Classification of Evaluation Methods for the Effective Assessment of Simulation Games: Results from a Literature Review

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Abstract—As a current trend in teaching, simulation games play an active and important role in the area of technology-based education. Simulation games create an environment for scholars to solve real-world problems in a risk-free environment. Therefore, they aim to increase the knowledge base as well as learning experiences for students. However, assessing the effectiveness of a simulation game is necessary to optimize elements of the game and increase their learning effect. In order to achieve this aim, different evaluation methods exist, which do not always involve all phases when running a simulation game. In this study, we conduct a literature review to analyze evaluation methods for three phases: pre-game, in-game, post-game phases of simulation games. Thirty-one peer-reviewed research papers met specified selection criteria and were classified according to a didactic framework that illustrates the four phases of running simulation games: Preparation, Introduction, Interaction and Conclusion. Based on the results, we provide a concrete evaluation strategy that will be a guide to assess simulation games during all the phases. This study contributes to the theory by providing an overview of methods for simulation game assessment within the different game phases. It contributes to the practice by providing a concrete evaluation strategy that can be adapted and used to assess simulation games.

Keywords—Simulation games, serious games, game-based learning, evaluation methods, assessment

1 Introduction

Simulations have played an essential role in the area of technology-based education along many decades so far. In 1956, the first renowned simulation game named Top Management Decision Simulation, was released to be used in management seminars [1]. Simulation games teach learners how to fly airplanes or how to drive fast cars. However, at a deeper level, they address several issues such as making quick decisions, grasping the knowledge about the rules by playing instead of by asking someone else, and understanding complex systems through experimentation [2]. Simulation games not only allow the replication of real-world problems, but also increase the applicability of the acquired knowledge to real-world situations. One of the dimensions of these games is "Realism", which is defined as the game-users' perception about the extent to which a simulation game reflects real life situations. The more realistic a simulation game is, the higher is the degree that gamers learn from it [3]. Playful learning keeps its popularity in the educational field as it focuses on teaching through hands-on methodology and play-based learning methodology rather than passive learning approach, activating learners between free play and guided play [4]. In general, the term "playful learning" covers simulation games, business games, serious games and game-based learning. Among these, especially simulation games trigger experiential learning by engaging the learners or gamers in a dynamic experience where problems have to be solved or decisions have to be taken [5].

Constructivist pedagogy is defined as the classroom activities focusing on individual learners' and their developing of profound understanding in the subject matter that leads to building interest and habits of their future learning [6]. As an important part of technology-based education, games and simulations are linked to a constructivist pedagogy, which allows getting practical experience in content areas such as marketing, finance, management or languages [7]. Especially, simulation games focusing on business management education have gained more importance. In this field, simulation games guide student gamers to learn business skills while managing a company in teams [8]. Business games enhance students' learning experience by demonstrating a part of the reality and simulating active situations [9]. In addition to empowering learning experience, simulation games facilitate learning through discovery, experimentation and practice with concrete examples in a risk-free environment [10]. Student`s time management and team-work skills improve significantly through simulation games [11]. Moreover, student gamers learn how to make decisions, reexamine past decisions critically, work in a team cooperatively and manage time effectively. Through these tasks, students' cognitive skills are developed by demanding attention, concentration, memory capacity, creativity, critical reasoning, communication, teamwork, self-regulation, investigation skills, problem-solving skills and digital literacy skills [12]. Overall, the mentioned skills become more and more important in a constantly changing global society.

Simulations are likely to help employees of challenging job markets when they are required to learn and develop digital transformations and technology skills. These demands have been reported by Hoberg et al. (2016) [13], who surveyed companies about the required digital competencies. Only 17% of the companies agreed on the statement "*we have enough personnel with the skills necessary for the digital transformation of our company*", while 53% disagree. A competency model developed by Prifti et al. (2017) [14] for the future workforce in the digitized world lists eight important skills. To successfully face companies' digital transformation challenges, these skills are "*leading and deciding, supporting and cooperating, interacting and* *presenting, analyzing and interpreting, creating and conceptualizing, organizing and executing, adapting and coping, enterprising and performing*". When the business world sounds so complex and requires a wide range of social and management skills, traditional learning methods such as reading materials, listening to lectures or notetaking are not enough to prepare students for the modern business environment [15]. Technologically enhanced classroom teaching can prepare future employees best and equip them with the expected skills through simulation games. For instance, implementing a simulation game into a classroom and supporting learning with scenarios take learners beyond the traditional learning environment and make them experience working with new digital technologies [11]. The purpose of simulation games is not only to be entertaining and engaging, but also to be educational. For this reason, students prefer simulation games over other classroom activities [16].

Teaching the mentioned skills and competencies through simulation games as well as assessing their usefulness carry great importance to optimize elements of the game while taking into consideration student's learning types, pace, performance and motivational level to learn. Bellotti and others (2013) [16] highlight the necessity to improve simulation games design as they lack accurate assessment. Furthermore, students' performance should be also evaluated because simulation games intend to increase the learning progress and the success of learning outcomes. Hence, the motivation with the present paper is to have a close examination of the literature related to the assessment of simulation games and to bring into view which assessment types are used during the different simulation games phases. Educational institutions, lecturers, and teachers need effective assessment methods and instruments to evaluate the usefulness of simulation games as well as their students' readiness, motivation and learning outcomes. Aiming to analyze the assessment types used in simulation games and also their effective application and evaluation of the simulation games, the following two research questions are posed:

- What are the existing evaluation methods aiming to assess simulation games during the pre-, in-, and post-game phases and what are their success factors?
- How can evaluation methods be applied to assess the success of simulation games effectively?

2 Related Work

Exploring from the point of view of each participant, what has occurred during the simulation games is fundamental for learning [5]. As highlighted above, simulation games lack accurate assessment methods and should be improved [16]. Coming from the literature, which highlights the importance of evaluating students' learning processes as well as the games themselves, the didactic framework of a simulation game process is described in the following section.

2.1 Didactic framework

A didactic framework developed by Utesch (2016) [17] illustrates the flow of business games in four phases. The first phase is called "Preparation", it aims to manage organizational conditions needed to operate business games. During this step, participants are informed about the objectives of the course. This phase requires careful planning to create a successful experiential learning atmosphere for learners. Following is the "Introduction" phase, in which the students become familiar with the roles, management boards and the problems to solve in the game. In the "Interaction Phase", participants face challenging tasks that they have to solve [17]. This phase consists of five sub-steps: analyzing the problem, developing a business strategy, implementing a business strategy, running the simulation and presenting the results [17]. Finally, in the "Conclusion" phase, the achieved business objectives and the applied strategies and criteria to improve a company's success are summarized.

This didactic framework was the inspiration to build the literature review of assessment types based on the different phases in simulation games. Therefore, we divided the assessment types into pre-game, in-game and post-game assessment consecutively (see Fig. 1). The identified assessment types from our literature review guided us to answer the first research question as well as to extend this didactic framework by integrating evaluation methods for each phase. For addressing the second research question, the focus was set on the effective transfer and application process of the assessment types into a simulation game.

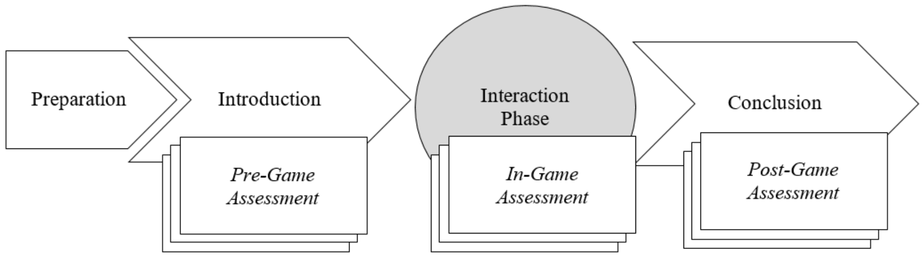

Fig. 1. Applied Didactic Framework for the Assessment of Simulation Games (drawn upon Utesch (2016) [17])

2.2 Assessment types

In general, two assessment types in the field of education were identified: summative and formative. Summative assessments measure and summarize students' learning and achievements by using certification for school completion [18]. Formative assessment refers to regular, interactive assessment to identify learning needs and adjust future teachings accordingly [18]. Formative assessment can help teachers to measure learning outcomes and make quick adjustments to improve them. However, the assessments that are conducted after learning sessions in a game-based environment might miss out important changes during the learning process, because an end-of-game assessment lacks immediate feedback during the game [19]. This type of in-game assessment is called "embedded" or "stealth assessment". Stealth assessment is an evidence-based process by which assessments can be blended directly to the learning environments [20]. Ifenthaler et al. [19] divided types of game-based learning assessments into three categories: game scoring, external assessment and embedded assessment. Game scoring focuses on targets achieved, obstacles or time needed to complete a task or an iteration. Secondly, external assessment includes debriefing interviews, tests or surveys. Lastly, embedded or internal assessment gives information about the learner's behavior such as clickstreams or log files [19]. Implementing feedback assessment into a game and providing feedback such as score, stage, accuracy, level of understanding strengthen sense of understanding and retain motivation of gamers, and therefore help gamers to reflect on their performance [21]. Coming from the didactic framework and assessment types, in the next section, the methodology used for conducting this literature review is explained as well as how the evaluation methods used in the four phases of simulation games were categorized.

3 Methodology

In order to analyze the different assessment types for simulation games, a systematic literature review of empirical studies was conducted following the methodology suggested by Webster and Watson [22] and Vom Brocke et al. [23]. Essentially, literature reviewing principle proposed by Vom Brocke et al. (2009) [23] was adopted by including and excluding the sources as transparently as possible to increase the credibility. For our search, IEEE Xplore and ERIC databases were chosen since they provide publications in the fields of Information Systems (IS), Economics, Computer Science and Engineering, and also they have a strong focus on Education outlets. In order to analyze different kinds of assessment types for simulation games, the keywords "*simulation games*" or "*business games*" or "*serious games*" or "*game-based learning*" were used in combination with "*evaluation*" or "*assessment*". Overall, following the literature review principles provided by Vom Brocke et al. [23], a representative literature review was conducted by analyzing a broad number of articles in order to get a representative view on the different assessment types that were used to evaluate simulation games. To assure the transparency of sources' inclusion and exclusion, two of the authors of this paper used inter-rater reliability. The search included all the articles published in the mentioned databases until November 2018. Initially, all the hits were screened by checking keywords, title and abstract, and filtered according to two criteria: which evaluation methods were used, and whether or not the source was related to any kind of educational game such as Simulation Games (SG), Serious Games (SRG), Business Games (BG), or Game-Based Learning (GBL). Afterwards, the remaining articles were examined in detail following the criterion of whether or not they explained or applied a concrete assessment type or evaluation strategy on a simulation game from IS, Economics, Computer Science, or Engineering.

In total, 344 hits were obtained in the IEEE Xplore database, which led to 38 articles after the first review and 24 in the final selection. In the ERIC database, 672 hits were gotten, which led to 18 articles after the first review and seven in the final selection. In total, in the search yielded 31 articles that were selected for a detailed analysis (see Table 1).

For each paper, it was analyzed whether authors conducted any kind of pre-game, in-game or post-game assessment during the simulation games. Afterwards, these results were categorized according to the three phases mentioned in the framework. Finally, following Webster and Watson [22], a concept matrix was created to illustrate the results, which are explained in the section below.

Table 1. Databases, Search Terms, and Selected Publications

Database	Search Term	Search Fields	Hits
IEEE Xplore	(simulation games OR business games OR serious games OR game-based learning) AND (evaluation OR assessment)	Title, Abstract, Keywords	344
ERIC			672
		Number of sources selected	1016
			31

4 Results

The first research question "What are the existing evaluation methods aiming to assess simulation games during the pre-, in-, and post-game phases and what are their success factors?" was answered by creating a concept matrix based on the analysis of 31 papers. Table 2 characterized the research papers by showing authors' names, publication year, game type, assessment type used during either pre-game, in-game or post-game and assessments' names.

Table 2. Assessment Types for Simulation Games in the Literature

Author	Game Type	Pre-Game	In-Game	Post-Game	Assessment Types
Costantino et al. (2012) [24]	SG		X	X	Counting Mistakes; Questionnaire
Zeng (2012) [25]	SRG		X	X	Data Mining Algorithms
Al-Smadi et al. (2012) [26]	SG		X	X	Assessment Rules
Merkuryev & Bikovska (2012) [27]	BSG			X	Tracking Success of the Teams
Boughzala et al. (2013) [28]	SRG			X	Evaluation Grids
Utesch et al. (2016) [29]	BSG	X		X	Questionnaires
Michel (2016) [30]	SRG			X	Performance Evaluation by Observer
Utesch et al. (2016) [31]	BSG	X		X	Questionnaires
Chatterjee et al. (2016) [32]	GBL			X	Learning Assessment Tools (LATs)
Cleophas (2012) [33]	SRG			X	Descriptive and Causal Analysis using a Discussion Format
Krassmann et al. (2015) [34]	GBL	X	X	X	Analysis of Cognitive Improvements; Questionnaire; Exam
Escudeiro & Escudeiro (2012) [35]	SRG			X	Quantitative Evaluation Framework Assessing Functionality, Efficiency, and Adaptability

Bhardwaj (2014) [36]	SRG			X	Long-term Effect Assessment
Smyrnaiou et al. (2017) [37]	SG		X		In-Game Performance Tracking (Real-Time Feedback to students about their performance)
de Carvalho (2012) [38]	GBL	X	X		Questionnaire; Semi-structured Interviews
Tantan et al. (2016) [39]	SRG			X	Survey; Debriefing; Discussion
Callaghan et al. (2015) [40]	SRG		X	X	Monitoring students' progress; Score Evaluation Summative
Yang et al. (2016) [41]	GBL			X	Questionnaire with exam-like questions
Duin et al. (2013) [42]	SRG	X	X	X	Demographic Information Survey; Questionnaire of Students' Self-Evaluation
Mettler & Pinto (2015) [43]	SRG		X	X	Discussions; One-on-one Interviews
Wilson et al. (2016) [44]	SRG	X	X	X	Theoretical, Technical, Empirical, and External Evaluation; Focus Group Interviews, One-on-one Playtests
Zolotaryova & Plokha (2016) [45]	SRG		X		Questionnaire; Testing; Case Study
Abdellatif et al. (2018) [46]	SRG			X	Questionnaire
Allen et al. (2009) [47]	SRG	X		X	Questionnaire
DiCerbo (2017) [48]	GBL	X	X	X	Cognitive Labs; Think Aloud Interviews; Online Performance Tasks
Hainey & Connolly (2010) [49]	BSG	X		X	Knowledge Tests; Aspect Ratings, Perceptions and Preferences of the Learners
Tan et al. (2013) [50]	GBL	X	X	X	Pre-Game Questionnaire; Heuristic Evaluation; Participatory Evaluation; Storyboarding
Cowley et al. (2014) [51]	SG	X	X	X	Multiple Choice Questionnaire (MCQ); Self-Assessment of Learning Questionnaire (SAL); Game Experience Questionnaire (GEQ)
Wideman et al. (2007) [52]	BSG	X	X	X	Pre-Post Test Questionnaire; Think Aloud Protocol
Cutumisu et al. (2015) [53]	GBL		X	X	In-Game Assessment that Gives Informative Feedback to Participants; Checklist Items to Assess Learning Outcomes
Meerbaum-Salant et al. (2010) [54]	GBL	X	X	X	Field Notes; Interim Test; Teacher Interviews; Questionnaires

In general, most of the authors focus on collecting data through questionnaires [16, 29, 34, 37, 52]. The literature further highlights the importance of in-game assessment as only this type can provide instant feedback about the learning process [55]. For this, several authors provide concrete examples such as counting implanted errors in the game [24], performance tracking [37], monitoring students' progress [40], think-aloud protocols [48, 51], field notes during classroom observations, heuristic participatory evaluation methodology and storyboarding [50]. In addition to the results of the concept matrix, some of the qualitative methods presented in Table 2 are explained below.

Counting the number of mistakes is used to measure learners' appropriate decisions The game is considered to be successful when players succeed to avoid mistakes for the next sessions of the game [24]. Moreover, the number of mistakes determines the impact of the game on the learning process [24].

Assessment rules also named as checkpoints, are embedded into the serious games and are used for assessing players interactions and decisions without interrupting the dimensionality of the games [26]. Generally, game designers or educators define the assessment rules to provide implicit feedback to the player using a virtual character [26].

Evaluation grids are used to collect relevant and useful information regarding the serious game's distinctive attribute and quality such as features of the game, interface ergonomics and possibility of interaction with other players [28]. Additionally, the learners' technical as well as general skills and behaviors are measured through evaluation grids [28].

In-game performance tracking operates through a simulation-based assessment tool. It gives real-time feedbacks to students about their performances by evaluating their capabilities and competences regarding their knowledge and skills [37]. Some of the competences are analytical thinking, expertise, innovation, information seeking and decision making [37].

During **unobtrusive observation**, participants are observed by a research team during the game play and the only interaction happens with the learners when there is a technical problem [50].

Participatory heuristic evaluation is a discussion method during which participants review the playability of the game in groups and observers record and prescribe participants' responses [50].

Storyboarding is a technique during which students express their views and ideas directly by creating their own designs using templates, paper, crayons, pencil colors and markers [50].

Game Experience Questionnaire (GEQ) evaluates game participants' feelings and thoughts while playing, and measures the attributes of competence, sensory and imaginative engagement, flow, tension, challenge and negative and positive feelings [51, 56].

As a part of summative assessments **an interim test** is used to assess the learning progress of students and shows the level of performance results whether they can achieve future tasks [54]. **Think aloud interview** [52] [48] and **cognitive labs** [48] are methodologies used to capture data when students put into words their experiences and interactions within the environment.

5 An Evaluation Strategy for Simulation Games

The previous section presented the results from analyzing 31 papers that implemented various qualitative and quantitative assessments into their game-based learning and teaching environments. Moreover, seven research articles showed regularity by assessing simulation games in three phases. Based on these results, an evaluation strategy that can be applied to evaluate simulation games successfully is proposed (see Fig. 2).

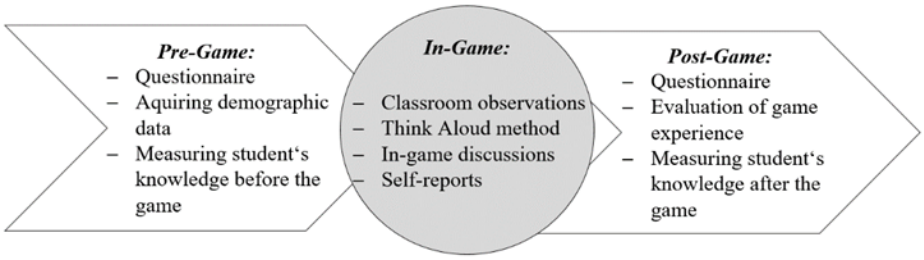

Fig. 2. Evaluation Strategy for Simulation Games

The implications of these results are manifold. First, the focus of research designs has representative characteristics with a variety of assessment types. For instance, during the pre-game phase, questionnaires are the most frequently used evaluation tool. This type of assessment allows to get a feedback from a large number of students as well as provides the evaluator information about respondents' opinions, attitudes, feelings and perceptions on a particular matter [57]. When educators want to inform participants about their learning progress, they can use retrospective questionnaires as a pre-game evaluation. This evaluation gives educators the opportunity to identify students' perception about changes of their knowledge, skills, attitudes and behaviors after their participation in an educational intervention [58]. Retrospective questionnaires help learners to look back in their learning journey and question themselves to make improvements with questions such as "*What went well? What have I learned? What still puzzles me?*"[59]. Besides performance-based evaluation, lecturers can collect demographic data as well as information about students' learning styles through questionnaires.

As an in-game phase evaluation, classroom observation, think-aloud protocols and in-game group discussions can be used to measure the learning improvement of players in the heat of the moment. Classroom observation or unobtrusive observation is a method that gives lecturers data about the interaction happening in the classroom and allows lecturer's intervention only when a question or problem arises [50]. This method can be useful to get an instant picture about issues happening in the classroom. A cognitive task analysis technique such as the "think-aloud methodology" enables the players to verbalize their thinking processes during the game. Moreover, this technique helps to players' decision-making processes as well as gives concrete explanations about players' interaction with the user interface and other design elements [52]. Another term of in-game discussions is the participatory heuristic evaluation. Tan et al. (2013) [50] focused on measuring the playability of a game through participatory heuristic evaluation via asking questions, recording and transcribing answers. As a result, players experienced knowledge gain, skill improvement and fun through careful application of instructional system design and game principles [50]. Sharing the same aim of in-game discussions, self-reports can measure players' subjective mood as well as their experience, performance and learning [51].

During the post-game assessment, students' knowledge gains and improvements can be measured through questionnaires. Simulation game should be evaluated considering its usefulness and effectiveness for improving learning goals. Questionnaire is the most common evaluation method to assess simulation games [24]. This assessment can also include evaluating the scenarios given in the game, both its quality and its degree of reflecting life situation [3]. Together with the initial test of the pre-game phase, one can compare and analyze game players' knowledge gain with post-game knowledge tests [49].

6 Discussion and Future Work

The aim of this literature study is to shed light on the evaluation methods that were used to assess the quality and learning effectiveness of simulation games as well as students' learning experiences. In this sense, we identified and classified the already utilized assessment methods into three different categories: game type, assessment type and the phases used to implement each method. The selection of the relevant papers considered whether a game type of interest, i.e., simulation games, business games, serious games, or game-based learning, and whether they applied a concrete assessment type in one of the assessment phases. The two reviewers among the authors of this paper used the same inclusion and exclusion criteria and each reviewed different databases. At the end of the review process, both reviewers exchanged the relevant articles and approved the relevancy as a second time. This process resulted in creation of a concept matrix (see Table 2). The concept matrix can give a broader picture with the list of methods for effective assessment for the simulation game types. Moreover, deriving the most common assessment types based on the findings of seven research papers to create an intensive strategy from the concept matrix's broader picture, we created an exemplary evaluation strategy (see Figure 2). This evaluation strategy can either be implemented into the simulation game environment or it can be conducted as a traditional way of paper pencil. However, finding the right assessment instrument or developing a new one will always require setting the goals and objectives of the simulation game. For instance as the pre-game assessment in our evaluation strategy, measuring learners' pre-knowledge shall involve the questions related with the simulation game goals.

Furthermore, in this literature review study, we excluded the preparation phase due to the lack of enough evidence that is associated with pre-game assessment. Nevertheless, the preparation phase carries importance in playful learning environment because good preparation brings success in learning. As a future work, pre-game assessment types can be the focus of a further literature review study.

7 Conclusion

In this paper, 31 papers that focus on at least one of the three phases of simulation game assessment were analyzed. The findings of the concept matrix are to be used through combination of the methods by researchers, lecturers as well as game designers. Questionnaires are the most popular method to assess simulation games because they are easy to conduct and allow evaluating a large number of students simultaneously. However, other qualitative data collection methods such as classroom observations and think-aloud methods are proven to give deeper insights about the learning experiences.

In conclusion, our findings provide an extensive avenue for future research in the area of simulation games' design and evaluation. On the one side, our literature review and the proposed evaluation strategy can be used for the assessment of future simulation games. The significance of this evaluation strategy is that it gives a glimpse of assessment types for all the three phases of a simulation game. Lecturers, researchers or game designers have the possibility to either directly apply the proposed assessment types or select different methods out of the provided overview as part of the search results. On the other side, our work can be used as a basis to conduct more research on evaluation methods and assessment types from a theoretical perspective. For instance, the results of this literature review can be used to develop an evaluation model for simulation games that includes further concepts of the assessment types and considers different contexts, learner types or environments. Moreover, assessing the efficiency and quality of the games will create a successful playful learning environment, which is distinctive than traditional learning environment and carries great importance to teach the skills and competencies required in a digitized working environment through a hands-on methodology.

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