to student engagement, and the results revealed no statistically significant difference between the two groups. Both groups agreed to a large degree that they were engaged while playing (95% for Event vs. 89% for Semester), and to a less degree that they were emotionally engaged (52% for both groups). It was surprising that close to 90% of the students after playing the same quiz game in every lecture for five months agreed that the game was still so engaging. The observations from the classroom support the result of high engagement of students playing the game by the change of atmosphere every time Kahoot! was played. Also the Kahoot!-sessions were the only time during lectures got 100% focus from all students. Open-ended comments from the survey revealed that the competitiveness by earning points and trying to make the scoreboard as well as the audio from the game created the engagement.

The results from the course evaluation of the software architecture course revealed how Kahoot! engages students. Many students mentioned that they got more engaged in the lecture when it was spiced up with something fun and exciting that made it possible to keep or re-establish the attention. Other students said that Kahoot! simply provided a nice variation and break in the lecture that actually was useful. Some students said that Kahoot! improved their engagement simply because they wanted to do well in the game. A common denominator from the students’ feedback was that interactive lectures boost engagement.

3.3 *Research Question 3: Student Motivation*

The statements eight to ten in Table II are related to how Kahoot! affected the motivation of the students. The Mann-Whitney test did not result in any statistically significant differences between the two groups ($p \geq 0.05$). There is a tendency of lower number for the Semester group, but not to a very large degree. Both groups agreed that it was fun and motivating to play the game (95% for Event vs. 89% for Semester). Almost the same percentage of students wished that Kahoot! should be used in other classes (85% for Event vs. 83% for Semester). Over half of the students were more positive about the subject because of playing Kahoot! (64% for Event vs. 57% for Semester).

The software architecture course was in 2013 scheduled to have lectures from 08:15-10:00 in the morning every week. As the lectures are not mandatory, students are tempted to skip these lectures to sleep in. The course evaluation revealed many students were motivated to come to the morning lectures (named "night lectures" by the students) just to play Kahoot!. The game kept them motivated to listen to what being lectured and keeping them awake during the morning lectures.

3.4 *Research Question 4: Perceived Learning*

The last statements in Table II asked if the students perceived to have learned anything from playing Kahoot!. The results from the two different groups are almost identical (74% of the Event students compared to 76% of the Semester students agreed). Further, as little as 4% for Event and 2% for Semester disagreed in learning something from Kahoot!.

The open-ended question "what has been good" in the software architecture course evaluation gave more details into how students learn from a GSRS like Kahoot!. Some students said they paid more attention and focused more to what was lectured as they knew they had use this knowledge at the end of the lecture to compete in a knowledge competition. Very competitive students said that they even read the textbook more carefully before coming to lectures with the goal of winning over classmates. Other students said that they remembered the subjects being taught better from playing through the knowledge as a repetition. Some students said it was very useful to get an immediate feedback on if they have understood what the teacher said or not. Using a GSRS also gave the teacher an opportunity to discover and explain things that most of the class answered incorrectly.

3.5 *Research Question 5: Frequency of Usage*

The last research questions asked if the students wanted to continue to use a GSRS like Kahoot! after recurrent usage, and if yes – how often? The results are shown in Fig. 3 (only the Semester group was asked this question).

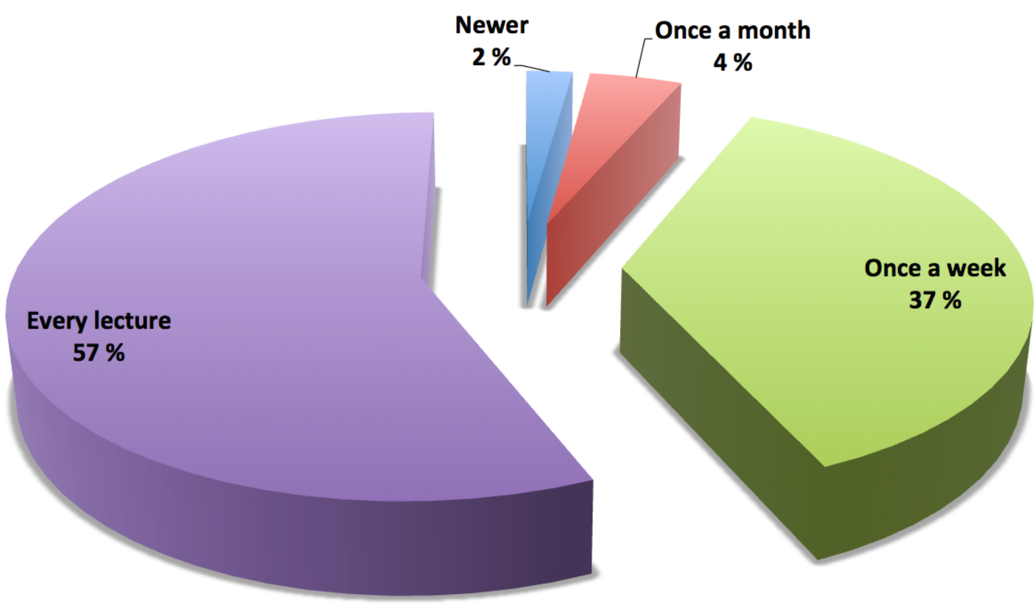

Fig. 3. How often the students wanted to use Kahoot!

The chart shows that even the students played Kahoot! in every lecture for five months, the majority wanted to play it at least once a week (94%), and over half of the student wanted to play it in every lecture (57%).

4. DISCUSSION

This section discusses the results presented in previous section and discusses some threats of validity.

4.1 *Discussion of the Results*

The results presented in Section 3 gave strong indications that there was no major wear of effects from using the GSRS Kahoot! frequently in lectures over time compared to use it one time in a motivational lecture. The main difference discovered was in classroom dynamics, where students from the single event in contrast to the students that had used it for five months interacted more through discussion and comments in the classroom as well they appreciated more the uniqueness of playing many together in the same room. Overall, the results were very promising for frequent usage of a GSRS as closed to 90% of both groups agreed to be engaged during playing, close to 90% of both groups agreed it was fun to play the GSRS, over 83% of both groups wished that the GSRS would be used in other lectures, and over 75% of both groups perceived they learned something from playing the GSRS. We predict that there wear off effect will be much more noticeable if the same GSRS is frequently used simultaneously in all the students' classes. However, some written comments from the students show that heavy usage of GSRS might not be such a big problem after all: "The alternative teaching methods to Kahoot! are not so fun and engaging, so we are willing to play a lot of Kahoot! before we get feed up."

Currently, Kahoot! only provides three variations of gamified student interactions which are very similar: a quiz, a discussion (no points, and no right or wrong answers), and a survey. Also, the quiz game has only one game mode, which is the competitive game mode. A wider variety of games and game modes would be preventive against a wear off effect and allow for more frequent usage without loosing engagement and motivation. Results from research in organizational learning show that variation in itself can improve the learning rate significantly (Schilling, Vidal et al. 2003). The introduction of Web 2.0 technology has made it possible to use a wide variety of tools in education to support greater learner interaction, choices and self-direction (McLoughlin and Lee 2007). Example of tools that can give positive learning effects are Massively Multiplayer Online Games (MMOGs), instant messaging, chat (text, audio, and video), blogs, Wikis, Learning Management Systems (LMSs), social media tools like Facebook, and more (Mejías 2005). As social software tools become ubiquitous, how these tools are used in education becomes more important. The use of technology in education demands for a new pedagogy that can harvest the benefits of sharing, heterogeneous communication and social networking (McLoughlin and Lee 2007). However, introduction of technology in classroom can yield negative results such as significant distractions, less learning, less understanding of course material and lower course performance (Fried 2008). Note that the Fried's results were from studying the effect of introducing laptops in the classroom without any direction or restrictions to the students on how to use them. It is therefor very important how the technology, and tools are used and integrated with the other learning activities. The success of using any technology in education depends on how it is integrated. In a study where three different social class room applications were used, the way these applications were integrated with what being taught made a huge impact on the students' engagement, learning, demand for thinking, creativity, social interaction, activity level, attention and contribution (Wang, Elvemo et al. 2014).

Introduction of social tools in the classroom can give many positive results, but the way they are deployed make all the difference in the world.

The one aspect that distinguish Kahoot! from other student response systems is the focus on learning through playing. Children learn quite naturally without the direction of adults, and play is very often the mode of that children develop skills and knowledge (Kleiber 1976). Research consistently finds that players learn new skills, knowledge insights, attitudes or even behaviors in games that challenge them to think, explore, and respond (Lieberman 2006). Kahoot! focuses mainly on challenging the students to think and respond, but also exploration through allowing students to make their own game content. An observation from classes where Kahoot! is being used is that the atmosphere of the classroom changes positively as a game start. Playing students can be recognized through laughter, smiles and amusing comments. The positive aspects of playing to learn can also be found when video games are not involved. A study of university students doing creative language play in a Spanish class showed that humorous play with words and conversations resulted in new and more varied forms of participation and language use – expanding the learners' overall communicative repertoires (Pomerantz and Bell 2007). The latter shows that the playing in it self is valuable for learning.

4.2 *Threats to Validity*

We now turn to what are considered to be the most important threats to the validity of this evaluation.

4.2.1 Intern Validity

The intern validity of an experiment concerns "the validity of inferences about whether observed covariation between A (the presumed treatment) and B (the presumed outcome) reflects a causal relationship from A to B as those variables were manipulated or measured" (Shadish, Cook et al. 2002). If changes in B have causes other than the manipulation of A, there is a threat to the internal validity. Note that our evaluation cannot be described as a controlled experiment but rather a quasi-experiment, but it is worth considering some of the most evident internal validity concerns anyway.

There are two main internal validity threats to this evaluation. The *first internal threat* is that the sample of the two groups (Event and Semester) used in the evaluation was not randomized. One could argue that it would have been better to do two samples of the same group (e.g. of the students from the software architecture course at the first lecture and the at the last lecture). We chose to use two different groups to ensure that the Event group consisted of students that had never tried Kahoot! before as well the chance to get a rather large sample (206 subjects). Further, in this evaluation we wanted to investigate how the context of a lecture affects the outcome. The motivational lecture for the Event group was not associated with any specific subject and fitted therefore perfect for the purpose. One concern about the randomization of the two groups is the major difference in distribution of gender in the two groups. To minimize this effect, we conducted a pre-test with a fairly equal gender distribution (37% female and 63% male). The results from the pre-test showed only minor variations between the genders (less than 3% on average). Only two statements were found to have some noticeable differences. The first one was that female students to a larger degree (+8%) thought it was easy to play the game using a mobile device. Similarly, female students to a larger degree (+9%) thought they learned something from using the GSRS. Neither of these results will change the conclusion regarding the wear-off effects found for this study.

The *second internal threat* is if there were any differences how Kahoot! was used in the two groups. For both groups, Kahoot! was used at the end of the lecture (lectures in the case for the Semester group) to summarize and give a repetition on they key points from the lecture. The Event quiz was on game-based learning, while the quizzes for the Semester group was on various topics related to software architecture. The Kahoot! survey was carried out at the end of the motivational lecture for the Event group and at the end of the semester from the Semester group. We do not believe that these differences have had any major impact in the way the students played, were engaged, were motivated and learned from the GSRS.

4.2.2 Construct Validity

Construct validity concerns the degree to which inferences are warranted, from (1) the observed persons, settings, and cause and effect operations included in a study to (2) the constructs that these instances might represent. The question, therefore, is whether the sampling particulars of a study can be defended as measures of general constructs (Shadish, Cook et al. 2002). The goal of this evaluation was to investigate how frequent usage and usage over time of the GSRS Kahoot! affected students' engagement, motivation, learning, and classroom dynamics. The GQM approach was used to detail this research goal into five research questions with supporting metrics. To give answers to the five research questions we used multiple data sources including a Kahoot! survey, a course evaluation, and observations in the classroom. It cannot be claimed that the selected data sources and metrics in our evaluation give evidence for all conclusions, but they are all strong indicators to a picture that describe the wear off effect.

4.2.3 External Validity

The issue of external validity concerns whether a causal relationship holds (1) for variations in persons, settings, treatments, and outcomes that were in the experiment and (2) for persons, settings, treatments, and outcomes that were not in the experiment (Shadish, Cook et al. 2002). The results reported in this article should be applicable for GSRS usage teaching various subjects. However, we acknowledge that the results might not be transferable to any GSRS or and especially not for non-game-based SRS. The results described in this article are only valid in the context the use of Kahoot! or systems that provide similar features as being highly competitive and provide game-like visuals and audio.

5. CONCLUSIONS

In this article, we have evaluated the wear out effect of the Kahoot! game-based student response system. The goal of the article was to find answers to the five research questions described in Section 2.3.1.

Research question one asked how the classroom dynamics is affected using a GSRS in a single lecture vs. one semester. Our results from the Mann-Whitney test showed some statistically significant differences in how actively students communicate during in GSRS sessions for a single lecture vs. frequent usage over time. However, open-ended feedback from the students that used the GSRS throughout the semester revealed that the main reason they did not communicate with fellow students during quizzes, was to be able to focus more on getting their answers correct. Further, although the software architecture students were not as enthusiastic as for the single motivational lecture, the class dynamics was highly improved during quiz sessions. We also found the same effect for the excitement of playing together in the same room. These results were also confirmed in observations from the two different cases (Event vs. Semester).

Research question two focused on how the GSRS affected the student engagement. The results from the quasi-experiments found no statistically significant differences between the two groups, although the students from the single lecture were more positive than the students that used Kahoot! throughout the semester. Close to 90% of the students of both groups agreed that they were engaged during the quiz sessions. The observations showed that all students (100%) were active during quiz sessions. Even the few students who did not have their own device were engaged, helping their neighbor student to get the answers correct.

In *research question three*, the focus was on how the GSRS affected the motivation of the students. Again, the Mann-Whitney test did not show any statistically significant differences between the two groups, although there was a tendency for slightly less motivated students in the Semester group compared to the Event group. For both groups, close to 90% agreed that they thought it was fun and motivating to play the game during lecture. Also, for both groups, 83%+ wanted to use Kahoot! in other lectures. From the teachers' perspective, Kahoot! was a really useful tool for motivating students to come to early morning classes and keep them awake. The feedback from the open-ended questions revealed that students were more motivated to focus on what being taught during lectures when GSRS was used, as well as read the textbook to prepare for lectures to do well in the quiz.

Research question four asked about the effect of perceived learning from using a GSRS. For this question, the response from the two groups was almost identical (about 75% agreed that they learned from using Kahoot!). Also, as little as 2-4% claimed that they did not learn anything from using Kahoot! in the lecture. The open-ended questions revealed that Kahoot! helped the students to learn in many different ways. First of all, the tool helped them to stay focus during class, as they knew that they soon had to use their knowledge in a quiz. Secondly, some students started to read the textbook before a class to do better on the quiz. Third, the students got immediate feedback on whether they have understood a topic or not. Fourth, the teacher got the opportunity to better explain topics where the tool revealed big holes in the knowledge of the students. And finally, repeating the important topics in a game helped the students to remember the knowledge through the social setting.

The final *research question five* asked how often students that had used the GSRS throughout a semester wanted to use the tool in a course. Only 2% said that they would never like to use Kahoot! in lectures. The feedback from the open-ended question revealed that this student (one student) did not like interaction in class and only wanted to listen to the teacher talking. The majority (57%) wanted Kahoot! to be used in every lecture, while 94% wanted to use Kahoot! at least once a week.

The results from research question five shows clearly that the wear off effect of using a GSRS is not major issue, at least not for Kahoot!. The results show that the wear off effect on motivation and engagement is minimal, and that there is no wear off effect on perceived learning. The results are overwhelmingly positive. However, we can predict that the wear off effect would be a larger problem if the same GSRS is used frequently in many courses. The best antidote for this problem is to make sure that the GSRS can provide many different games and game modes to keep the gameplay fresh and provide variation for the students. The Kahoot! company is working on prototypes for other game modes and games that will be included in the Kahoot! platform in the future to ensure that it can be used frequently in many courses without losing the positive engagement, motivation and learning effects GSRSs should provide.

REFERENCES

Baker, R. S., et al. (2010). "Better to be frustrated than bored: The incidence, persistence, and impact of learners' cognitive–affective states during interactions with three different computer-based learning environments." International Journal of Human-Computer Studies **68**(4): 223-241.

Basili, V. R. (1992). Software modeling and measurement: the Goal/Question/Metric paradigm, University of Maryland for Advanced Computer Studies.

Bessler, W. C. and J. J. Nisbet (1971). "The use of an electronic response system in teaching biology." Science Education **55**(3): 275-284.

Bradford-Networks (2013). The Impact of BYOD in Education, Bradford Networks**:** 1-16.

Burnstein, R. A. and L. M. Lederman (2001). "Using wireless keypads in lecture classes." The Physics Teacher **39**(1): 8-11.

Caldwell, J. E. (2007). "Clickers in the large classroom: Current research and best-practice tips." CBE-Life Sciences Education **6**(1): 9-20.

Carnevale, D. (2005). "Run a class like a game show:'Clickers' keep students involved." Chronicle of Higher Education **51**(42): B3.

Carver Jr, C. A., et al. (1999). "Enhancing student learning through hypermedia courseware and incorporation of student learning styles." Education, IEEE Transactions on **42**(1): 33-38.

Casanova, J. (1971). "An instructional experiment in organic chemistry. The use of a student response system." Journal of Chemical Education **48**(7): 453.

Coca, D. M. and J. Slisko (2013). "Software Socrative and Smartphones as Tools For Implementation of Basic Processes of Active Physics Learning in Classroom: An Initial Feasibility Study With Prospective Teachers." European Journal of Physics Education **4**(2).

Cutts, Q. I., et al. (2004). Maximising Dialogue in Lectures using Group Response Systems. CATE.

Distasio, J. and T. Way (2007). Inclusive computer science education using a ready-made computer game framework. Proceedings of the 12th annual SIGCSE conference on Innovation and technology in computer science education. Dundee, Scotland, ACM.

Ebner, M. and A. Holzinger (2007). "Successful implementation of user-centered game based learning in higher education: An example from civil engineering." Computers & Education **49**(3): 873-890.

El-Nasr, M. S. and B. K. Smith (2006). "Learning through game modding." Computer Entertainment **4**(1): 7.

Foss, B. A. and T. I. Eikaas (2006). "Game play in Engineering Education - Concept and Experimental Results." The International Journal of Engineering Education **22**(5).

Fried, C. B. (2008). "In-class laptop use and its effects on student learning." Computers & Education **50**(3): 906-914.

Gee, J. P. (2003). "What video games have to teach us about learning and literacy." Comput. Entertain. **1**(1): 20-20.

Gestwicki, P. and F.-S. Sun (2008). "Teaching Design Patterns Through Computer Game Development." J. Educ. Resour. Comput. **8**(1): 1-22.

Gruenstein, A., et al. (2009). A self-transcribing speech corpus: collecting continuous speech with an online educational game. SLaTE Workshop.

Judson, E. (2002). "Learning from past and present: Electronic response systems in college lecture halls." Journal of Computers in Mathematics and Science Teaching **21**(2): 167-181.

Kay, R. H. and A. LeSage (2009). "Examining the benefits and challenges of using audience response systems: A review of the literature." Computers & Education **53**(3): 819-827.

Ke, F. (2008). "A case study of computer gaming for math: Engaged learning from gameplay?" Computers & Education **51**(4): 1609-1620.

Kirriemuir, J. and A. McFarlane (2004). "Literature Review in Games and Learning."

Kleiber, D. A. (1976). "Playing to learn." Quest **26**(1): 68-74.

Lieberman, D. A. (2006). "What can we learn from playing interactive games." Playing video games: Motives, responses, and consequences: 379-397.

Lucas, A. (2009). "Using peer instruction and i-clickers to enhance student participation in calculus." Primus **19**(3): 219-231.

Malone, T. W. (1980). What Makes Things Fun to Learn? Heuristics for designing Instructional Computer Games. The 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems. Palo Alto, California, United States, ACM Press.

McLoughlin, C. and M. J. Lee (2007). Social software and participatory learning: Pedagogical choices with technology affordances in the Web 2.0 era. ICT: Providing choices for learners and learning. Proceedings ascilite Singapore 2007.

Mejías, U. (2005). "A nomad's guide to learning and social software." The knowledge tree.

Owston, R., et al. (2009). "Computer game development as a literacy activity." Computers & Education **53**(3): 977-989.

Papastergiou, M. (2009). "Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation." Computers & Education **52**(1): 1-12.

Pomerantz, A. and N. D. Bell (2007). "Learning to play, playing to learn: FL learners as multicompetent language users." Applied Linguistics **28**(4): 556-578.

Prensky, M. (2005). "Computer games and learning: Digital game-based learning." Handbook of computer game studies **18**: 97-122.

Rosas, R., et al. (2003). "Beyond Nintendo: design and assessment of educational video games for first and second grade students." Computer Education **40**(1): 71-94.

Schell, J., et al. (2013). "Catalyzing learner engagement using cutting-edge classroom response systems in higher education." Cutting-edge Technologies in Higher Education **6**: 233-261.

Schilling, M. A., et al. (2003). "Learning by doing something else: Variation, relatedness, and the learning curve." Management Science **49**(1): 39-56.

Sellar, M. (2011). "Poll everywhere." The Charleston Advisor **12**(3): 57-60.

Shadish, W. R., et al. (2002). Experimental and quasi-experimental designs for generalized causal inference, Wadsworth Cengage learning.

Sharples, M. (2000). "The design of personal mobile technologies for lifelong learning." Comput. Educ. **34**(3-4): 177-193.

Sindre, G., et al. (2009). "Experimental Validation of the Learning Effect for a Pedagogical Game on Computer Fundamentals." IEEE Transaction on Education **52**(1): 10-18.

Squire, K. (2005). "Changing the game: What happens when video games enter the classroom." Innovate: Journal of online education **1**(6).

Virvou, M., et al. (2005). "Combining Software Games with Education: Evaluation of its Educational Effectiveness." Educational Technology & Society **8**(2): 54-65.

Wang, A. I. (2011). "Extensive Evaluation of Using a Game Project in a Software Architecture Course." Trans. Comput. Educ. **11**(1): 1-28.

Wang, A. I., et al. (2014). "Three Social Classroom Applications to Improve Student Attitudes." Education Research International **2014**: 14.

Wang, A. I., et al. (2007). Lecture Quiz - A Mobile Game Concept for Lectures. IASTED International Conference on Software Engineering and Application (SEA 2007). Cambridge, MA, USA, Acta Press**:** 6.

Wang, A. I., et al. (2008). An Evaluation of a Mobile Game Concept for Lectures. Proceedings of the 2008 21st Conference on Software Engineering Education and Training - Volume 00, IEEE Computer Society.

Wang, A. I. and B. Wu (2011). "Using Game Development to Teach Software Architecture." International Journal of Computer Games Technology **2011**.

Wu, B., et al. (2011). Improvement of a Lecture Game Concept - Implementing Lecture Quiz 2.0. Proceedings of the 3rd International Conference on Computer Supported Education.