Let Them Play: The Impact of Mechanics and Dynamics of a Serious Game on Student Perceptions of Learning Engagement

Yichuan Wang, Pramod Rajan, Chetan S. Sankar, and P. K. Raju

Abstract—Serious games are becoming important educational tools and are increasingly being integrated into courses in many different academic areas and widely portrayed as a means of helping individuals concentrate on the subject matter and enjoy learning. This paper discusses the development and testing of a serious game by using a research model where the mechanics and dynamics of the game impact perceived usefulness, ease of use, and goal clarity, which in turn lead to higher concentration and user enjoyment. This model was tested in an undergraduate product design classroom, and evaluated using a survey and a focus group. The results of qualitative and quantitative analysis show that higher concentration and enjoyment occur when students perceive clear goals, ease of use, and usefulness during gaming. The results of the study leads to recommendations to game developers on the features of serious games that need to be built and the need to carefully consider the mechanics and dynamics of a game. The results should encourage instructors to consider incorporating serious games into their classes to increase their students' learning engagement.

Index Terms— E-learning, engagement, game mechanics, game dynamics, gamification

1 INTRODUCTION

Serious games built on computer game platforms are primarily designed for educational purposes [1]. The market for serious games is substantial, with recent estimates predicting that revenues will reach approximately US $2.3 billion by 2017, with an annual growth rate of 8.3% [2]. Serious games are increasingly being integrated into courses in many different academic areas and are widely portrayed as a means of helping individuals concentrate on the subject matter and enjoy learning [3], [4]. The commercial success of serious games along with its potential to improve enjoyment of learning has made them a popular subject for academic inquiry [5]. Thus, understanding whether a serious game will be effective in improving the concentration and enjoyment of students is a pertinent, practical research issue [1].

Concentration on a task is nothing but a persistent shift of attention to this task. Concentration refers to a player's focus of attention on a limited stimulus field [6], [7], [8]. The task should be able to mentally load students' cognition and also be intensive [7]. Concentration has been a critical factor in several online consumer behavior studies [9]. It has been found to positively influence many learning outcomes such as knowledge learning [10] and user's intention to use an e-learning system repeatedly [11]. Particularly in a serious game learning environment, concentration enables the students to increase learning effectiveness through the animation and immersive features of a game [12], [13] and encourage the students to solve a series of increasingly complex learning tasks that pose different levels of challenges. Thus, the improved concentration would be a major outcome in a serious game for the students while they learn specific principles.

On the other hand, enjoyment is defined by Csikszentmihalyi [7] as a sense of achievement that occurs when one's skills are matched with the task's challenges. Agarwal & Karahanna [14] define enjoyment as the pleasurable aspects of the interaction. In an academic context, the aspect of intrinsic motivation related to experiencing joy or pleasure translates as enjoyment of a course [15], [16] with the students describing classes using words such as "enjoyable," "fun," and "my favorite". Students who enjoy a game may experience psychological pleasure that is derived from their interaction with virtual roles and this pleasure is likely to lead students to acquire the knowledge and skills unconsciously [17]. Thus, student enjoyment acts as the second learning outcome of this study.

In order to design an effective serious game for improving concentration and enjoyment, academics and practitioners have suggested that the game design needs to balance the use of a set of elements and rules (mechanics) that when brought into practice (dynamics) provoke users' perceptions of usefulness, ease of use, and goal clarity [18], [19], [20]. However, a question on whether students' improved perceptions lead to increased con-

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centration and enjoyment of learning the subject matter remains vaguely understood. Despite the expenditures in implementing games in teaching and learning, empirical studies are sparse in studying the impact of serious games [12], [21]. To answer the calls for empirical research to evaluate the extent to which serious games can enhance learning, we formulated the following research question:

Does a well-designed game improve users' perceptions of ease of use, usefulness, and clear goals leading to higher perceived concentration and enjoyment?

To address this question, we designed and built a serious game to help students learn difficult engineering concepts that was, in the designer's perception, easy to use, useful, and emphasized clear goals, expecting that the students would become actively engaged in learning the concepts. Concepts such as product design lifecycle, project management processes, and communication may appear deceptively simple, but are actually very difficult to master [22]. Then, we tested this game in an undergraduate classroom and report the results of the experiment.

2 Research model and Hypotheses

2.1 Game Design and Learning Outcomes

The design of the serious game was driven by past research that states the dynamics of playing the game needs to integrate the mechanics of the game leading to active learning. We introduced the serious game in an undergraduate product design course with the expectation that the users will perceive benefits leading to higher concentration and enjoyment in applying product design concepts to play the game. This expectation is based on the paper by Ibanez et al [23] who discuss how the mechanics and dynamics of the game could trigger emotions of enjoyment and concentration [18]. Based on research by Fu et al [12], Morales et al [24] and Lang et al [25], we believe that by playing the game, students may improve perceptions of goal clarity, usefulness, and ease of use of the product design concepts leading to these positive emotions. Fig. 1 combines these ideas and displays the research model. The left half of Fig. 1 shows the integration of mechanics and dynamics of the game that lead to the design of the game. The right half of Fig. 1 shows how the impact of playing the game was assessed using an evaluation model and hypotheses.

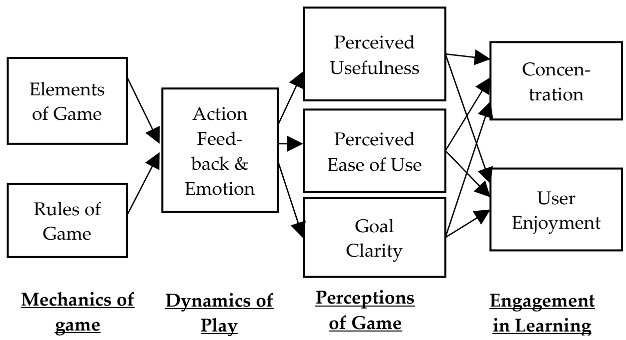

Fig. 2. Game User Flow Experience

2.1.1 Instructional Design: Mechanics of Game

Serious game mechanics is defined by Arnab et al [26] as the design decision that concretely realizes the transition of a learning practice/goal into a mechanical element of gameplay for the sole purpose of play and fun. The mechanics are composed of elements and rules. Elements include applying theoretical concepts in playing the game, dilemmas, clearly defined goals, scores, ownership, resource management, realism, movement, and cascading information to increase difficulty [23], [26]. Rules prescribe how to play the game, and achieve results [23], [26].

2.1.2 Instructional Design: Dynamics of Play

The dynamics of play are run-time behaviors when people play the game [23]. Players perform tasks that are rewarded by the system; this recognition of players' success generates positive perceptions of usefulness of the theoretical concept, ease of use in learning, and clarity of the goal of the lesson [23]. Conversely, failures generate some level of anxiety that encourages players to continue performing their tasks and expect to drive them to a flow state, which results in the improved perceptions [7].

2.1.3 Assessment of Playing the Game

By playing the game, students' emotions are expected to change resulting in achieving outcomes: increased concentration and enjoyment of the subject matter. The perceptions of the features of the game such as usefulness, ease of use and goal clarity are expected to be process factors that influence the extent of engagement in the course.

Both perceived usefulness and perceived ease of use are frequently used to measure students' behaviors and their adoption of new technology related to technology-mediated learning [14]. Perceived usefulness is defined as whether a person believes that using a particular system will enhance his or her job performance, while perceived ease of use considers how easily they are able to interact with a particular software artifact [27], [28]. Perceived usefulness and perceived ease of use are expected to have a positive effect on behavioral intention to use that information technology [29], [30]. Thus, in this study, we used these constructs.

Serious games simulate actual work environments by incorporating real-life facts or objects in the virtual environment, allowing players to communicate using virtual roles, safely take risks, and navigate their way through a variety of game situations. By using real-life simulations, serious games create a learning environment based on ease of manipulability and potential salience to users that enables them to step into the gaming role and iteratively engage in the learning experience [31]. Those playing the games often display periods of sustained concentration, thus digesting knowledge or concepts efficiently and gaining a positive perception of the game's value [32]. It therefore seems likely that these variables can also be used to evaluate the value of serious games. We assume that when serious game users have positive perceptions of the usefulness and ease of use of the serious game, this is likely to increase their concentration and enjoyment [33]. This leads to the first four hypotheses:

Hypothesis 1: An increase in perceived usefulness will increase concentration.

Hypothesis 2: An increase in perceived usefulness will increase enjoyment.

Hypothesis 3: An increase in perceived ease of use will increase concentration.

Hypothesis 4: An increase in perceived ease of use will increase enjoyment.

2.1.4 The Role of Perceived Goal Clarity in Improving Concentration & Enjoyment

A dominant theme in the literature on entertainment games focuses on the impact of goal clarity [34]; it is generally considered to represent the essence of digital game design because the goal in a game is assumed to be the primary reason why players perform tasks [35]. Players identify the goals of the task through either digital storytelling or messages presented in task bars. This increases players' awareness of the goals, thereby increasing their attention toward learning [36]. Serious games with clear goals allow players to simulate real-world dilemmas and experience the consequences when they make certain decisions, thus improving students' motivation and passion to learn, and helping maintain their concentration on the simulated situation [19], [37]. To investigate whether goal clarity acts as an enabler of learners' concentration and enjoyment, we developed the following hypotheses:

Hypothesis 5: An increase in goal clarity will increase concentration.

Hypothesis 6: An increase in goal clarity will increase enjoyment.

Based on the left half of the research model (Fig. 1), we designed a serious game to teach the concept of product design. In the next section, we discuss the mechanics and dynamics of the serious game.

3 Development of a Serious Game

A center in a Southeastern U.S. University with expertise in pedagogy research worked with an educational technology company based in California to design and test a serious game in order to teach product design concepts. The initial version of the game was based on an earlier smart scenario that was used by the company to teach high school students and tested in a pilot study. The project team then devoted considerable effort to improve the mechanics and dynamics of the game. We describe these next.

3.1 Overview

Product design is a systemic and intelligent process in which designers generate, evaluate and specify concepts for devices, systems or processes whose form and function achieve customer objectives or user's needs while satisfying a specified set of constraints. Thus, product design skills cannot be adequately taught in lectures alone; a more active learning experience is required [22]. Therefore, we designed a serious game to provide an active learning experience linking the product design process to a real-world simulation.

3.2 Description of the Game

The main goal of the game was to provide users with an opportunity to learn about the product design process in an interesting and engaging gaming environment. The game helps students understand the detailed processes involved in designing a structure capable of withstanding specified loads while still remaining within cost and height constraints. The design and development process of the game went through multiple iterations and stages of testing before being implemented in the classroom, with feedback being obtained after each stage to ensure the learning objectives and goals of the game were achieved. Fig. 2 shows a basic block diagram of the game's user flow experience. These blocks are described in more detail below.

- Overview

In this section of the game, the overall goal is defined, namely to teach users about the product design process. The overview introduces users to basic construction materials such as the beams and joints required to build a structure.

- Lab Introduction

This section presents each of the core product design process steps and gives users an opportunity to design a structure and make decisions that impact the weight, cost and load capacity of their structure.

Users have a choice to select from a set of structures (square, narrow and A-shapes), materials (wood, concrete and steel), lengths (short, medium and long), and joint types (small, medium and heavy) to build a structure. The game then simulates the estimated load that their structure would withstand.

- Building Game

This is similar to the lab introduction level but users have to build and test a structure from scratch without using any pre-defined choices of shapes. This is effectively a tutorial in that the users must join the dots and learn how to build their structure and then test it. There are a number of different goals (for example: achieve a minimum height, do not exceed a maximum cost, and bear a minimum load) for the users within this building game level.

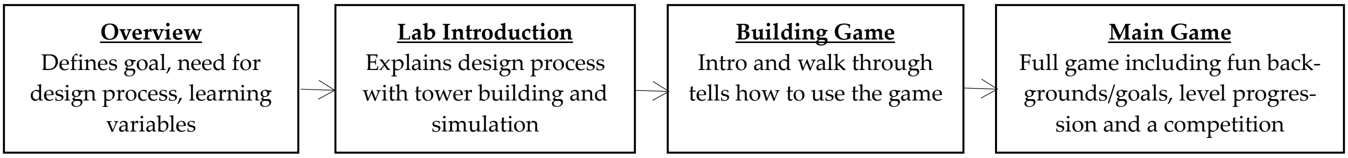

Fig. 2. Game User Flow Experience

TABLE 1
Elements of the Game

Elements of Game	Implementation in the game
Apply theoretical concepts	The steps in product design: problem definition, concept formation, concept selection, detailed design, prototyping, and testing formed the template that appeared in most screens in the game (Fig. 2). The students must apply their knowledge of the product design process, shapes and structures to solve the problem presented in each level of the game
Clearly defined goals in each level	At the beginning of each level, a game character narrates the specific goals to be achieved; these are highlighted at the bottom of the screen while the student plays the game.
Dilemmas	If the student does not build the structure correctly, the water tower and bridge collapses quickly making the student want to redo the structure. The different choice of materials, beams and joints also creates a dilemma in the students' mind. They can test out different combinations and see which one works better.
Scores	The game provides a score at the end of each stage showing the student's progression and effectiveness.
Ownership	The structure built by each student is different and withstands different loads; when the structure is constructed differently, higher loads are withstood. This provides ownership of the process to the student.
Resource management	The students must choose between different materials, structures and joints and learn through experimentation.
Realism	The students play the role of the project engineer in charge of building the bridge using the product design process. The water tower and bridges are common structures that students see in everyday life. Even though playing the game does not make the student competent to build real structures, it shows that the challenge of building one could be enjoyable.
Movement	The game provides different challenges at each level of the game, with the challenges increasing in difficulty as they progress to higher levels. At the end of each sequence, there is voice-over which informs the player about the completion of the goal. Students are continuously informed about their progress after each level.
Cascading information to increase difficulty	In the overview, introduction and building game stages, the students build test structures and are allowed to take risks and learn from their mistakes. During the main game (train bridge and water tower level), the students realize that the risk of failure rises as the structures become increasingly complicated to build.

- Main Game

The main game consists of three levels namely test tower, water tower level and the train bridge level. The difficulty increases as the users' progress through the different levels and the game computes a score for each level completed as a measure of the users' effectiveness.

3.3 Mechanics of the Game

The game was designed to incorporate the elements and rules of the game that were discussed in Section 2. Based on past literature [26], this game includes the elements of apply theoretical concepts, clearly define goals, dilemmas, scores, ownership, resource management, realism, movement, and cascading information. Screens were built according to these elements and are summarized in Table 1.

Fig. 3 shows that the game provides clear goals in the lab introduction level and explains the product design process through a tower building simulation. The product design process used in this study is based on Pahl and Beitz's [38] model of the design process which consists of six steps: problem definition, concept formation, concept selection, detailed design, prototyping and testing. These are highlighted on the screen and repeated for emphasis. The users can go back and forth in the product design process by clicking on the tabs at the bottom of the screen. The tower building parameters, which define the goals of the level, are to the right of the screen and the users can see the parameters change in real-time based on their choices.

Based on past literature [26], this game includes the rules of the game such as how to play, stress test, and achieving levels (Table 2). These rules of the game are explained in a tutorial where the narrator guides the students, discusses the materials used, and shows the user how to design, build and test a structure by clicking and dragging the elements of the structure (See Fig. 4). Stress test of the user's design is achieved where a built-in simulator evaluates the user's design and helps in checking if the tower will withstand the minimum load and also provides feedback on which beams and joints are failing (See Fig.5).

TABLE 2
Rules of the Game

Rules of Game	Implementation in the game
How to play the game	The game offers different levels (described in the game user flow experience) Each level is intuitive and has a tutorial or instructions on how to play at that level. For example, the game offers a tutorial in the building intro level which guides the students through the structure construction tools and screen areas to design and build a project from scratch.
Stress test of structure	The game has a built-in simulator based on physics principles that assesses the tower's success or failure based on the amount of vertical load the tower can hold. It also provides feedback on the beam/joint failures (highlighted in red color) when the tower is unable to support the load. The simulator also checks if the student has achieved the constraints (height and weight) in a particular level.
How to achieve results	The students become immersed in the game and enjoy it as they progress into the water tower and train bridge levels. At the end of each level, a narrator congratulates the student, applauding their achievement.

TABLE 3
Dynamics of the Game

Dynamics of Game	Implementation in the game
Narrative	The serious game has a consistent storyline throughout the game about building towers with different combinations of materials, beams and joints using the product design process.
Progression	The students' growth and development as they progress through the game is shown by the complexity of the structures they are able to build in each level. The game provides different challenges at each level of the game, with the challenges increasing in difficulty as they progress to higher levels.
Assessment	The performance of the students' structure is assessed based on the points they achieve. This depends on how well they have achieved the goals of each level (higher load capacity, better use of beams and joints)
Action points	The students are limited to the laboratory time to finish the game thereby providing a fast paced work environment and leading to a sense of completion and enjoyment at the end.
Emotions	Since the students play on the computer, they are able to express their emotions (curiosity and competitiveness) and the system does not critique them thereby encouraging their efforts to redo their structures. The game also creates some amount of frustration in the students when they do not achieve their goal in the first attempt.

3.4 Dynamics of Playing the Game

Based on past literature [23], the dynamics of the game includes narrative, progression, assessment, action points, and emotions (Table 3). The serious game has a consistent narration throughout all the levels and also sticks to the concept of building towers through the game while teaching product design process. The progression is achieved as the game was designed in three levels: Test Tower, Water Tower, and Train Bridge. For example, Fig. 6 is a screenshot of the water tower level, where the students have to build a support structure for a water tank. The design of the structure has to stay within the cost and weight constraints. The challenge for the students in this level is to prevent the water tank from rolling as it has a rounded bottom. Once the water tank structure is able to take the load, the students can progress to the next level, train bridge level (See Fig. 7). Building the train bridge is more complex and tedious than in the water tank level. Therefore, the progression of the challenge increases in complexity as the students master each level of the game.

3.5 Testing the Serious Game

The designers built the game so that the mechanics and dynamics worked together to make students engaged on the subject matter. This was then tested with students in an undergraduate classroom to assess whether the students were engaged in the subject matter by playing the game.

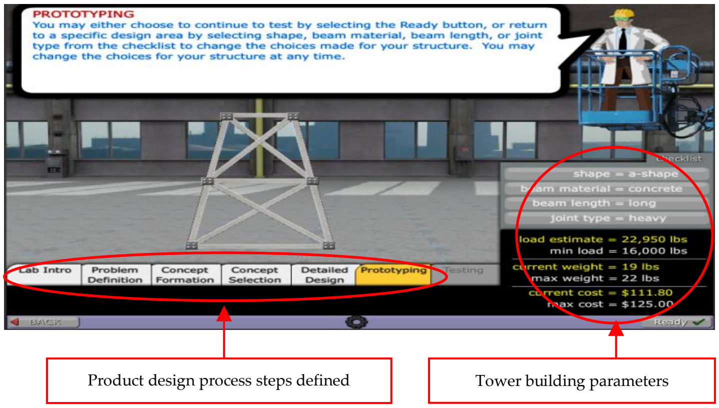

Fig. 3. Tutorial Showing the Theoretical Constructs and Clear Goals

Fig. 4. Screenshot Showing How to Play and the Different Levels of the Game

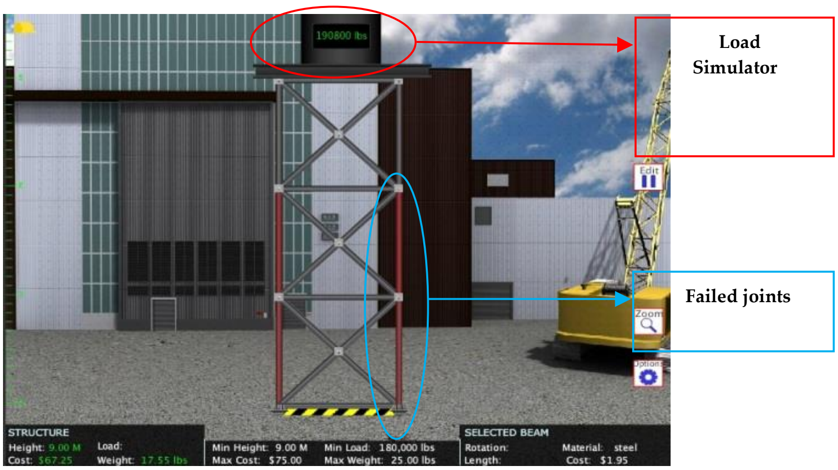

Fig. 5. Screenshot Showing Results of the Stress Test by the Load Simulator

Fig. 6. Screenshot Showing the Dynamics of Building a Water Tower

Fig. 7. Screenshot Showing the Dynamics of Failure of a Train Bridge under Load

4 Research Methodologies

We tested the effectiveness of the serious game usage using a mixed-methods research methodology [39]. In this study, the mixed methods research incorporates both qualitative and quantitative studies, with roughly equal values being placed on the quantitative and qualitative data sources. We used the focus group interviews (a qualitative data collection approach) and a survey (a quantitative data collection approach) to collect data to understand how a serious game can encourage students to learn the product design concepts. With this mixed method, on one hand, our results empirically validate the research model and provide evidence to understand whether the use of a serious game aided students' engagement. On the other hand, qualitative study allows us to triangulate and validate the empirical results and draw conclusions, as well as to acquire additional insights into the causes of the hypothesized associations by coding the students' comments obtained from the focus group interviews.

The serious game described above was integrated into the course structure of an introductory product design class to provide a realistic, hands-on experience for undergraduate college students, giving them an opportunity to learn about the product design process. In the first week, users were provided with fundamental knowledge on product design in the instructor's lecture and the course textbook. During the second week, students played the serious game and then received their game scores. The subjects and materials used, measurements developed, and statistical analysis tools are described below.

4.1 Study 1: Quantitative Method: Survey

The quantitative study employed a survey to collect primary data from students taking an introductory product design class in a southeastern U.S. university across two semesters with 114 subjects. Of these respondents, 78.07% were male, and 21.93% were female. The average age of the respondents was 20.

Scale items were adapted from prior IT usage literature and modified as needed for our research context (see Appendix A). The five-point Likert scale used in all of the items ranged from 1="strongly disagree" to 5="strongly agree". Perceived ease of use and usefulness were operationalized according to the recommendations made by Davis et al [28]. The four questions measuring perceived usefulness were modified from Malhotra and Galletta [40] to fit our research context, while perceived ease of use was measured using a six-item scale from Malhotra and Galletta [40] and goal clarity was treated as an independent variable based on the precepts of flow theory. A four-item scale taken from Guo and Klein [41] was used to evaluate users' responses to the serious game to test whether it provided users with goal clarity. User enjoyment was measured using a three-item scale taken from Agarwal and Karahanna [14] and the measure for concentration was adapted from a four-item scale developed by Koufaris [9].

Our data were collected from respondents using the same survey instrument, exposing the observed relationships to the threat of common method bias [42]. To reduce common method bias, Podsakoff and his colleagues [42] suggest utilizing structural procedures during the design of the study and data collection processes. Following these guidelines, we protect respondent-researcher anonymity, provide clear directions, and proximally separate independent and dependent variables [42]. We assessed the potential effect of common method bias statistically by conducting three tests. First, Harman's one-factor test [43] generated five principal constructs, and the unrotated factor solution shows that the first construct explains only 43.1 percent of the variance, indicating that our data do not suffer from high common method bias. Second, we performed a partial correlation technique using a marker variable to partial out the influence of common method bias. Following Lindell and Whitney [44], we used the second smallest positive correlation among measurement items (0.01) as a proxy for common method bias to adjust the correlations between the principal constructs. The adjusted correlations were only slightly lower than the unadjusted correlations and their significance levels did not change, suggesting that common method bias did not spuriously inflate the construct relationships [44]. Finally, following a procedure suggested by Pavlou, Liang, and Xue [45], we compared correlations among the constructs. The results revealed no constructs with correlations over 0.7, whereas evidence of common method bias ought to have brought about greatly high correlations (r>.90). Consequently, these tests suggest that common method bias is not a major concern in this study.

4.2 Study 2: Qualitative Method: Focus group

Focus group interview is a quick and convenient way to collect group interaction data from several people simultaneously. Rather than a one to one interview, this method allows the coordinator to ask questions, let participants share their gaming experiences and comment on each other's experiences. Through a group discussion, the participants' knowledge and experience are understood and lets the coordinator explore issues of importance and new directions.

To ensure the objectivity and accountability of research process, an external evaluation team from another university was recruited to conduct the focus group interviews. The nine open-ended questions listed in Appendix B guided the focus group sessions. The external evaluation team opened each focus group with the general questions to encourage every participant to contribute [46] and to elicit information on the students' overall experience with learning using the serious game, after which they asked questions about the students' perceptions of the serious game. The total number of participants that played the serious game during the two semesters is shown in Table 4.

TABLE 4
Number of Focus Group Participants

	Period	Focus Group Name	Participants
Serious game focus group	Fall 2012	C1	19
		C2	17
		C3	17
	Spring 2013	C4	20
		C5	20
Total			93

5 RESULTS

5.1 Quantitative Analysis and Results

The partial least squares (PLS) technique was chosen to test the research model for two reasons. First, PLS has an advantage over other covariance-based SEM methods when analyzing small sample sizes. Second, previous research has indicated that PLS has more power in maximizing variance explained than covariance-based SEM methods. This study intends to explain variance in students' engagement in learning. We thus believe that PLS is suitable for analyzing the data in this study. Data analysis proceeded in two stages: the measurement model and structural models were performed simultaneously. The measurement model was evaluated by testing each construct's reliability and validity. In the structural model, a bootstrapping procedure was applied to test the statistical significance of the parameter estimates.

5.1.1 Measurement model

The measurement model was evaluated by examining each construct's reliability, convergent validity, and discriminant validity. Table 5 shows that the Cronbach alphas are greater than the threshold of 0.70, confirming the adequate reliability of the measures [50]. Moreover, we employed two methods to assess discriminant validity: (1) checking whether each item loads more highly on its intended construct than on other constructs, and (2) checking whether each construct's square root of average variance extracted (AVE) is greater than its correlations with other constructs [51]. The results in Table 5 and Appendix C indicate acceptable discriminant validity.

TABLE 5
Descriptive Statistics and Correlations

Variables	Mean [S.D.]	α	CR	1	2	3	4	5
Goal Clarity	3.44 [.66]	.83	.86	.91				
Perceived Ease of Use	3.45 [.69]	.90	.97	.49**	.84			

Perceived Usefulness	3.26 [.56]	.92	.94	.56**	.69**	.78		
Concentration	3.24 [.88]	.75	.97	.12	.04	.12	.89	
Enjoyment	3.44 [.75]	.78	.96	.56**	.68**	.64**	.05	.89

Note: N=114; CR: composite reliabilities; AVEs on diagonal; *p<0.05, **p<0.01, ***p<0.001

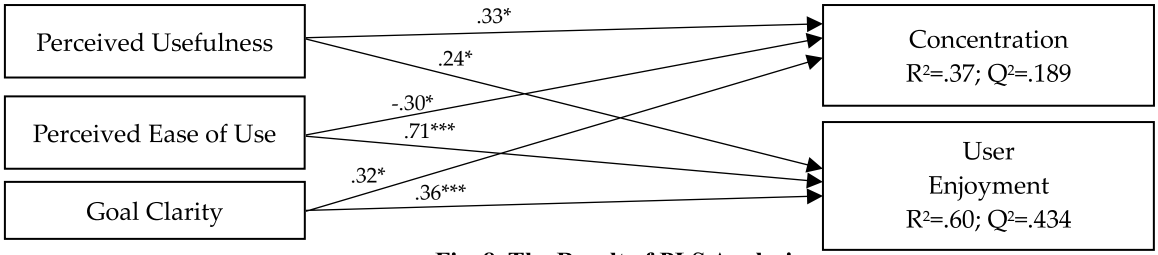

Fig. 8. The Result of PLS Analysis

5.1.2 Structural model

The results from the PLS analysis are shown in Fig. 8. Significant paths are shown in solid lines with a star above the path coefficients; the values for R^2 and Stone-Geisser's Q^2 are displayed immediately under the names of the constructs. Our research model explained a large amount of variance in the dependent variables. Goal clarity, perceived ease of use and perceived usefulness jointly explained 37 percent and 60 percent of the variance for concentration and student enjoyment, respectively. In addition to the size of R^2, the cross-validated redundancy measures, Stone-Geisser's Q^2 can effectively be used as a criterion for predictive relevance [52], [53], [54]. Based on blindfolding procedure, Q^2 for concentration and student enjoyment are 0.189 and 0.434, respectively, exhibiting sufficient predictive relevance [55].

The hypotheses were tested by checking the direction and significance of path coefficients (β) between constructs generated by the bootstrapping procedure. Since perceived usefulness was found to be significantly related to concentration (β=0.33; t-value=1.98; P<.05), H1 was supported. Perceived usefulness was positively related to students' enjoyment in playing serious game (β=.24; t-value=2.72; P<.05), thus supporting H2. Perceived ease of use was another significantly predictor of students' perceived concentration (β=-.30; t-value=-1.97; P<.05) and enjoyment (β=.71; t-value=6.41; P<.0001) in serious games, supporting H3 and H4. In addition, the results indicated that goal clarity had significant effect on concentration (β=.32; t-value=2.02; P<.05), lending support to H5. Finally, goal clarity was found to be significantly related to student enjoyment (β=.36; t-value=4.05; P<.0001), H6 was supported.

5.2 Qualitative Analysis and Results

The evaluation team produced a 65-page report that summarized the results and quoted individual comments and group conversations from the students.

To extract the insights from the comments, we followed Hsieh and Shannon's [56] guidelines to perform the deductive content analysis. In order to identify and categorize all possible occurrences of a phenomenon, we began by reading the report carefully and highlighting all text by a researcher that on first impression appeared to represent the students' learning experience or reactions to the serious game. To increase the trustworthiness of this identification of the relevant text, another researcher repeated the highlighting exercise with a clean copy of the report to ensure that all the statements associated with the research questions were accurately captured. A total of 30 textual responses that were directly related to the research questions were obtained from the qualitative evaluation report. In the next step, we coded all the highlighted statements using a set of predetermined codes using a three-rater panel. During the coding process, we not only categorized the statements into appropriate codes, but also identified the association among the predetermined codes based on our research model [57]. Where conflicts occurred, the three raters collectively reassessed each response and arrived at a consensus. The three raters agreed on 75.6 percent of the classifications. Table 6 summarizes the results of the content analysis, including 7 associations corresponding to our research model and their occurrence frequency and percentage.

6 Discussions

6.1 Findings

We derive three key findings. First, we have found evidence that perceived usefulness is one of the key elements enabling users to enjoy and concentrate on the serious game. Our qualitative result also shows that 63.34% of the comments were related to this finding, showing that serious game simulated the real-world, was engaging and interactive leading users to perceive it as a useful learning tool in understanding complex concepts of product design. For example, one student liked the game for job training and said, "It's much better than someone telling you how to do something and a lot more interesting." The serious game offered a safe place where students were able to rebuild their structures without fear of failures. This enables them to learn from failures in designing products. Therefore, some students reported spending close to 10 hours working on the game, although the designers had planned the game to be played in an hour.

TABLE 6.
Summary of Results from Qualitative Analysis

Hypothesized Associations and Examples of Responses	# of responses
Hypothesis 1: PU(+)→C(+) • Students felt that the digital game gave them control of their learning and provided them with a feedback mechanism to help them improve their design skills. • This game was challenging and it was not easy to finish the game tasks; one student spent 3-4 hours at home attempting to beat the game.	2 (6.67%)
Hypothesis 2: PU(+)→UE(+) • The digital game allowed me to "work with stuff and put things together" without having to "deal with the added stress of doing the math, which hinders it." • The digital game was more real-world, engaging, and interactive than textbook reading. • One student liked the digital game for job training and said, "It's much better than someone telling you how to do something and a lot more interesting." • The planning aspect of this game was appreciated by students, who recognized how important it is to try pilot test an idea prior to implementation, particularly when lives are at stake. • "Wisdom comes from experience, and I now have a better foundation of how to build a structure" • This game was an effective tool for helping us to learn whether they like engineering and feel they have made the right choice in major.	17 (56.67%)
Hypothesis 3: PEU(-)→C(-) • I did not like the clean slate button. When you accidently click on it, it doesn't check to see if you really meant to hit the button. On most programs, if you hit a delete button, there will be a pop up window that asks you something like "are you sure that you want to delete this file?" There wasn't anything like that with this game. • We had to start over from the beginning each time and that was very frustrating.	3 (10%)
Hypothesis 4: PEU(+)→UE(+) • This game presented the learning experience in a simple, straightforward format. • Working with stuff and put things together without having to deal with the added stress of doing the math • This game allowed me to work at my own pace.	4 (13.33%)
Hypotheses 5: GC(+)→C(+) • I am eager to dig deeper into it. I spent 12 hours trying to figure out the design game, and when I solved all the problems, I felt a huge sense of accomplishment.	1 (3.33%)
Hypothesis 6: GC(+)→UE(+) • This game provided good introduction for learning to build structures with consideration for price and weight, making the enjoyable experience simulate a real-world design project.	3 (10%)
Total	30 (100%)

Coding Scheme: PU: Perceived usefulness; PEU: Perceived ease of use; GC: Goal Clarity; C: Concentration; UE: user enjoymen

Second, the quantitative result reveals that perceived ease of use has a positive impact on user enjoyment. For example, some students believe the serious game presented the learning experience in a simple, straightforward format. They further stated that the game put things together without having to deal with the added stress of doing the math. Surprisingly, perceived ease of use has a negative impact on concentration. This implies that when users play an easier-to-use serious game, they may lack focus when playing [58]. This result does support the earlier study by Lowry et al. [59], however, who found a negative impact of perceived ease of use on intention to use a serious game. Meanwhile, the qualitative result shows that 10% of the comments indicated that the students disliked a few functionalities of the game (clean state button; no memory of earlier structure) leading to lack of concentration when playing [58], [59].

Third, quantitative evidence showed that goal clarity is a key element enabling users to concentrate on the serious game. We thus conclude that a serious game with clear goals is most likely to facilitate students' concentration on learning product design concepts. From the qualitative result, we also identified goal clarity was likely to influence user enjoyment and concentration (e.g., "This game provided [a] good introduction for learning to build structures with consideration for price and weight, making the enjoyable experience simulates a real-world design project"). This implies that the game led students to concentrate on the gaming situation and enjoy learning the concept of product design as they perceived clear goals in the serious game.

Overall, these three key findings reaffirm the previous theory by Venkatesh and Morris [29] and Venkatesh [30] in which perceived usefulness, perceived ease of use and goal clarity are expected to alter users' behavioral intention on information technology usage. A number of useful insights regarding the theoretical and managerial implications of this research will be discussed next.

6.2 Implications for Theory

This research demonstrates how the mechanics and dynamics of the game play a significant role in improving users' concentration and enjoyment. Over the years, researchers have pointed out the strong links among cognitive absorption, Technology Acceptance Model, and flow theories as applied to various research contexts [9], [59], [60]. Our findings show that the mechanics and dynamics of the game need to be designed so that the users perceive improved usefulness, ease of use, and goal clarity. These factors explain significantly more of the variance in enjoyment (R^2=60%) than in concentration (R^2=37%).

To date there has been only limited research to establish the links between mechanics and dynamics of a game, perceptions, and increased concentration and enjoyment. Subjects such as product design are deemed to be "boring" by many students and learning them needs to be more enjoyable [61]. Researchers have demonstrated that some cognitive and business issues need to be overcome if serious games are to be widely adopted for training and teaching purposes [62]. The findings in this study address some of these issues and could thus encourage academicians and practitioners to use serious games. Our model provides guidance on the features of serious games that need to be built and the need to carefully consider the mechanics and dynamics of a game if players are to achieve significant improvements in concentration and enjoyment.

6.3 Implications for Practice

We found the need for instructional designers and game designers to work together during the game design so that the games are perceived to be useful in achieving the learning objectives. As Arnab et al [26] mention this might be the major difference between serious games and regular games where instructional designers need to be part of the game creation process. In our project, members with strong background in product design from the University worked closely with the game builders from the private company. During the final few months, they talked to each other at least twice a week and shared common folders where they were able to review each other's work constantly. Since the background of instructional designers (theory focused) and game designers (practice focused) were very different [26], it was critical that these two teams work together to develop the serious game. Such a strong collaboration made the students perceive the final game to be useful. The results thus show the need for close collaboration among designers of the game, instructors, and evaluators when designing the game.

7 Limitations and Future research

This research study has many limitations. First, the data used to evaluate the serious game was gathered from students attending a single university over two semesters. The generalizability of the results would be enhanced if the experiments were conducted with a more diverse group of students. Second, we did not consider the difference of students' learning styles since previous studies have shown that different learning styles can have a major impact on student learning outcomes, especially in a gaming learning environment [18]. Third, the measures used in this study are all based on students' perceptions of their learning experience. Actual learning assessment, such as testing the students' understanding of the product design process, would be a good addition to quantify specific learning outcome in future studies. Fourth, a longitudinal study implementing several serious games in a curriculum could provide useful insights about the feasibility of using serious games as a supplement to traditional lecture methodologies. Fifth, this game was not developed to make the students as experts in product design who become competent to build water towers or bridges after playing the game; it was designed only to emphasize the foundational principles of product design. Sixth, user's concentration and enjoyment may vary over the playtime and these were not examined in this study. Seventh, we did not explicitly study how specific mechanics and dynamics of the games influence the perceptions of the students; therefore, the study cannot provide specific guidelines on which specific features of the game led to improved perceptions.

There are several possible directions for further research in this area. First, the research model proposed in this study is derived primarily from education and psychology sources and it has been used to study how the mechanics and dynamics of a game affect concentration and enjoyment. This model could be extended and applied in other types of organizational learning, such as on-the-job training and new training environments.

Second, this study sought to examine previously unmapped relationships based on a combination of several theories. Based on this model, the relationships among these factors pose some interesting questions: How do the individual elements of mechanics or dynamics lead to greater learner concentration and enjoyment? How to evaluate the impact of the specific elements of mechanics or dynamics on improved perceptions? How do these impact other active engagement factors such as time control, loss of self-consciousness, or arousal?

8 Conclusion

This study has demonstrated the benefits to be gained by implementing serious games that incorporate mechanics and dynamics, create an effective learning environment, and enhance students' concentration and enjoyment of the task. This research should encourage instructors in educational institutions and companies considering incorporating serious games for training in their classrooms. Thus, this study shares the experiences in building and testing a serious game and offers lessons for others who develop such games.

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Appendix A Measurement Scales and Items

The following multi-item scales were used in the study. The source in the prior literature from which they are adapted is shown for each.

Goal Clarity (Guo & Klein, 2009)

GC1. I knew clearly what I wanted to do during game time.

GC2. I had a strong sense of what I wanted to do during game time.

GC3. I knew what I wanted to achieve during game time.

GC4. My goals were clearly defined during game time.

Perceived Ease of Use (Malhotra & Galletta, 2005)

PEU1. Learning to operate the serious game was easy for me.

PEU2. I found the serious game flexible in tasks and activities.

PEU3. I found it easy to get the serious game to do what I wanted.

PEU4. It was easy for me to become skillful at using the serious game.

PEU5. I found the serious game easy to use.

PEU6. My interaction with the serious game at work was clear and understandable.

Perceived Usefulness (Malhotra & Galletta, 2005)

PU1. Using the serious game was useful for learning.

PU2. Using the serious game increased my learning productivity.

PU3. Using the serious game increase my learning effectiveness.

PU4. Using the serious game made it easier to do my work.

User enjoyment (Agarwal & Karahanna, 2000)

SE1. The serious game has been enjoyable

SE2. The serious game was one of my favorite learning modules

SE3. I had fun interacting with the serious game

Concentration (Koufaris, 2002)

C1. I was absorbed intensely in the serious game activity.

C2. My attention was focused in the serious game activity.

C3. I concentrated fully in the serious game activity.

C4. I was deeply engrossed in the serious game activity.

Appendix B Focus Group Questions

1. What particular activities have been helpful to you related to learning product design?

2. What materials were presented that helped you understand the concepts of product design?

3. Were the goals of these activities (or instructional materials) clear to you when learning product design?
4. Did these activities (or instructional materials) help you focus and concentrate on learning about product design?
5. Did you find these activities (or instructional materials) to be useful to your educational plans/career?
6. Did you think these activities (or instructional materials) were easy and understandable to you?
7. Did you think these activities (or instructional materials) helped you understand how to solve the design problem?
8. Did you find these activities (or instructional materials) helped you understand how to make a decision during the design process?
9. Did you find these activities (or instructional materials) helped you identify what was important when you designed a product?

Appendix C: Factor Loadings and Cross-Loadings

Items	Concentration	Goal Clarity	Perceived Ease of Use	Perceived Use-fulness	User Enjoyment
C1	**0.7900**	0.4623	0.4075	0.5319	0.4659
C2	**0.8234**	0.4074	0.5220	0.2703	0.3460
C3	**0.7980**	0.2245	0.4111	0.1102	0.2598
C4	**0.7471**	0.3156	0.4010	0.2511	0.3521
GC1	0.2947	**0.7934**	0.3858	0.4181	0.3974
GC2	0.2887	**0.8382**	0.2775	0.4598	0.3114
GC3	0.4845	**0.8717**	0.4275	0.3856	0.3319
GC4	0.4275	**0.8308**	0.3812	0.3949	0.3427
PEU1	0.3484	0.2799	**0.8276**	0.4288	0.5728
PEU2	0.5235	0.3371	**0.8282**	0.4163	0.5871
PEU3	0.3773	0.2852	**0.8260**	0.5221	0.5685
PEU4	0.5321	0.4125	**0.8334**	0.5219	0.6979
PEU5	0.5095	0.4446	**0.8568**	0.3857	0.6141
PEU6	0.4788	0.4735	**0.8729**	0.4078	0.5699
PU1	0.2934	0.4162	0.3796	**0.8039**	0.4653
PU2	0.2474	0.2209	0.4891	**0.8075**	0.5108
PU3	0.2414	0.4505	0.4093	**0.7777**	0.4704
PU4	0.4250	0.4842	0.4305	**0.8220**	0.5209
UE1	0.2778	0.3037	0.5779	0.5976	**0.8494**
UE2	0.4273	0.3910	0.6379	0.5602	**0.9075**
UE3	0.4040	0.3099	0.6816	0.4177	**0.8739**
UE4	0.4925	0.4470	0.6334	0.5799	**0.8833**

Coding Scheme: C: Concentration; GC: Goal Clarity; PEU: Perceived ease of use; PU: Perceived usefulness; UE: User enjoyment.