Comparing Usability, User Experience and Learning Motivation Characteristics of Two Educational Computer Games

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Abstract: Educational computer games are very popular nowadays and can bring a lot of benefits to improve the learning process. *Usability*, *user experience* and *learning motivation* are important factors in the design of educational computer-based games. Although there are existing educational games designed under these principles, there is a need of comparison between different educational tools in order to try to understand which design criteria can make a tool more successful than another. This work presents the results of a comparison between two competitive educational games. The study was conducted with 41 master students evaluating two competition-based educational computer games. The study, based on quantitative and qualitative data, has shown features that might drive to better usability, user experience and learning motivation. Additionally, we found a strong positive correlation among usability and user experience with learning motivation.

1 INTRODUCTION

Usability and *user experience* (UX) are highly relevant and interlinked topics in *Human Computer Interaction* (HCI), practice and research. These two software evaluation approaches are focused on assessing the experience conveyed by a computer system to its users. On one hand, usability measures the effectiveness and efficiency of users to carry out specific tasks using computer systems (*pragmatic nature*). While on the other hand, user experience investigates the user's emotions triggered by the system (*hedonic nature*) (Hassenzahl, 2003).

Various instruments and methods to evaluate pragmatic and hedonic software's characteristics are available, including: SUMI, QUIS, CSUQ, SUS, UMUX and UMUX-Lite, questionnaires considering different amount of items to measure usability of computer systems (Lewis 2013; Lewis et al., 2013); and the AttrakDiff 2 questionnaire (Hassenzahl et al., 2003), addressing UX evaluation. In (Vermeeren et al., 2010) and (Lewis et al., 2013) a comprehensive evaluation about usability and UX methods and instruments is presented.

Regarding computer games, due to their impact in entertainment and their increasing influence in education, usability and user experience are important aspects to study. In the videogame industry, an effective UX determines the digital games acceptability. The *Game Experience Questionnaire* (GEQ) is a psychometric instrument used to assess specifically the UX in entertaining games; it is recommended to be administered immediately after the game session (IJsselsteijn et al., 2008). However, in *Educational Computer Games* (ECG), usability and user experience evaluation is still open for research consideration. While students expect a satisfactory pragmatic and hedonic experience while playing, there is still their reasonable expectation to improve learning outcomes. Based on the previous statements, for computer-based educational games, it is highly important to assessing usability, user experience and the learning motivation as three closely interrelated factors. Learning motivation refers to the affective domain of learning; it is about how instructional material enhances learners' internal perception that motivates them to learn (Satar, 2007).

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Although there have been several educational games based on the principles of usability, user experience and learning motivation, there is a need of further comparison among educational games in order to gain insights into the best features.

In this work, we present the results of an evaluation and comparison of two competition-based ECG. The evaluation was performed by 41 master students, using a questionnaire to assess usability, user experience and motivation to learn in ECG. In order to have homogeneous systems evaluation criteria, the same group of students evaluated the two systems at two different points in time.

This paper is organized as follows: Section 2 presents the literature review; section 3 describes the educational computer games evaluated and compared in the study; the proposed questionnaire is described in section 4; section 5 addresses the study methodology and results; section 6 presents the results and discussion of the study; and section 7 concludes the paper.

2 RELATED WORK

In HCI, usability and UX are considered similar but different terms regarding user satisfaction. It is understood that the system's functional characteristics are vital, but the user motivation to keep using the product is critical as well (Hassenzahl, 2003; Vermeeren et al., 2010; Lewis et al., 2013). In fact, they complement each other. User satisfaction could not be accomplished without adequate system functionality, and for the user to be willing to use the system, he/she must be stimulated to do it. However, there are a few effective methods to assess UX separately or in combination with usability.

Many methods and instruments are available to conduct usability evaluation (Lewis 2013; Lewis et al., 2013). However, UX is still not being addressed comprehensively (Vermeeren et al., 2010; Hassenzahl, 2003). To understand how the user really feels about a system is important to obtain that information directly from him/her. Differing from some usability methods, the use of logging to evaluate UX could not be fully effective.

In order to know the UX evaluation methods used in industry and academia, in (Vermeeren et al., 2010) is described a study conducted with 35 participants of the CHI'09 conference. A total of 33 UX evaluation methods were initially considered. However, researchers reported that only 15 methods were evidently considering the hedonic nature of UX in addition to the pragmatic emphasis of usability. The paper does not include details of the names of all the detected instruments. The identified methods were categorized into seven groups, including *lab studies* (individual or by group), *field studies* (short term or longitudinal), *surveys*, *expert evaluation* and *mixed methods*. In this study a mixed method was implemented, based on the data collected through individual surveys in a short term field study.

Specific instruments to evaluate the pragmatic and hedonic characteristics of software are available in the literature, including: SUMI, QUIS, CSUQ, SUS, UMUX and UMUX-Lite (Lewis 2013; Lewis et al., 2013), instruments to measure computer systems usability; and the AttrakDiff 2 questionnaire to explicitly evaluate UX (Hassenzahl et al., 2003). Particularly, the System Usability Scale (SUS) instrument is one of the most used questionnaires for usability testing. The SUS is a 10 items questionnaire (using positive and negative tone), released about 20 years ago as a reduced version of the instruments already proposed (Brooke, 1996). Recently, authors of the Usability Metric for User Experience (UMUX) (Finstad, 2010; Finstad, 2013) and UMUX-Lite (Lewis et al., 2013), in conformance with the ISO definition of usability (standard 9241), introduced two even shorter versions. However, in the HCI research field, there is some polemic regarding reliability, validity, and sensitivity of these two instruments (Lewis, 2013; Pribeanu, 2016). In the presented work, in order to include more specific questions, we opted for elaborate our own questionnaire items. Similar to SUS and UMUX, we elaborated an evaluation instrument considering the constructs usability ("…achieve specified goals with effectiveness, efficiency and satisfaction") and user experience ("…users' emotions, beliefs, preferences, perceptions, physical and psychological responses"), based on the ISO 9241 standard (ISO 9241-11, 1998).

Regarding the learning motivation construct, proposed in (Satar, 2007) as a new usability measure for e-learning design, we considered the four affective learning sub-constructs from the ARCS Model of Motivational Design: 1) *attention*, arouse and maintain interest in the game; 2) *relevance*, significant for students' needs; 3) *confidence*, produce positive expectation for successful achievement; and 4) *satisfaction*, reinforcement for effort.

In (Hassenzahl, 2003), it is proposed an evaluation model that combines UX elements with functional characteristics (subjective nature of

experience, product perception and emotional responses to products in varying situations). The model is based on the user and designer perspectives. In addition, based on the weak or strong perception of the pragmatic and hedonic attributes, the product character is categorized into four levels: *unwanted*, *SELF*, *ACT* and *desired*. Unwanted category derives from a combination of weak hedonic and weak pragmatic attributes. Desired systems are those that combine strong hedonic and pragmatic characteristics. SELF and ACT categories imply a strong and weak combination of hedonic and pragmatic attributes (Hassenzahl, 2003). The proposed taxonomy for ECG presented in this work is an extension of this categorization scheme, where desired systems are those combining strong hedonic, pragmatic and learning motivation characteristics.

3 EDUCATIONAL COMPUTER GAMES

This section includes a brief overview of the educational computer games evaluated in the case study: shopC and ISCARE (*Information System for Competition based on pRoblem solving in Education*).

3.1 ShopC Educational Game

Some traditional games have been adapted to educational computer games. The games that used to be played, or are still being played now, are a good option to be implemented as computer-based educational tools. One of the main advantages of traditional games is that they have proved to be accepted by the users and players already know the mechanics of the game. Specifically, board games are traditionally well adopted by a large majority.

ShopC is a computer game based on an adaptation of the board game Monopoly. The game board, as in the original one, includes a set of properties to be acquired by the players, such as restaurants, bars or jewelry stores. When a player falls into one of the properties, he/she must answer some questions in order to buy it; the set of questions can be configurable from any educational domain. The properties price is determined by the number of correct answers provided by the students about a specific subject.

ShopC was designed for multiple players (for one up to four). One of the players starts the game by rolling a dice in order to know the number of squares to advance. Then, the mechanic used to determine which player goes next is similar to the original game. When a player falls into a property previously sold, he/she must answer a question to avoid paying the corresponding fee. The game finishes after fifty turns for each player, or when they lose all their money. After that, information about the performance of players is provided.

In order to obtain a positive effect in the learning process, the system was developed considering three design principles: *motivation*, *learning* and *gaming*; features in accordance with the factors stated in our study. Firstly, the motivation principle includes the elements that take students to play the game (e.g. flow, curiosity, autonomy, rewards, feedback and a competition scenario). Secondly, the learning fundamentals are based on the *Learning Mechanics-Game Mechanics* model (LG-GM), which considers learning theories such as constructivism, behaviorism and personalism (e.g. questions and answers, instruccional guidance, action/task, repetition and reflection and self-assessment). Finally, the gaming features were designed to entertain and amuse players with the game mechanics while learning (goals and rules, player's control and challenges). More details about the design of shopC are presented in (Julian-Mateos, Muñoz-Merino, Hernández-Leo, Redondo-Martínez and Delgado-Kloos, 2016).

3.2 ISCARE Educational Game

Problem solving is a skill required at all educational levels. Problem representation and choosing the problem solving procedure are recognized as being vital elements within the framework of solving a problem (Frederiksen, 1984). This capability allows students to address situations using general or ad-hoc methods to solve specific problems.

ISCARE is an educational computer game that combines three particular features. Firstly, the instructional materials of ISCARE are based on problem solving educational activities. Secondly, as an innovation within the field of competition-based ECG, the competition functionality of the game is based on the Swiss-system non-eliminating tournament. According to the mechanics of this type of competition, the system divides a tournament in different rounds, participants are paired and then they play the same amount of matches against each other. Finally, ISCARE is a competition-based Intelligent Tutoring System (ITS). The system includes artificial intelligence algorithms for pairing

students and assigning problems according to their knowledge level (Muñoz-Merino, Fernández-Molina, Muñoz-Organero, Delgado Kloos, 2012). Besides the problem information, student can see tournament statistics such as his/her round points, tournament performance and information about the current opponent.

In summary, both ECG are constructed under the category of competition games. However, while shopC is an adaptation of a board game considering characteristics that emphasize motivation to play the game, based on multiple learning theories and gaming features, the ISCARE game accentuates the importance of problem solving skills and the competition feature of the system.

4 EVALUATION INSTRUMENT

In order to conduct our study to evaluate the design characteristics of the described ECG, a questionnaire has been elaborated. This instrument is based on the questionnaire developed in (Julian-Mateos et al., 2016). Our questionnaire has been extended with new questions. The created instrument covers the three key factors stated previously as relevant to evaluate in the interaction with CEG: usability, experience of user and learning motivation. The different questions are classified in the mentioned three categories, which is a different classification than the one proposed by Julian-Mateos et al., (2016).

Fundamentally, in order to evaluate CEG performance, we extended the product character categorization proposed by Hassenzahl (2003). In addition to the pragmatic and hedonic elements (see Figure 1a, retrieved from the original paper), specifically for ECG, we included the learning motivation factor as a new element for product character categorization (see Figure 1b).

The elaborated instrument consists of two sections, intended to gather quantitative as well as qualitative data. The first section is an 11 items questionnaire, intended to assess the usability, UX and learning motivation characteristics of the ECG; three items addressing each assessed factor and two additional items intended to evaluate the overall performance of the systems. Table 1 shows the items and the factor category to which they belong. This instrument section is an opinion survey, with a 5-points measurement Likert scale; from strongly disagree to strongly agree.

Qualitative data is collected through the second section of the instrument, a survey consisting of two framed open-ended questions. The main objective of these questions was to complement and validate the users' opinion gathered through the quantitative survey. The two qualitative questions were the following:

What are three positive aspects of the game?

What are three negative aspects of the game?

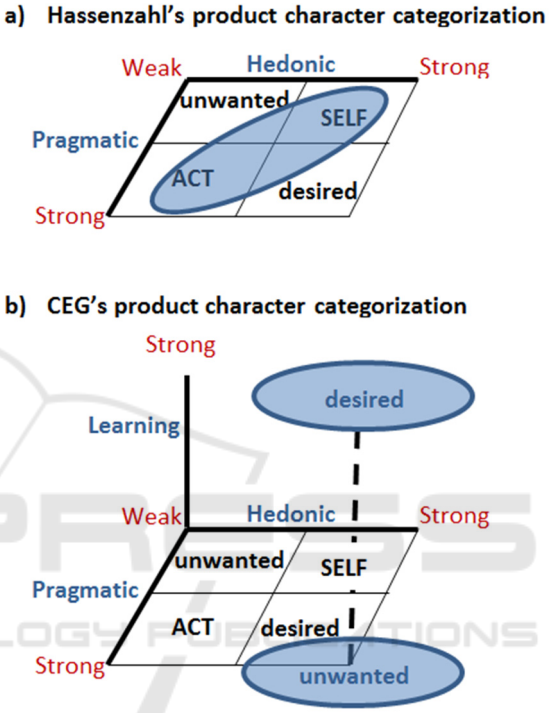

Figure 1: Adapted product character categorization to classify ECG.

5 STUDY METHODOLOGY AND RESULTS

In this study we evaluated the usability, user experience and learning motivation factors, as well as the general performance, of the two educational games. The study was conducted through a questionnaire based on available previously validated instruments.

Table 1: Questionnaire items categorized by evaluated factors.

	Item	Factor
1	It has been easy to understand the different functionality of the game.	Usability
2	The elements of the game interface are easily identified and are illustrative of the functionality they perform (buttons, images, etc.)	Usability
3	The tool has a nice interface.	General
4	It has been easy to know my position in the game ranking (you can always know if you are winning or losing).	Usability
5	I have had the impression that this game complements or help to improve my knowledge, skills and experience.	Learning Motivation
6	I think I can learn more with this game than with a traditional system of questions with a piece of paper.	Learning Motivation
7	I like the objectives, rules and philosophy of the game.	UX
8	The outcome of the game has been according to my level of knowledge.	Learning Motivation
9	The use of this game has increased my motivation and interest for the course.	UX
10	I would like to repeat this experience.	UX
11	I liked the game used.	General

5.1 Study Design

This study was conducted in a threefold perspective: evaluate the usability, user experience and learning motivation of students while using two different types of competition ECG. During the study we collected both quantitative and qualitative data to evaluate the performance and characteristics of the two educational digital games. Qualitative data was intended to confirm, and with the aim to obtain a better understanding of, the quantitative outcomes. In order to have homogeneous systems evaluation criteria, the same group of students participated in the evaluation of the two systems at two different points in time.

5.2 Participants

A total of 41 master students participated in this study. During the study period, participants were enrolled in *Telecommunications Engineering* master's degree at *Universidad Carlos III de Madrid*, taking the *Network Security Fundamentals* class. The students in the class were invited to participate voluntarily in the study, all of them agreed to take part in the evaluation of the two ECG. Considering that the study was conducted in two different days, unfortunately, due to personal reasons, two students could not attend the second part of the evaluation process. At the end, 41 students evaluated the ISCARE game and 39 the shopC game.

5.3 Evaluation Procedure

The study was conducted at two different days. On the first day, students played the ISCARE game (intervention-1), and on a different day they played the shopC game (intervention-2). Consistently, each intervention took an average of two hours to be completed. During each intervention, the students performed three main activities:

1. Students attended a one-hour class about a specific topic of network security fundamentals (different topic per intervention).
2. Students received instructions and the dynamic for the game (purpose, roles, how to play, educational goal, and so forth), after that we defined the competition program (pairs of students to compete), and then they started playing for an interval of 30 minutes.
3. Students answered the quantitative and qualitative questions.

6 RESULTS AND DISCUSSION

In this section we present and discuss separate results by the evaluated educational games (shopC and ISCARE) and by comparing the outcomes of both studies. Quantitative analysis of the survey data is presented first, and then we complement this study with the examination of the qualitative information.

6.1 ShopC Educational Game

We used the mean and standard deviation for quantitative analysis, qualitative data is expressed as

percentages. The results of the quantitative survey are presented in Table 2. Similar to the GEQ instrument, factors score were computed as the average value of its items.

According to the quantitative evaluation, shopC game was rated positively by the study participants (N=39). The factors' evaluation results indicate a significantly good rating of perceived system usability (M_U = 4.470, SD_U = 0.837). Similarly, the mean score for the UX factor was equally rated (M_{UX} = 4.491, SD_{UX} = 0.766). The high ratings assigned by participants to these two factors indicate the effectiveness and efficiency of the game, as well as the fulfilment of the expected level of students' satisfaction (see Table 2).

Regarding learning motivation, students consider this game as an adequate environment to enhance their domain knowledge. Surprisingly, the mean score of the learning motivation factor (M_{LM} = 4.559, SD_{LM} = 0.766) was slightly higher than the rates obtained for usability and UX. As expected, considering the shopC system's characteristics, its overall evaluation was rated satisfactory; a mean score above 4.5 (up to a maximum of five) indicates that the system is suitable for learning and recreation. Based on the proposed product character categorization schema, we classified shopC within the "desired" category (see Figure 2).

Table 2: Descriptive statistics by evaluated factor.

Factor	shopC		ISCARE	
	Mean	SD	Mean	SD
Usability	4.470	0.837	4.439	0.570
User Experience	4.491	0.766	4.228	0.647
Learning Motivation	4.559	0.766	3.911	0.712
General	4.583	0.923	4.110	0.719

Additionally, we analyzed how usability and UX factors had influenced the learning motivation conveyed by the shopC system. We found a strongly positive correlation between the motivation to learn by using this educational game and the perceived system usability (Pearson's r=.621, n=39, p=2.5E-05), and a higher correlation between UX and learning motivation (Pearson's r=.770, n=39, p=1.0E-05). These findings outline the important role that usability and user experience play in the design of ECG in order to enhance the motivation of students to learn.

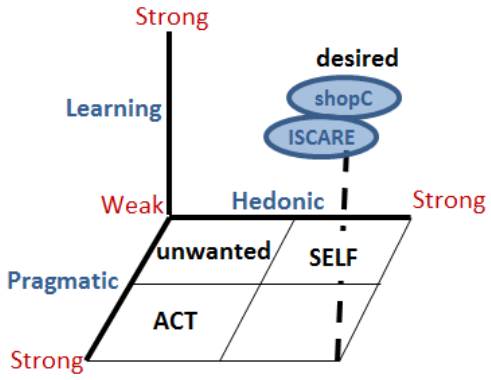

Figure 2: Product character category assigned to shopC and ISCARE games.

About the qualitative questions, most of the students provided at least one aspect per question. Table 3 shows the three main students' recommendations per question, based on percentage of recommendation. For shopC game, the most notable positive aspects detected by students enclosed the three evaluated factors: user experience (students felt motivated and satisfied with the game), learning motivation (they perceived learning outcomes while playing) and usability (they considered the game was easy to play), in that order of importance.

Table 3: Positive and negative aspects of shopC game.

Positive Aspects	Students
It is an entertaining game	20.50 %
Helps to learn while playing	17.98 %
It is easy to play	12.82 %
Negative Aspects	Students
Questions repetition	38.46 %
We don't know who the next player is	5.12 %
Poor user interface	5.12 %

Regarding the negative aspects, students mainly expressed their concern about educational matters; participants recommended an increase in the amount of questions in the game. A number of participants indicated that they suddenly were asked the same question during the game. Second and third negative aspects, with a very low percentage of participants, were related to improve the system interface (usability) and game mechanics (UX).

6.2 ISCARE Educational Game

The ISCARE evaluation results were lower but very similar to those obtained in shopC game. The findings indicate high ratings for usability (M_U =

4.439, SD_U = 0.570) and user experience (M_{UX} = 4.228, SD_{UX} = 0.647) factors (see Table 2). Again, students appeared satisfied with the functionality and experience using this game. However, ISCARE obtained a lower mean score in the learning motivation factor (M_{LM} = 3.911, SD_{LM} = 0.712). The result of the overall evaluation of ISCARE game was lower but acceptable as well (M_G = 4.110, SD_G = 0.719). Using our categorization scheme, based on the evaluation results, ISCARE was classified within the ECG "desired" category (see Figure 2).

Compared with shopC, ISCARE presented lower factors correlation. However, the correlation between usability and learning motivation (Pearson's r=.546, n=41, p=2.2E-04) and UX with learning motivation (Pearson's r=.558, n=41, p=1.5E-04) remains stable; we can observe a moderate positive correlation. These results emphasize the importance of usability and UX as elements capable of raising the learning motivation level of students while using ECG.

The qualitative results of ISCARE game are described in Table 4. Even though quantitative findings were lower than the obtained in shopC, contradictorily for the learning motivation factor, most of the students expressed a positive opinion regarding their motivation to learn by using this game. More than 58% of the participants pointed out that ISCARE helps them to learn while playing and also motivate to study. Nevertheless, qualitative results confirm the quantitative findings; students complemented the study indicating an acceptable usability and UX of the ISCARE game. With regard to the negative aspects, the main concern was the amount of time available for the learning experience; slightly more than half of the students agreed that there was not enough time to answer the questions. This could be the reason why ISCARE obtained a lower mean score about the learning motivation factor.

According to the results of the quantitative analysis, both educational games were classified within the optimal/desired category; based on the proposed categorization scheme. An ECG that falls under this category implies not only the fulfilment of usability and UX principles, but also the user perception of positive learning outcomes and motivation to learn.

Since both systems were evaluated by the same group of students, and assuming that they used the same evaluation criteria or point of view, we consider that competition-based ECG are well situated to address learning motivation factors. Even though the two evaluated systems did not use the same instructional technique, their competition feature helped to motivate students to play the game and learn. At the same time, ensuring adequate user experience and usability systems' characteristics increase the user learning motivation perception.

Table 4: Positive and negative aspects of ISCARE game.

Positive Aspects	Students
Helps to learn while playing/motivate to study	58.54 %
It is easy to play	31.71 %
It is an entertaining game	31.71 %
Negative Aspects	Students
There is not enough time to answer questions	51.11 %
There is not available feedback	22.22 %
It is stressful	8.89 %

7 CONCLUSIONS

Empirical research on how students perceive computer-based educational games allows improving the performance and acceptability of this type of educational technology. Conducting research about usability and user experience of ECG can have a significant impact on the implementation of future systems. However, addressing the main goal of ECG, the analysis of learning gains and learning motivation is vital to understand what really enhance students learning experience while playing educational digital games.

This paper presents the evaluation of two competition-based ECG systems, shopC and ISCARE, analysing the correlation among usability and user experience with learning motivation. The presented work has shown how usability and UX can be crucial factors to enhance learning motivation of students using ECG. At the same time, based on the quantitative and qualitative data gathered, students reported as significant the importance of system functionality, feelings conveyed and learning motivation.

For future work, we plan to follow students' recommendations to improve shopC and ISCARE games performance, as well as evaluate the proposed questionnaire items in order to conduct further evaluations addressing topics from different educational domains.

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