Evaluation Tools for Digital Educational Games: A Systematic Review

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Abstract- This systematic review investigates various evaluation tools for digital educational games and answers the question of which evaluation tools could be used to evaluate digital educational games. A systematic review of studies, by searching for related keywords in the title, abstract, and keywords of studies in the scientific databases EMBASE, Web of Science, Scopus, and PubMed, was launched without time-limited on November 2, 2021. The same checklist was used to extract data such as reference, first author's name, year of publication, tool name, type of tool, instructional strategy, and evaluation factors. A total of 3516 articles were extracted and finally, an analysis of the included studies gave us 22 different approaches to the systematic evaluation of educational games. The same study developed some proprietary evaluation tools exclusively for game evaluation. However, some tools evaluated games in different dimensions, most of which did not consider the tool's validity. In the same sense, we have five prominent evaluation guidelines, including E-GESS, MEEGA+, EGameFlow, HEP, and Kato evaluation guideline, all of which have been developed by explicitly decomposing the evaluation objectives into criteria and using a questionnaire assessed through a collection of case studies. Our systematic review showed the need to identify more consistent and uniform patterns in different dimensions for the systematic evaluation of digital educational games to achieve valid results that can be used as a basis for deciding on the use of digital educational games.

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Keywords: Digital educational game; Evaluation; Evaluation tool

Introduction

Digital educational games are defined as a combination of digital games and educational content; they would facilitate learning through playing games (1). They have been designed to educate people in specific areas, extend the concepts, enhance development rate or help people practice or learn a skill and approach during the game. In recent years, educational games have been used as an innovative strategy for more effective learning at higher levels (2). and have improved cognitive practices such as attention and memory skills (3). The main goal of educational games is to aid the education area (4). Digital educational games are developing very quickly, but most educational games have not been confirmed as a tool that could improve results. The rarely available studies have poor study designs, and their results could not provide valid evidence for supporting or rejecting the effectiveness of the games (5). Considering the complexities of digital games' environments and designing non-entertainment (or educational) objectives in the game, there is a need for proper selection and comparison of the evaluation methods (6). The important, less-understood problem, which was the motivation behind this study, was the lack of studies on the proper selection of valid evaluation methods in determining the effectiveness of digital educational games. Without a valid educational methodology, there will be only a little development in educational design studies regarding effective learning environments to gain the specialty in complex and unsuitable knowledge areas (7). Therefore, this systematic review investigated various evaluation tools for digital educational games and tried to answer the question of which evaluation tools could be used to evaluate digital educational games.

Materials and Methods

This systematic review was conducted on the basis of previous evidence and similar studies to provide an

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answer to the research question (Which Tool Should We Use to Evaluate the Digital Educational Game?) Therefore, a systematic review of studies, by searching for related keywords in the title, abstract, and keywords of studies in the authoritative scientific databases EMBASE, Web of Science, Scopus, and PubMed, was launched on November 2, 2021. The keywords searched are as follows:

1. ("Assessment" OR "Evaluation")
2. ("Scale" OR "Framework" OR "Tool" OR "Criteria" OR "Checklist" OR "Questionnaire" OR "Form" OR "Model")
3. ("Educational game" OR "Digital game-based learning" OR "DGBL" OR "Digital game" OR "Serious game")

Figure 1 shows the steps for searching for articles using Preferred Reporting Items for Systematic Reviews and Analyzes-Meta (PRISMA) to select articles. As shown in figure 1, of the 3516 identified articles, 604 duplicates were removed. After a review of the titles and abstracts of the remaining articles, 2813 were determined to be irrelevant to this study and were hence removed. The full texts of the remaining 99 articles were reviewed, and 77 of these articles were removed as being irrelevant to this review. The 22 remaining articles were discussed and summarized by 2 reviewers. Inclusion criteria included articles published in reputable scientific journals, access to the full text of articles and studies that are based on title and content, providing a possible answer to the research question, and the design or development of an evaluation tool for digital educational games. Exclusion criteria included abstracts without full text, the absence of one of the keywords in the title or text of the articles, and studies that did not provide any scientific, theoretical, laboratory, or statistical evidence. Titles and abstracts were screened independently based on eligibility criteria. Complete texts were retrieved and screened independently by two authors based on eligibility criteria. The same checklist was used to extract data such as reference, first author's name, year of publication, tool name, type of tool, instructional strategy, and evaluation factors. This study was approved by the ethical committee of MUMS (approval number IR.MUMS.REC.1400.336).

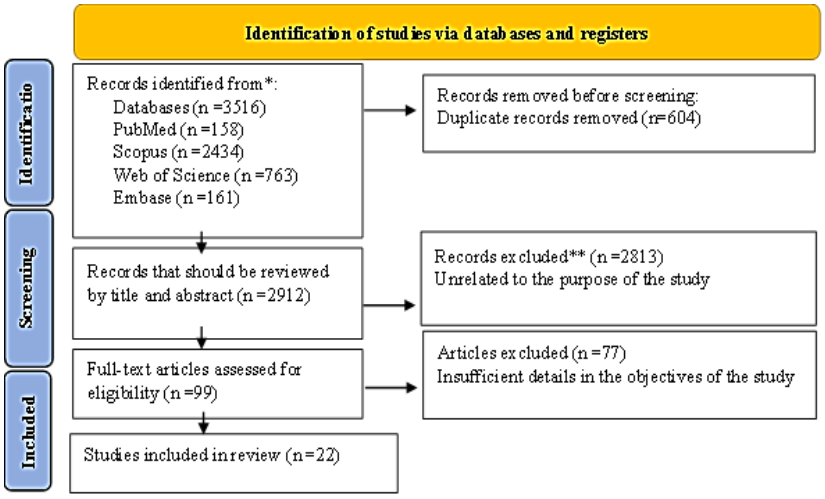

Figure 1. Flow diagram of the literature search and study selection

Results

The evaluation included various levels developed based on a four-level Kirkpatrick model and has been used as a base for more than 40 years. This model provides a framework for evaluating efforts, educational interventions, and partnerships at four different levels, including reaction, learning, behavior, and results (8). Considering the evaluation objectives, models, scales, questionnaires, and frameworks can be used for the study. Analysis of the included studies gave us 22 different approaches to the systematic evaluation of educational games. As shown in table 1, 10 approaches provide a framework (9-18), four scaled approaches (19-22), six model approaches (4,6,23-27), and other approaches include checklists (28) and instructions (5) which are used for the evaluation of digital educational games. We provide a brief description of each approach.

Table 1. Characteristics of the 22 selected studies

Reference	First author's name	Year of publication	Tool name	Type of tool	Instructional Strategy	Evaluation factors
(9)	Carlos Vaz de Carvalho	2012	Not defined	Framework	Game-based learning	Beta testing: - Gameplay - Game-story Mechanisms/Usability Gamma testing: - Knowledge - Motivation - Satisfaction
(10)	Sarade Freitas	2006	Not defined	Framework	Games- and Simulation-based learning	Pedagogic Considerations Learner specification Context Mode of representation Learner Performance/Learning
(11)	Thomas Connolly	2009	Not defined	Framework	Game-based learning	Learner/academic Motivation Learner/academic perceptions Learner/academic Preferences GBL environment Collaboration between players where appropriate Content Strategies Assessment method
(18)	Yassine El Borji	2014	Not defined	Framework	Serious games	Attractiveness (Fun) Playability aspects Technical Efficiency Requirements
(16)	Frederik De Grove	2016	Not defined	Framework	Digital Games	Habit (3) Moral self-reaction (4) Agency (5) Narrative Escapism Pastime Social
(12,29)	Paula Escudeiro	2012, 2013	Quantitative Evaluation Framework (QEF)	Framework	Serious games in mobile platforms	Technical Domain Ergonomic Dimension Pedagogical Dimension
(15)	Deniz Eseryel	2013	Not defined	Framework	Educational massively multiplayer online game (MMOG)	Surface matching [SFM] Structural indicator Graphical matching [GRM] Structural indicator Structural matching [STM] Structural indicator Gamma matching [GAM] Structural indicator Concept matching [CCM] Semantic indicator Propositional matching [PPM] Semantic indicator Balanced semantic matching [BSM] Semantic indicator

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Cont. table 1

(14,30)	David Geerts	2019	Serious Game Design Assessment (SGDA)	Framework	Serious Game	Purpose Content & information Mechanics Fiction & Narrative Aesthetics & Graphics Framing Mentality change Emotional fulfilment
(17)	J-C. Hong	2009	Not defined	Framework	Digital games	Knowledge enhancement Thinking skill development Interpersonal skills Spatial ability Bodily coordination
(13)	Giannis Altanis	2019	Not defined	Framework	Motion-based game	**Quality in use:** Effectiveness Efficiency Satisfaction Freedom from risk Reliability Context coverage **Product Quality:** Functional Suitability Performance efficiency Usability Compatibility Reliability Security Maintainability Portability
(23,31)	Igor Mayer	2012	Not defined	Methodology	Serious games	Game performance Game play Game experience Player satisfaction Learning
(4,24)	Rafael Savi	2011	Model for the Evaluation of Educational Games (MEEGA), MEEGA+	Model	Educational games	Motivation User Experience Learning
(6)	Kamal Omari	2020	Fuzzy Multi-Criteria Decision Making (FMCDM)	Method	Serious game	Targeted skills (Ts) Pedagogical consideration (Pc) Learning result (Lr) Error Management (Em) Game design (Gd) Performance (P) User Interface (Ui) Usability (U) Challenge (C) Fun (F) Gameplay (G) Immersion (I) Motivation (M) Engagement (E) User experience (Ue)
(25)	Esther Oprins	2015	Game-based learning evaluation model (GEM)	Model	Serious games	Design and learning indicators Learning indicators Emotional–motivational indicators Cognitive indicators
(26)	Heather Desurvire	2004	Heuristic Evaluation for Playability (HEP)	Model	Games	Game Play Game Story Mechanics Usability
(24)	Ghada Al-Hudhud	2016	Not defined	Quality Model	Mobile Game	Reliability Efficiency Maintainability
(20)	OguzAk	2012	Not defined	Scale	Educational computer games	Enjoyment Learning

Cont. table 1

(19)	Fong-Ling Fu	2009	EGameFlow	Scale	E-learning games	Concentration Goal clarity Feedback Challenge Control Immersion Social Interaction Knowledge 8improvement Usability/Playability Narrative Play Engrossment and Pleasure Creative Freedom Audio Aesthetics Personal Gratification Social Connectivity Visual Aesthetics Educational Content and Pedagogical Issues
(21)	Aleph Campos da Silveira	2020	Educational-Game User Experience Satisfaction (E_GUESS)	Scale	Educational games	
(22)	John Brooke	1996	Usability Scale System (SUS)	Scale	Systems	Usability
(27)	Kastney Frazão	2020	Not defined	Checklist	Mobile Educational Games	User interface Mobility Pedagogy Gameplay
(5)	Pamela M. Kato	2012	Not defined	Guideline	Games for Health	Ground your game in theory Conduct a randomized trial Include adequate control groups Recruit an adequate number of participants Include objective measures of health Monitor and report potential negative side effects Publish even null results

Digital educational game evaluation frameworks

- Connolly *et al*., developed the evaluation framework for Game-Based Learning (GBL). GBL is based on key metrics identified in the studies (11). This framework aims to identify items that could potentially be evaluated in GBL. This approach proposes GBL evaluation in terms of performance, motivation, perceptions, preferences, Learner/academic GBL environment, and collaboration between players. This framework can be customized based on specific analytical measurement requirements.
- Freitas *et al*., developed a four-dimensional framework (10), which helps instructors assess the potential of using games and simulation-based learning in self-assessment practice. The four dimensions evaluated by the framework included context, learner or learner group, internal representation world, and process of learning.
- Carvalho provides an evaluation framework to investigate the GBL performance, focusing on engineering education (9). Considering the first two levels of the Kirkpatrick evaluation model (reaction and learning) (8), this framework has been divided into three phases: alpha, beta, and gamma, each of which has clear objectives, predefined protocols, and data collection tools. This framework evaluates the games' performance in terms of game story, mechanisms, usability, knowledge, motivation, and satisfaction.
- Grove *et al*., used different measurement tools to examine the individual motivations for digital games from different theoretical perspectives. They developed a social cognitive theory-based framework for evaluating digital games that permeates human behavior and demonstrates the theoretical and psychometric strength of the tool (16).
- Escudero provides a qualitative model based on software engineering paradigms to evaluate digital learning content, especially games for mobile platforms (12). This model is known as the

Quantitative Evaluation Framework (QEF) and measures the system's quality over its development life cycle. QEF evaluates the quality of educational software, especially digital learning content (ISO 9126 is the reference standard), in a three-dimensional environment, including technical domain, pedagogical dimension, and ergonomic dimension. Another study used this model to evaluate serious games and guarantee the final product's quality (28).

- Serious Game Design Assessment (SGDA) is an evaluation framework for the better development and design of serious games. In a quasi-experimental study on three research games, the tool showed that the framework can be used for research games and is useful, therefore, providing clear guidance to HCI researchers when developing new research games (14,29).
- Hong *et al*., provided an introductory framework for future game designers, parents, and instructors to assess the educational value of digital games (17). This framework is based on identity, space, continuity, and action. These elements could be used as indicators to assess whether our systems can facilitate a sense of social presence and then social learning.
- Altanis *et al*., provided a framework based on the quality-in-use model (ISO/IEC 25010) with immersion quality characteristics (13). This model considers the quality of the software system during its use. This framework was developed specifically to conceive, design, and evaluate a serious cultural heritage game.
- Eseryel *et al*., provided a framework for investigating learning progress in complex and poorly structured problem-solving to assess the impact of a large multiplayer online learning game designed to support interdisciplinary training in acquiring complex and inappropriate skills for ninth-graders (15).
- In a comparative study, Borji *et al*. developed a network to evaluate and analyze the quality of serious games in education (18).

Digital educational game evaluation models

- Mayer proposed a detailed methodology for assessing serious games (30), which includes frameworks, conceptual models, research designs, evaluation structures and scales, and data collection techniques. The method provided by Mayer has been designed to assess serious games based on three intervals (before the game, during the game, and after the game) and evaluates the experiences and skills, the performance of the game, game, user, experience as well as the user satisfaction and learnability.
- Another method is the Model for the Evaluation of Educational Games (MEEGA) (4) has been developed specifically to evaluate educational games. Using a standard questionnaire, this model focuses on level 1 Kirkpatrick assessment (reaction) (8) and records students' reactions after the game. MEEGA measures three qualitative dimensions of educational games, including motivation, user experience, and learning from the perspective of learners within an educational unit. MEEGA+ is an augmented MEEGA model based on the original version's literature review and systematic analysis (24). The following sections provide the MEEGA+ model, including the definition of the objective, the theoretical model underlying the MEEGA+ model, and the development of measurement tools. The formal validity of the MEEGA+ tool has been analyzed and validated by a multidisciplinary team of experts in computing and statistics.
- Desurvire *et al*., developed a Heuristic Evaluation for Playability (HEP) based on a systematic review (26). This tool has been reviewed by several game capability experts and game designers. The tool categorizes evaluation into four dimensions, including gameplay, a game story, mechanics, and usability, and ultimately, alternative solutions are created by the game evaluator and designer to solve game problems.
- Oprins *et al*., developed a Game-based learning evaluation model (GEM) (25) to measure the effectiveness of serious games in practice. The results of the GEM evaluation provide insight into why serious games are effective. This evidence helps serious game designers to improve their games.
- Omiri *et al*., developed a Fuzzy Multi-Criteria Decision Making (FMCDM) method to validate the selection of different options and weight the multiple criteria involved in evaluating serious games (6). Using fuzzy TOPSIS and fuzzy ELECTRE methods to rank the evaluation dimensions, they provided alternatives for the serious game evaluation model, which uses the fuzzy AHP method.
- Al-Hudhud developed an evaluation tool for learning Arabic vocabulary. The evaluation of the quality of this tool is justified by three indicators of reliability,

efficiency, and maintainability (11).

Digital educational game evaluation scales

- Fu *et al*., provided the EGameFlow Scale (19) that measures the gamers' pleasure of e-learning games and helps developers identify strengths and weaknesses in students' perceptions according to a level of Krikpatrik assessment (reaction) (8). This scale evaluates the quality of the game according to eight factors: immersion, social interaction, challenge, goal clarity, feedback, focus, control, and knowledge improvement.
- Another scale was proposed by AK (20) to select good educational computer games. This scale is intended to measure the quality of games before using them in the classroom. In this scale, the quality of the game is measured in terms of pleasure and learning.
- Another scale provided by Silveira aimed to measure user satisfaction with video games using nine scales. It was known as the Educational-Game User Experience Satisfaction (E-GUESS) user experience scale. E-GUESS was shown to have content validity, internal consistency, convergent validity, and differentiation. E-GUESS contains 55 items with nine scales, including usability/play, narratives, game attractiveness, fun, freedom of creativity, audio aesthetics, satisfaction, social relationships, and visual aesthetics. At the same time, Nielsen's assessment tools are integrated into the tool (21).
- Brooke *et al*., developed the SUS scale (22) to assess its usability. The scale consists of ten items and is answered in the form of a five-point Likert scale.

Other digital educational game evaluation approaches

- Using a systematic review of the literature and meta-analyses, Kato suggests guidelines in seven items for high-quality studies in health-related games, which contribute to efficient studies on these games (5).

Frazão *et al*. also proposed a checklist for evaluating mobile educational games (27). This evaluation form contains 82 items distributed in evaluation categories, such as user interface, mobility, training, gameplay, etc. Preliminary results of checklists in two mobile educational games showed that it allows the identification of problems pointed out by users in the comments in the App Store.

Discussion

Analysis of the included studies gave us 22 different approaches to the systematic evaluation of educational games. Some proprietary evaluation tools were developed exclusively for game evaluation in the same study (7,13,25). However, some tools evaluated games in different dimensions, most of which did not consider the tool's validity (6,10,11,18,20,31). There were also a few numbers of valid tools (19,21,22,24,26) that only evaluated games in certain dimensions. Also, there was no tool to evaluate all aspects of the game, ensuring validity and reliability. The provided approaches also differ greatly in terms of the quality factors assessed. In addition to the effectiveness in learning, they also consider the challenges, usability, social interaction, etc., which indicate that there is no pattern for the factors to be evaluated. Most approaches also seem to be developed relatively temporarily and do not provide a clear definition of the purpose, criteria, or tools for data collection (30). Mayer suggests a general evaluation method for a serious game. Although this method provides comprehensive support, including frameworks, conceptual models, research designs, evaluation structures, scales, and data collection techniques, there is no information on the application and validity of this method (30). In addition, Omiri *et al*., developed an FMCDM approach to cover and weigh the multiple (four) criteria involved in evaluating serious games (6). The approach has only been devised and used in the mentioned study and has not been assessed. In the same sense, we have five prominent evaluation guidelines, including E-GESS (21), MEEGA+ (24), EGameFlow (19), HEP (26), and Kato (5), all of which have been developed by explicitly decomposing the evaluation objectives into criteria and using a questionnaire assessed through a collection of case studies. MEEGA is currently more widely used, and various studies have reported its use in evaluating various games and contexts. On the other hand, although the SUS has not been developed for evaluating digital educational games, in many studies, the SUS scale has been used to evaluate the usability of digital educational games (1,2,32-34). One of the limitations of this study was the systematic review only of digital educational game evaluation tools and did not include the tools available for other educational games such as non-digital games, board, and card games. Furthermore, the search keywords may not be sufficient and complete to receive further studies, and some prominent and relevant studies may have been missed in this review. Additionally, this study included only peer-reviewed studies published in scientific journals and

conferences; therefore, articles published in the gray literature are not included in the present study. However, a systematic review of the available evidence gives an integrated view of the existing situation. Hence, this study provides valuable insights to overcome the barriers in future research (35-40).

In conclusion, our systematic review showed the need to identify more consistent and uniform patterns in different dimensions for the systematic evaluation of digital educational games in order to achieve valid results that can be used as a basis for deciding on the use of digital educational games.

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