Quality of Games for Teaching Software Engineering: An Analysis of Empirical Evidences of Digital and Non-digital Games

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Abstract— Educational games have been used as an innovative instructional strategy in order to achieve learning more effectively in Software Engineering (SE) education. However, it is essential to systematically evaluate such games in order to obtain sound evidence on their benefits. And, although, several SE games have been evaluated adopting diverse research designs and measurements, so far no larger scale study across different games has been conducted. In this respect, this article presents a comprehensive analysis in order to summarize empirical evidence on the benefits of digital and non-digital games used for SE education. The analysis is based on data collected from 43 case studies that use MEEGA, the most commonly used model for educational game evaluation, evaluating 20 different SE games, involving a total population of 723 students. Our analysis indicate evidence that digital and non-digital games can yield a positive effect on the learning of SE, providing a pleasant and engaging experience to the students and motivate them. Our analysis also points out that non-digital games more easily seem to promote a more positive experience, principally in terms of fun and social interaction than the digital ones used for teaching SE. These results may guide SE instructors in the selection of educational games as instructional methods and guide game creators with respect to the development of new games.

Empirical evidence; evaluation; SE game (key words)

I. INTRODUCTION

Software Engineering (SE) is the discipline concerned with the application of theory, knowledge, and practice to effectively and efficiently build reliable software systems that satisfy the requirements of customers and users [1]. In this respect, SE professionals are not only expected to successfully cope with technical challenges but also to deal with non-technical issues, including management, communication and teamwork [2].

Typically, SE is taught through traditional lectures [3]. This instructional method is adequate to present abstract and factual information, but may not be the most suitable for achieving higher cognitive objectives aiming at the application and transfer of knowledge to real-life situations [3]. Yet, practical course constraints usually limit the exposure of students to realistic scenarios, which may hinder them to learn how to apply the concepts. On the other hand, other instructional methods such as educational games may be better fitted to achieve learning on higher levels more effectively [5, 6, 7, 8]. Educational games are specifically designed to teach people about a certain subject, expand and revise concepts, reinforce development, or assist them in drilling or learning a skill or seeking a change of attitude as they play [9].

Driven by the need to provide more hands-on opportunities for SE students, various educational games have been developed [5], including digital games such as SimSE [10], the Requirements Collection and Analysis Game (RCAG) [11], as well as non-digital games, e.g., SCRUMIA [12], Problems and Programmers [26], among others.

Educational games are believed to result in a wide range of benefits, like increasing the learning effectiveness, increasing interest and motivation as well as reducing training time and instructor load [6, 13]. Games are expected to be a fun and safe environment, where students can try alternatives and see the consequences, learning from their own mistakes and practical experiences [14]. Thus, they are supposed to be an effective and efficient instructional strategy for SE education. However, these claims seem to be questionable [6]. In practice, SE games seem to lack the empirical evidence of either the expected learning impact and/or the engagement they promise [8, 15]. Thus, these claims seem not rigorously established as most evaluations of SE games are performed in an ad-hoc manner in terms of research design, measurement, data collection & analysis [4, 5, 6, 7, 8].

On the other hand, there are some initiatives underway to provide a more systematic support to obtain empirical evidence of games' quality [16]. In this respect, MEEGA (Model for the Evaluation of Educational Games) [17] is a well-defined model developed for the evaluation of educational games. The model measures the perception of students after they played the game by applying a standardized questionnaire answered by the students in a case study with a one-shot post-test design. It has been developed by using the GQM (Goal/Question/Metric) approach [18] to explicitly define a measurement program for evaluating three quality factors: motivation, user experience, and learning [17]. Currently, MEEGA seems to be one of the most widely used evaluation models in practice [4, 7, 16].

Thus, in order to obtain a more comprehensive understanding of the quality of SE games in general, we collected empirical evidence from the evaluations of digital and non-digital games used for SE education from case studies that used MEEGA. Our analysis is based on a large-scale data set from 43 case studies that reported the usage of the MEEGA

model, evaluating 20 different SE games in different higher computing education institutions and professional IT training, involving a total population of 723 students.

II. BACKGROUND

A. Educational Games

An educational game is an instructional strategy that typically involves competition and is organized by rules and restrictions to achieve a certain educational goal [9]. They are specifically designed to teach specific concepts or to strengthen competencies [19]. Educational games are characterized by various elements, such as goals, rules, restrictions, interaction, challenge, competition, rewards and feedback [9, 19]. Intrinsic characteristics of games, such as competition stimulating the will to win, help students to stay focused on the learning activity [19].

There exist a broad scope of games including digital and non-digital ones [4, 5, 7, 15]. Digital games are electronic games that involve human interaction with a user interface to generate visual feedback on an electronic device such as smartphones, computers, tablets, etc. [20], whereas non-digital games are played with non-digital resources such as game boards, cards, pencils and papers, etc. [21]. There exist a broad spectrum of games genres including action, adventure, strategy, simulation, puzzle, quiz, role-playing games (RPGs), among others [5].

B. Games for teaching Software Engineering

So far many educational games (more than 100) for teaching computing have been developed [4, 5]. The majority of these games focus on teaching Software Engineering [4, 5, 6]. This emphasis on SE can be explained by the possibility they offer to provide practical experience to the students in a safe and controlled environment helping to achieve learning on the application level, which otherwise due to practice restrictions may not be possible in Software Engineering [22].

Many of these games are simulation games, typically covering topics of Software Engineering Management (e.g., DELIVER! [23], SimSoft [24], SCRUMIA [12]), in which the learner assumes the role of a project manager and performs the planning, monitoring and control of a software project [5]; the Software Engineering Process (e.g., SimSE [25], Problems and Programmers [26]), simulating the execution of a specific kind of software development process or requirements engineering; Software Testing (e.g., Secret Ninja Testing [27], U-Test [28]), in which the player must solve challenges by preparing unit test cases. In addition, there can also be observed a trend to quiz games in order to review knowledge (e.g., PMMaster [29], KahootPMQuiz [30]).

Although, this indicates that games are widely used for teaching SE, it is essential to evaluate such games in order to obtain empirical evidence of the games' quality as a basis for an effective and efficient adoption.

C. Evaluation of Educational Games for Teaching SE

The evaluation of an instructional method, such as educational games, aims at measuring the level of its success, evaluating whether the target audience has achieved the defined objectives. Evaluation should cover both the student learning, as well as the elements, materials and resources that compose the instructional strategy [31].

In this context, several studies summarize the state of the art on games evaluation for computing/SE education [4, 5, 6, 7, 8, 15]. These studies show that besides evaluating the learning effect of those games, a wide variety of quality factors are considered, including motivation, user experience, usability etc. demonstrating also that there does not exist a consensus on the factors to be evaluated [4, 6, 7, 16]. In addition, most evaluations of educational games are performed in an ad-hoc manner in terms of research design, measurement and data collection & analysis lacking scientific rigor [4, 5, 6, 7, 8, 15]. Furthermore, most evaluations are run with small samples (typically applying the game in one class without replication) leaving the validity of the obtained results questionable [4, 7, 16].

On the other hand, MEEGA [17] and EGameFlow [32] are models specifically developed for the evaluation of games for computing education [4, 16]. Both models have been systematically developed by explicitly decomposing evaluation goals into measures and defining a questionnaire, validated through series of case studies. Both models focus on the evaluation of learning/knowledge improvement and user experience during the game play, including also in case of MEEGA the motivation promoted through the game. Currently, MEEGA seems to be used more widely in practice being reported by several studies from different authors evaluating different games and contexts [4, 7, 16]. For this reason, in this work, we consider this well-defined and evaluated approach in order to summarize empirical evidences of SE game evaluations.

In this respect, MEEGA is a model specifically developed for the evaluation of educational games [17]. The model focuses on the evaluation of educational games (including digital as well as non-digital games). Following the empirical study process [33] and the guide for the development of measurement scales [34], MEEGA was developed by systematically decomposing quality factors using the GQM (Goal/Question/Metric) approach [18]. These quality factors were refined into a set of dimensions from which the questionnaire items have been derived. It assumes that the quality of a game is given if it provides a positive learning effect, motivates students to study and provides a pleasant and engaging learning experience. Accordingly, the goal of MEEGA is to evaluate an educational game with respect to motivation, user experience and learning from the viewpoint of the learners in the context of an instructional unit. Each of these quality factors is further refined in dimensions as presented in Fig. 1. The quality factor motivation was decomposed based on the ARCS model [35], a well-known model of motivation that has also been used in several studies to assess the motivation of students utilizing educational resources. The ARCS model decomposes motivation into four dimensions: attention, relevance, confidence and satisfaction. Attention refers to students' cognitive responses to instructional stimuli. Relevance refers to the students' need to realize that the educational proposal is consistent with their goals and that they can link content with their professional

future. Confidence means to enable students to make progress in the study of educational content through their effort and ability (e.g., through exercises with increasing level of difficulty). Satisfaction means that the students feel that the dedicated effort results in learning.

The quality factor user experience was decomposed into [36, 37, 38]: immersion, challenge, social interaction, fun, and competence/control. Immersion allows the player to have an experience of deep involvement within the game, creating a challenge with real-world focus, so that s/he forgets about the outside world during gameplay. Challenge means that a game needs to be sufficiently challenging with respect to the players' competency level. Social interaction refers to the creation of a feeling of shared environment and being connected with others in activities of cooperation or competition. Games should also provide feelings of fun, enjoyment, pleasure, relaxation, recreation and satisfaction. When playing becomes something special to the player, it will provide a strong positive experience, accompanied by the desire to rejoin the game and recommend it to others. The game should also allow the player to have a sense of control over the game interactions, which should be easy to learn and allow them to explore the game freely and at their own pace. To provide a good experience, games should support the development and mastery of competencies so it is possible to overcome the challenges of the game [36, 37, 38].

The quality factor learning is measured in relation to the first three levels of the revised version of Bloom's taxonomy (remembering, understanding and applying) [39] including two dimensions with respect to short-term and long-term learning based on the assessment model by Sindre and Moody [40]. The evaluation of short-term learning is based on the more immediate educational goals, whereas long-term learning focuses on the contribution to the professional life of the individual.

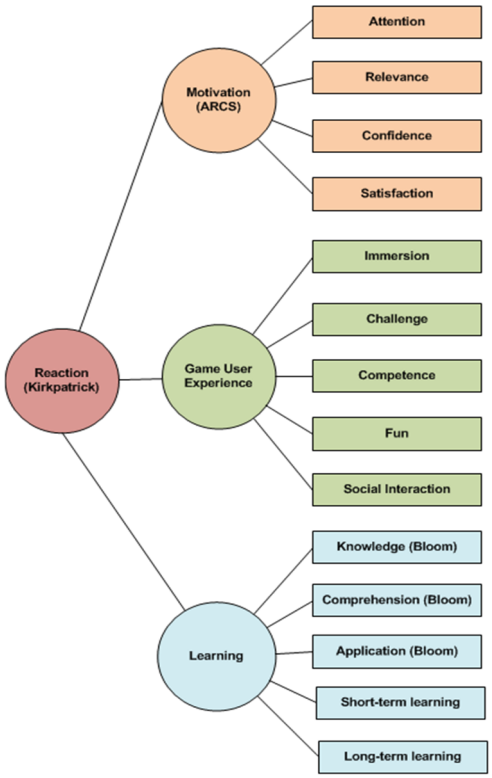

Figure 1. Decomposition of the quality factors [17].

Based on the defined quality factors a questionnaire has been developed customizing and unifying existing standardized questionnaires [35, 36, 37, 38, 40, 41, 42]. The response format for each of these standardized items is based on a 5-point Likert scale ranging from strongly disagree to strongly agree [34].

The MEEGA model is intended to be used in case studies with a one-shot post-test only design, in which the case study begins with the application of the treatment (educational game) and after the game play the MEEGA questionnaire is answered by the learners in order to collect their perceptions.

III. RESEARCH METHOD

In order to summarize empirical evidence of games used for SE education, we conduct a case study [33, 43] structured as illustrated in Fig. 2.

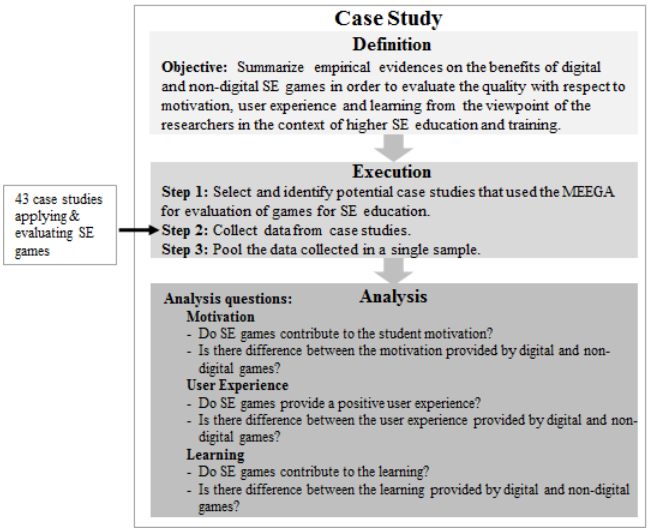

Figure 2. Research method.

Following the GQM approach [18], the study objective is decomposed into quality aspects and analysis questions to be analyzed based on the data collected in the game's evaluation.

The execution phase was organized in three steps. First, we identified and selected potential case studies by searching via Google and Google Scholar for articles that reported the evaluation of SE games using the MEEGA model. As result, we identified 43 case studies (Table I). Then, we contacted the authors (via email) requesting the collected data. In step 3, we grouped the data collected in the selected case studies (Table I) into a single sample

In the analysis phase, we performed a comprehensive analysis, thus, used them cumulatively in order to summarize empirical evidence in terms of motivation, user experience, and learning. Then, we analyzed each of the analysis questions.

IV. DEFINITION AND EXECUTION OF STUDY

The objective of this study is summarize empirical evidence on the benefits of digital and non-digital SE games in order to evaluate their quality in terms of motivation, user experience and learning from the viewpoint of the researchers in the context of higher SE education and professional IT training.

From this objective, we derive the following analysis questions, grouped by the evaluated quality factors:

Motivation

AQ1: Do SE games contribute to the students' motivation?

AQ2: Is there a difference between the motivation provided by digital and non-digital games?

User Experience

AQ3: Do SE games provide a positive user experience?

AQ4: Is there a difference between the user experience provided by digital and non-digital games?

Learning

AQ5: Do SE games contribute to learning?

AQ6: Is there a difference between the learning provided by digital and non-digital games?

In order to maximize the sample size, we collected data from case studies that evaluated SE games in computing courses in higher education and professional IT trainings using MEEGA. As a result, we obtained data from 43 case studies, with responses from a total of 723 students in 6 different contexts/institutions as summarized in Table I.

TABLE I. SUMMARY OF CASE STUDIES.

Game	Platform	SE Knowledge [54]	Course/Semester	Institution/ Country	Sample size
Dealing with difficult people [45]	Non-digital	SE Management	Project planning and management/2013-1	UFSC/ Brazil	14
			Project management/2013-1		28
			Project planning and management/2015-2		23
DELIVER! [23]	Non-digital	SE Management	Project planning and management/2010-2	UFSC/ Brazil	15
			Project management/2010-2		13
DOJO	Digital	SE Management	Project management/2013-1	UDESC/ Brazil	19
EAReqGame [46]	Digital	Software Requirements	Software Engineering/2014-2	UFSM/ Brazil	14
Paper Tower [47]	Non-digital	SE Management	Project management/2013-1	UDESC/ Brazil	4
PERT-CPM Game	Non-digital	SE Management	Project management	UNISUL/ Brazil	5
PizzaMia [48]	Non-digital	SE Management	Project management/2013-1	UDESC/ Brazil	17
			Project management/2014-1		19
			Project management/2015-1		13
PMMaster [29]	Non-digital	SE Management	Project planning and management/2010-2	UFSC/ Brazil	7
			Project management/2010-2		16
			Project planning and management/2012-1		21
			Project management/2012-1		33
			Project planning and management/2015-1		17
			Project planning and management/2015-2		12
PMQuiz [30]	Digital	SE Management	Project planning and management/2015-1	UFSC/ Brazil	20
			Project management/2015-1		13
			Project planning and management/2015-2		18
			Project management/2015-2		20
Project Detective [49]	Non-digital	SE Management	Project planning and management/2011-2	UFSC/ Brazil	18
			Project management/2011-2		31
			Project planning and management/2013-1		13
Risk Game	Non-digital	SE Management	Project management/2013-1	UDESC/ Brazil	15
Risk Management Game	Non-digital	SE Management	Project planning and management/2015-2	UFSC/ Brazil	18
Schedule and Risk Game	Non-digital	SE Management	Project management/2014-1	UDESC/ Brazil	5
SCRUM'ed [50]	Digital	SE Management	Project planning and management/2015-1	UFSC/ Brazil	23
SCRUMIA [12]		SE Management	Project planning and management/2010-2		16

	Non-digital		Project management/2010-2	UFSC/ Brazil	12
			Project planning and management/2011-1		15
			Project management/2011-1		30
			Project planning and management/2015-1		13
			Project planning and management/2015-2		18
			Agile Methods/2013-1	UDESC/ Brazil	23
SCRUM-SCAPE [51]	Digital	SE Management	Project planning and management/2013-2	UFSC/ Brazil	17
ThatPMGame [52]	Digital	SE Management	Project management/2013-1	UDESC/ Brazil	6
			Project management/2013-1		13
TRIVIAL PURSUIT – IFPUG FPA	Non-digital	SE Management	Training course on IFPUG FPA v4.2	Engineering .IT/ Italy	14
			Training course on IFPUG FPA v4.2		5
UsabiliCity [53]	Digital	Software Design	Human-Computer Interaction/2014	Uninorte/ Brazil	37
XPEnigma	Non-digital	SE Management	Project management/2013-1	UDESC/ Brazil	20

V. ANALYSIS

Data collected in the selected case studies (Table I) were pooled in a single sample, using them cumulatively in order to summarize empirical evidence of SE games (and no to evaluate a specific game). However, in order to analyze the differences between digital and non-digital games, we also grouped the data collected according to the respective platform (digital or non-digital), as detailed in Table II.

TABLE II. SUMMARY OF CASE STUDIES PER PLATFORM.

Platform	Number of Case Studies	Population
Digital	11	200
Non-digital	32	523
Total	**43**	**723**

The grouping of data was possible due to the similarity of the selected case studies and standardization of the data collection [44]. In this respect, the selected studies are similar in terms of definition (with the objective to evaluate an educational SE game with respect to motivation, user experience and learning), research design (case studies), and context (higher SE education and professional training). In addition, all selected case studies are standardized in terms of measures (quality factors/dimension), data collection method (MEEGA questionnaire), and response format (5-point Likert).

We analyze the collected data using descriptive statistics in terms of frequency distribution and central tendency in order to answer each of the analysis questions as defined in the research methodology, grouped by each quality factor (motivation, user experience and learning). From the collected data, the frequencies of responses were identified, considering the range of responses on a 5-point Likert scale ranging from -2 (complete disagreement) to 2 (complete agreement).

A. Motivation

AQ1: Do SE games contribute to the students' motivation?

Overall, in terms of motivation, the students perceived a positive contribution of SE games to motivate them (Fig. 3(a)), especially, due to the relevancy of the game content and the easy way to use the game as study material. The students also indicated that the attractiveness of the design of the game it is important to motivate them.

In terms of the satisfaction provided by the games, the students confirm that they are moderately satisfied, as they know that will have opportunities to practice in their professional work things that they learned playing the games. In addition, the majority of students also confirmed that they managed to advance due to their personal effort – an essential element of an educational game, which should only allow those students to win, who achieved the respective learning objective(s) [9].

The students also indicated that the ease of understanding the game and its rules is important to use it as study material. Yet, as this confidence was rated only moderately positive, it may indicate that in general the games' rules/mechanisms can be improved in order to better enable students to make progress in the learning tasks through their own effort.

In terms of relevance, the students confirm that the SE games are relevant in terms of content, and are consistent with their goals and that the students can link content with their professional future.

The attention promoted by the games has been rated highly. This confirms, mainly, that the variation of the form, content and activities and the attractive design are important issues to capture the student's attention. Yet, this may still be improved, as we observed some negative ratings indicating that students did not perceive anything interesting at the beginning of the game.

AQ2: Is there a difference between the motivation provided by digital and non-digital games?

Analyzing the differences between the motivation provided by digital and non-digital SE games, we observe that both platforms contribute to the students' motivation (Fig. 3(b)). Regarding satisfaction and confidence, the analysis of both platforms also show similar positive results, mainly, with respect to the use of the games as study material.

In terms of relevance, again, both digital and non-digital games show a positive evaluation. However, a slightly more positive evaluation on the connection of the game content to other knowledge was perceived with respect to digital games. This, of course, could also be related to the game content itself and its instructional context in which the game has been applied rather than to the fact being digital games.

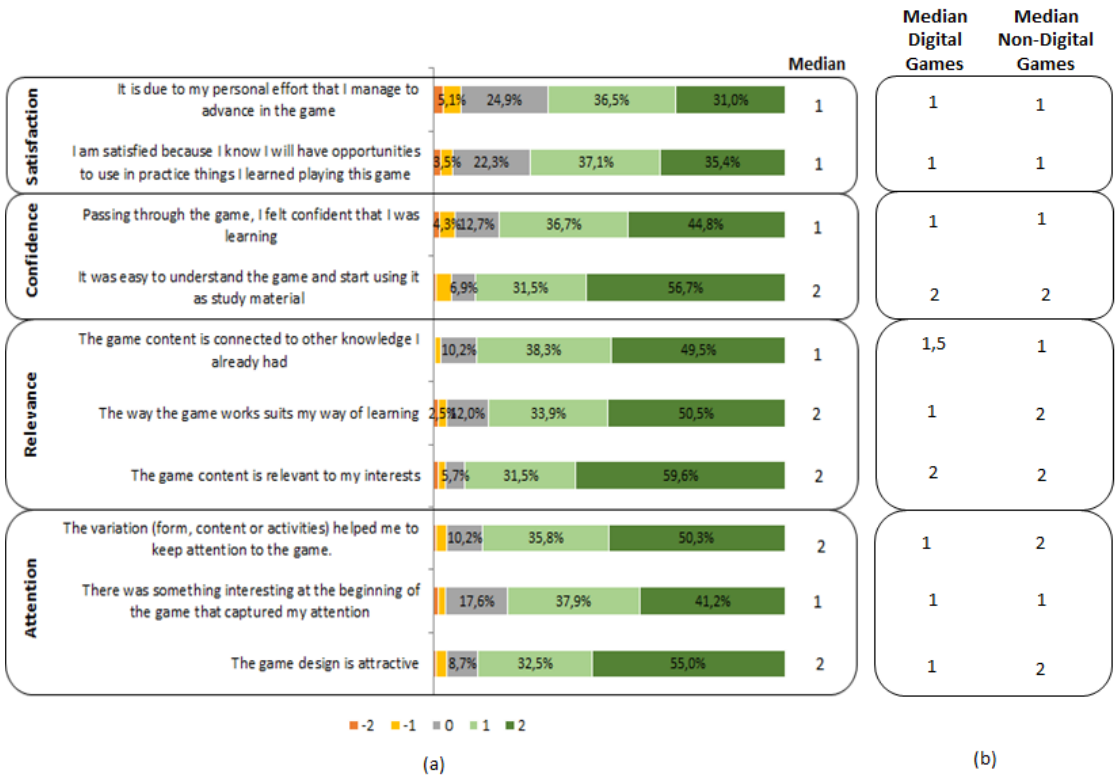

Figure 3. (a) Frequency diagram and medians of answers with respect to motivation for any kind of game. (b) Medians of digital and non-digital games with respect to motivation.

B. *User Experience*

AQ3: Do SE games provide a positive user experience?

In general, the user experience provided by the games has been rated very positively (Fig. 4(a)). This demonstrates that the use of SE games as instructional method provides a good experience for the students, especially, in terms of social interaction, cooperation and/or competition among the players. The students also indicated that they had fun playing the games.

Students also confirmed (moderately) that they had a positive feeling on the efficiency of the games and that they achieved the goals of the games applying their previous knowledge.

Students also pointed out that they would like to play the games again and would recommend them to their colleagues. Even so, the students were not disappointed when interrupted at the end of class. Yet, this may express a normal attitude of students eagerly awaiting for the class to end.

Concerning the challenge provided by the games, the students indicated moderately positive that the games progressed at an adequate pace and were appropriately challenging. Yet, taking into consideration some negative ratings, improvement opportunities may include the creation of new obstacles, activities, and situations with respect to the players' competency level.

Social interaction has been the highest rated factor of the games. This demonstrates that SE games are a good strategy to promote interaction among the students. The students pointed out that the games contributed to the cooperation and/or competition and provided a fun experience with other people. In addition, the students were able to interact with others during the game, providing a feeling of shared environment. We also observed that in several cases the interaction during game play motivated a continuation of a closer interaction between the students outside the class.

With respect to immersion, the games have been rated moderately positive. This result shows that the students had an experience of deep involvement within the game forgetting about their daily activities, focusing on the game tasks, and losing track of time during the gameplay.

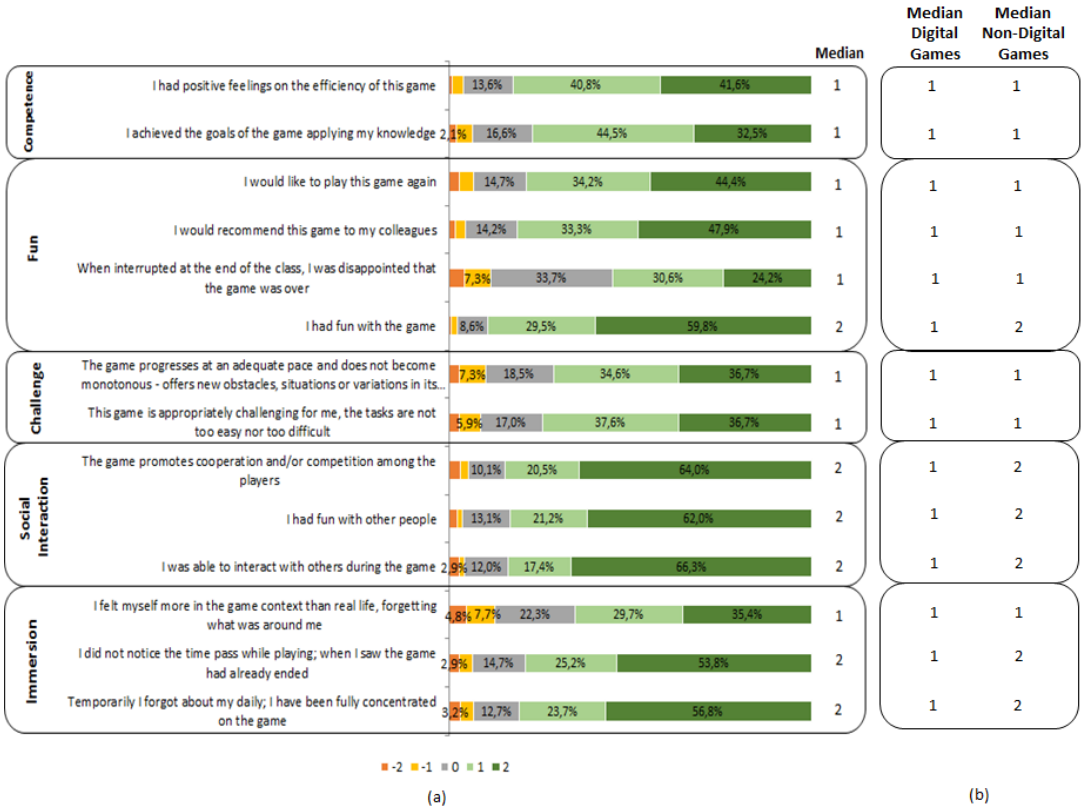

Figure 4. (a) Frequency diagram and medians of answers with respect to user experience for any kind of game. (b) Medians of digital and non-digital games with respect to user experience.

AQ4: Is there a difference between the user experience provided by digital and non-digital games?

Overall, analyzing the user experience provided by digital and non-digital SE games, we can identify that both platforms have been rated moderately positive (Fig. 4(b)). This demonstrates that the students experienced the games as a positive and engaging learning strategy using both digital and non-digital games. In terms of competence and challenges, both platforms gave been evaluated similarly.

Although recognizing the fun promoted by both platforms, non-digital games have been rated to be more fun than digital ones. This result can be related to a stronger social interaction among the players of non-digital games making the game more fun, interacting and competing with their colleagues, as shown in Fig. 5.

Figure 5. (a) Students playing the non-digital game PMMaster. (b) Students playing the digital game SCRUM-SCAPE.

Yet, an explanation for the lack of social interaction provided by the digital games here may be the fact that none of the analyzed digital games is a multi-player game. This may be explained by the fact that most of the educational SE games are developed by instructors themselves with very limited resources and time. And, thus, as the development of digital games requires a considerable effort, often these games do not achieve their full potential of attractiveness and interaction mode, which seems to reduce the degree of fun and immersion promoted by these games.

An exception among the analyzed digital game is the digital game PMQuiz [30]. In this game students answer a question presented by the instructor to the class simultaneously on their cell phones and after each question, the game presents the top five ranking. This promotes a social interaction through the competition among students. In this respect, this kind of competition also motivates the students to concentrate on answering the questions correctly and, thus, increases the immersion of the students on the learning task.

C. Learning

AQ5: Do SE games contribute to learning?

In general, the majority of the students recognized that the games contributed positively to their learning (Fig. 6(a)). The students especially considered the SE games to be efficient for their learning when comparing them to other course activities. In this respect, we observed that students even asked to play a game again in preparation for exams indicating the game as

their preferred way of studying. In addition, students also expressed that they expect the games to contribute positively to their professional practice.

AQ6: Is there a difference between the learning provided by digital and non-digital games?

No significant difference with respect to learning has been observed as both platforms have been rated moderately positive (Fig. 6(b)). Only in terms of professional practice, non-digital games seem to be able to contribute more than digital games. This result can be related to the environment promoted by the non-digital game, promoting the interaction, sharing ideas, etc. among the players, simulating some characteristics of the environment the students will find in their future profession.

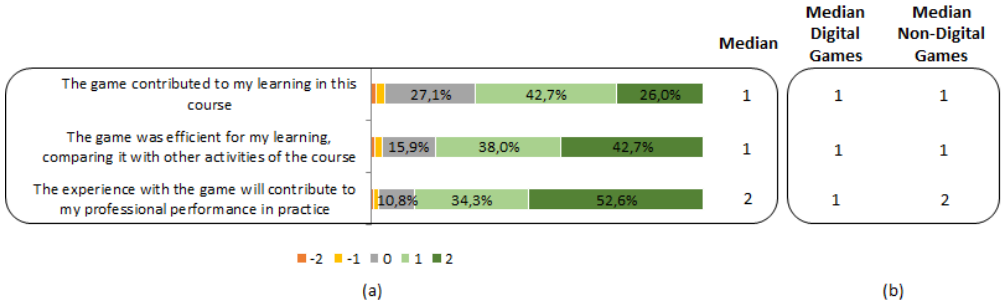

Figure 6. (a) Frequency diagram and medians of answers with respect to learning. (b) Medians of digital and non-digital games with respect to learning.

VI. DISCUSSION

The results obtained from the analysis of the evaluation of 20 different SE games provide evidence that games can yield a positive effect on the learning of SE, provide a pleasant and engaging experience to the students and motivate them.

We observed that the SE games helped to motivate the students, being considered a relevant instructional method that contributes to keep students attentive in the learning activity. We also observed that, different to other kinds of instructional methods (e.g., traditional lectures or exercises), where students often get distracted from the learning task, students participated actively and maintained their attention throughout the game play. Although both platforms contribute to the students' motivation, the results indicate that non-digital games seem to promote a better way to keep the attention of the students on the learning task.

The students expressed that playing SE games was a pleasant and engaging experience. The games contributed to the immersion of the students on the learning task and provided a fun experience. Mainly, the social interaction promoted by the games has been recognized as a very positive factor by the students. This result indicates that the social interaction is an important attribute of educational games [9], as it promotes a feeling of shared environment giving the opportunity to share ideas/opinions/knowledge during the interacting with others students. In this respect, the non-digital games have been evaluated more positively than the digital games. This could be explained by the fact that it is easier to develop an attractive non-digital game with simple cards, game board, etc., than developing an attractive digital game with multiplayer mode requiring a considerable development effort, often not available as most of these educational games are being developed by the instructors themselves.

In terms of learning, the students expressed that the games contributed positively to their learning. Often, educational games are used as complementary instructional strategy for SE education, typically used to expand and/or reinforce concepts and provide more hands-on opportunities to the students. Most of the analyzed games are designed to teach knowledge rather than skills or attitudes, mainly, knowledge on SE Management (90% of the analyzed games (including digital and non-digital-games)). On the other hand, the example of the game Dealing with difficult people [45], also illustrates that games can be used in order to teach a change of attitude with respect to the difficulty to deal with difficult people in software projects.

In summary, we can observe that based on our analysis both digital and non-digital games contribute to the students' motivation, user experience, and learning. However, taking into consideration the fact that most of these games are developed by the instructors themselves with limited resources, the resulting non-digital games seem to be a more suitable way to capture the attention and to promote the immersion of the students on the learning task. Principally through the social interaction they often promote as an intrinsic feature, they easily create a more fun, engaged and pleasant learning experience.

Threats to validity. Due to the characteristics of this type of research, this work is subject to various threats to validity. We, therefore, identified potential threats and applied mitigation strategies in order to minimize their impact on our research.

Construct validity. Some threats are related to the design of the study [33]. In order to mitigate this threat, we defined and documented a systematic methodology for our study using the GQM approach [18]. Another risk is related to the omission of existing data sets related to the evaluation of SE games using the MEEGA model. In order to mitigate this risk, we searched for existing evaluation studies via Google and Google Scholar representing broad search engines. We included data sets from all studies we encountered and for which we received the collected data. Another risk refers to the quality of the data pooled into a single sample, in terms of standardization of data (response format) collected and adequacy to MEEGA model. As our study is limited

exclusively to evaluations that used the MEEGA model the risk is minimized as in all studies the same data collection instrument has been used. Another issue refers to the pooled data from different contexts. To mitigate this threat, we selected studies considering only the context of higher education and professional training with respect to only one knowledge area: Software engineering.

External validity. In terms of external validity, a threat to the possibility to generalize the results is related to the sample size and diversity of the data used for the evaluation. With respect to sample size, our evaluation used data collected from 43 case studies evaluating 20 different digital and non-digital SE games, involving a population of 723 students. In terms of statistical significance, this is a satisfactory sample size allowing the generation of significant results. The data has been obtained from game applications in 6 different institutions/contexts. However, as the data collection was restricted to the evaluations of SE games that used the MEEGA questionnaire for data collection, the majority of the data is from Brazil where it is used more prominently, with only one application from an organization in Italy.

Reliability. In terms of reliability, a threat refers to what extent the data and the analysis are dependent on the specific researchers. In order to mitigate this threat, we documented a systematic methodology, defining clearly the study objective, the process of data collection, and data analysis.

VII. CONCLUSIONS

The results from our analysis of 43 case studies involving 723 students and 20 different SE games provides evidence that digital and non-digital games can yield a positive effect on the learning of SE, providing a pleasant and engaging experience to the students and motivate them. In terms of motivation, the results show that educational games (including digital and non-digital games) are a suitable instructional method for teaching SE that keeps the students attentive to the learning task. SE games also provide a positive experience contributing to the immersion, fun and, principally, to the social interactions among the players during the game play, promoting a shared environment. Based on the perception of the students, the games also contribute positively to their learning.

Comparing digital and non-digital games, the results indicate that non-digital games seem to more easily promote a positive user experience, principally in terms of fun and social interaction than digital ones. In this respect, considering that the majority of educational SE games are developed by the instructors themselves with limited, non-digital games may represent a more viable alternative for SE education.

ACKNOWLEDGMENTS

We would like to thank all researchers, who shared their data on game evaluations.

This work was supported by the CNPq (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* – www.cnpq.br), an entity of the Brazilian government focused on scientific and technological development.

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