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Using MEEGA/MEEGA+ for the Evaluation of Educational Games: A Retrospective

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Abstract

Educational games are assumed to be an effective and efficient instructional strategy. However, it is essential to systematically evaluate such games in order to obtain sound evidence of their impact. An alternative is the MEEGA/MEEGA+ model, providing support to evaluate games in terms of motivation, user experience, and learning based on the reaction of the students. Since its first publication in 2011 originally focusing on games for teaching Software Engineering, it has been adopted for a wide range of games and knowledge domains. Thus, the objective of this article is to present a systematic mapping on the application of the MEEGA/MEEGA+ model identifying 166 relevant articles, and describing 170 studies on the evaluation of 178 serious games. Findings show that the model is mostly used as-is in case studies as an easy way to evaluate games in the classroom, with fewer studies simplifying the data collection instrument and/or completing the data collection with other measurement instruments. This shows that especially the improved version MEEGA+ is a well-accepted model for the evaluation of serious games in order to assist game creators and instructors to improve such games as well as to support decisions on their application within instructional units.

Keywords: *Evaluation; Educational games, MEEGA+*

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1 Introduction

Games have been widely used as an educational strategy in diverse knowledge areas such as mathematics, science, computing, health, and chemistry (Connolly et al., 2012; Battistella & Gresse von Wangenheim, 2016; Gomes et al., 2023; Díaz et al., 2024). Educational games (or "serious games") are specifically designed to teach people about a certain subject, expand concepts, reinforce development, or assist learners in learning a skill or changing an attitude (Prensky, 2007; Djaouti et al., 2011; Kalmpourtzis, 2018). They are supposed to be an effective and efficient strategy for education by providing deeper and more active learning, through which students learn from their own experiences (Connolly et al., 2012; Gibson & Bell, 2013; Petri et al., 2019). Intrinsic characteristics of games, such as competition, that stimulates the will to win, often help students stay focused on the learning activity (Abt, 2002). They are also expected to provide a fun and safe environment, where students can try alternatives and see the consequences, learning from their own mistakes and practical experiences (Prensky, 2007). Consequently, serious games are believed to result in a wide range of benefits, like increasing learning effectiveness, increasing interest and motivation as well as a reduction of teaching time and instructor load (Gresse von Wangenheim & Shull, 2009).

However, it is essential to systematically evaluate such games in order to obtain sound evidence of their benefits. Yet, there are only a few approaches available that provide systematic support for game evaluations (All et al., 2016; Petri & Gresse von Wangenheim, 2017; Sharma et al., 2022).

A prominent model is MEEGA (Model for the Evaluation of Educational Games) (Savi, 2011; Savi et al., 2010; Savi et al., 2011), which provides systematic support to evaluate the game's quality in terms of motivation, user experience and learning. To facilitate its application, the model provides a standardized questionnaire for collecting data on the perception of the students after they played a serious game as part of a case study with a one-shot post-test design. A large-scale evaluation, based on data collected in 43 case studies, evaluating 20 different Software Engineering games, involving a population of 723 students, indicates that the MEEGA questionnaire can be considered reliable (Cronbach's alpha =.915) (Petri et al., 2017b). In terms of construct validity, there exists evidence of convergent validity through an acceptable degree of correlation of almost all item pairs within each dimension. Yet, a need for the regrouping of items was identified based on the results of a factor analysis, mainly with respect to items related to motivation and user experience (Petri et al., 2017b).

Aiming at the improvement of the original model and in order to provide more comprehensive support, the model has evolved in 2019 into the MEEGA+ method (Petri et al., 2024; Petri et al., 2019; Petri, 2018; Petri et al., 2017a) by also widening the application domain to any serious game used for teaching computing. The MEEGA+ method is composed of the quality model, defining quality factors to be evaluated through a standardized measurement instrument, a process to evaluate the quality of games as well as a game quality scale. Results of a statistical analysis of the MEEGA+ model, analyzing a series of 62 case studies indicate an excellent internal consistency of the MEEGA+ measurement instrument (Cronbach's alpha α=.927) (Petri et al., 2018). Results of an exploratory factor analysis and item correlation, confirm the original structure of the MEEGA+ model evaluating the game quality in terms of usability and player experience.

Observing the widespread application of the MEEGA/MEEGA+ model, we conducted a systematic mapping analyzing how the model is used for the evaluation of games. We specifically summarize the studies have used the MEEGA/MEEGA+ model for the evaluation of games and provide an overview on the characteristics of games evaluated in terms of knowledge domain, type of game, and educational stage. We also indicate which of the version of the MEEGA model has been adopted and if adaptions have been made. Furthermore, evaluations of the reliability/validity of the MEEGA/MEEGA+ model as part of these studies are analyzed and summarized. This retrospective may also provide evidence of the applicability of the model as a way to obtain feedback and identify improvement opportunities.

The remaining article is structured as follows: Section 2 provides a background on the MEEGA/MEEGA+ model presenting the measurement dimensions, measurement items and response scales of the different versions of the model. Section 3 presents the systematic review protocol and reports the execution of the search and selection of relevant publications. The detailed analysis of the relevant data is presented in Section 4. The results are discussed in section 5. Section 6 presents the conclusion of this research.

2 Background: MEEGA/MEEGA+

The **MEEGA model** (Savi, 2011; Savi et al., 2010; Savi et al., 2011) provides support for the evaluation of serious games in terms of motivation, user experience, and learning. The model was developed by a multi-disciplinary group based on literature and practical experiences in 2010/2011 focusing originally on the evaluation of games for teaching Software Engineering in higher education. Aiming at the creation of an easy to applicable and non-intrusive evaluation, the model aims at the evaluation of the reaction of the students to the game (Level 1 of Kirkpatrick's Four Levels of Evaluation (Kirkpatrick & Kirkpatrick, 2006)). Adopting this research strategy, the evaluation objective is assessed based on the student's perceptions through a questionnaire after the game application. Such an approach is commonly used to measure variables that are difficult to observe directly, such as motivation or user experience (Gámez, 2009; Jennett et al., 2008; Keller, 2009; Poels et al., 2007; Sweetser & Wyeth, 2005; Takatalo et al., 2010). While evaluating learning effectiveness in this way may be controversial, there exists evidence that self-assessment can yield reliable, valid, and useful results (Topping, 2003). And, although an experimental research design might provide more valid results, it also faces several threats to validity, including disparities in pre/post-test difficulty, teacher assessment, and the control of external factors (Falchikov & Boud, 1989; Topping, 2003). Examining these challenges, an evaluation from the student's perception still appears to be an acceptable alternative for gathering feedback in a straightforward, quick, and minimally intrusive manner.

As part of the MEEGA model, the evaluation objective is hierarchically decomposed into the sub-components motivation, user experience, and learning (Savi et al., 2011). The sub-component motivation is decomposed based on the ARCS model (Keller, 2009), into attention, relevance, confidence, and satisfaction. The sub-component user experience (UX) considers immersion, challenge, competence, fun, and social interaction (Gámez, 2009; Poels et al., 2007; Sweetser & Wyeth, 2005; Takatalo et al., 2010, Tullis & Albert, 2008). The learning sub-component is assessed with respect to the initial three tiers of Bloom's taxonomy (knowledge, comprehension, and application) (Bloom, 1956). Furthermore, it includes two dimensions concerning short-term and long-term learning based on the assessment model of Sindre and Moody (2003). Each of these subcomponents is further refined in measures as shown in Table 1 (Savi et al., 2011). For data collection, MEEGA provides a standardized questionnaire (Table 1) (Savi et al., 2011), which has been developed based on the evaluation model adapting and unifying existing standardized questionnaires (Gámez, 2009; Keller, 2009; Poels et al., 2007; Sindre & Moody, 2003; Sweetser & Wyeth, 2005; Takatalo et al., 2010).

Table 1: Dimensions and items of the MEEGA model

No.	Dimension	Questionnaire Item
Sub-component: Motivation		
1	Attention	The game design is attractive.
2		There was something interesting at the beginning of the game that captured my attention.
3		The variation (form, content or activities) helped me to keep attention to the game.
4	Relevance	The game content is relevant to my interests.
5		The way the game works suits my way of learning.
6		The game content is connected to other knowledge I already had.
7	Confidence	It was easy to understand the game and start using it as study material.
8		Passing through the game, I felt confident that I was learning.
9	Satisfaction	I am satisfied because I know I will have opportunities to use in practice things I learned playing this game.
10		It is due to my personal effort that I manage to advance in the game.
Sub-component: User Experience		
11	Immersion	Temporarily I forgot about my daily; I have been fully concentrated on the game.
12		I did not notice the time pass while playing; when I saw the game had already ended.
13		I felt myself more in the game context than real life, forgetting what was around me.
14	Social Interaction	I was able to interact with others during the game.
15		I had fun with other people.
16		The game promotes cooperation and/or competition among the players.
17	Challenge	This game is appropriately challenging for me, the tasks are not too easy nor too difficult.
18		The game progresses at an adequate pace and does not become monotonous - offers new obstacles, situations or variations in its tasks.
19	Fun	I had fun with the game.
20		When interrupted at the end of the class, I was disappointed that the game was over.
21		I would recommend this game to my colleagues.
22		I would like to play this game again.
23	Competence	I achieved the goals of the game applying my knowledge.
24		I had positive feelings on the efficiency of this game.
25	Digital Game	The controls to perform actions in the game responded well.
26		It's easy to learn how to use the interface and game controls.
Sub-component: Learning		
27	Short-term learning	The game contributed to my learning in this course.
28		The game was efficient for my learning, comparing it with other activities of the course.
29		The experience with the game will contribute to my professional performance in practice.

The response format for each of these items is a 5-point Likert scale with response alternatives ranging from strongly disagree (-2) to strongly agree (2).

With respect to the perceived impact on learning, tailored questions have to be added on the knowledge level before and after the game concerning the specific content to be learned by the game as illustrated in Table 2.

Table 2: Questions on perceived knowledge level

Rate your degree of knowledge before and after the game on a scale from 1,0 – low to 5,0 – high.

	Remember what it is …		Understand how it works …		Apply …	
	Before	After	Before	After	Before	After
Content to be learned 1						
…						

The MEEGA model has been evaluated for its applicability and usefulness as well as the evaluation of the questionnaire items in terms of reliability and validity through a large-scale series of 43 case studies in different contexts on 20 different Software Engineering games (Petri et al., 2017b). Findings show that the model is acceptable in terms of its applicability, usefulness, and reliability (Cronbach's alpha =.915), offering an easy alternative to evaluate Software Engineering games in a non-intrusive way. In terms of construct validity, there exists evidence of convergent validity through an acceptable degree of correlation of almost all item pairs within each dimension. Yet, there was also identified a need for the regrouping of items based on the results of a factor analysis, mainly concerning items related to motivation and user experience.

Thus, aiming at the improvement of the original model's validity and in order to provide more comprehensive support to guide instructors and/or researchers on how to conduct game evaluations, in order to obtain reliable and valid results, the model has evolved in 2019 into the **MEEGA+ method** (Petri et al., 2018; Petri et al., 2019; Petri, 2018; Petri et al., 2017a), which aims to evaluate the quality of serious games, improving the initial version of the MEEGA model and also by widening the application domain beyond Software Engineering to any game used for teaching computing in higher education. The MEEGA+ method (Figure 1) is composed of the quality model, defining quality factors to be evaluated through a standardized measurement instrument and a game quality scale, besides defining a process to evaluate the quality of games used for computing education using the MEEGA+ model.

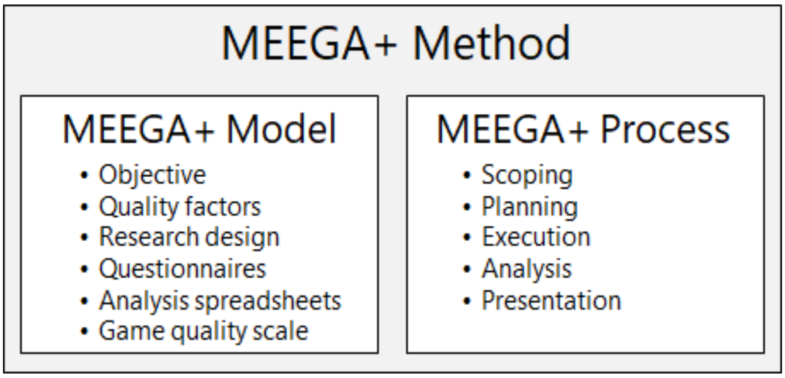

Figure 1: The MEEGA+ method

The MEEGA+ model is decomposed into two quality factors: usability and player experience (Table 3). Usability is defined as the degree to which a serious game can be used by students to achieve specific goals with effectiveness and efficiency in the context of computing education, considering the dimensions of aesthetics, learnability, operability, and accessibility. Player experience is defined as a deep involvement of the student in the gaming task, considering the dimensions of focused attention, fun, challenge, social interaction, confidence, relevance, satisfaction, and perceived learning.

Data collection is operationalized through a standardized questionnaire (Table 3), which has been designed based on the quality factors/dimensions, customizing and unifying existing standardized questionnaires in the literature. The response format is a 5-point Likert scale with response alternatives ranging from strongly disagree to strongly agree.

Table 3: MEEGA+ model

Quality factor	Dimension	No. Item	Description
Usability	Aesthetics	1	The game design is attractive (board, cards, interface, graphics, etc.).
		2	The text font and colors are well blended and consistent.
	Learnability	3	I needed to learn a few things before I could play the game.
		4	Learning to play this game was easy for me.
		5	I think that most people would learn to play this game very quickly.
	Operability	6	I think that the game is easy to play.
		7	The game rules are clear and easy to understand.
	Accessibility	8	The fonts (size and style) used in the game are easy to read.
		9	The colors used in the game are meaningful.
Player experience	Confidence	10	The contents and structure helped me to become confident that I would learn with this game.
	Challenge	11	This game is appropriately challenging for me.
		12	The game provides new challenges (offers new obstacles, situations or variations) at an appropriate pace.
		13	The game does not become monotonous as it progresses (repetitive or boring tasks).
	Satisfaction	14	Completing the game tasks gave me a satisfying feeling of accomplishment.
		15	It is due to my personal effort that I managed to advance in the game.
		16	I feel satisfied with the things that I learned from the game.
		17	I would recommend this game to my colleagues.
	Social Interaction	18	I was able to interact with other players during the game.
		19	The game promotes cooperation and/or competition among the players.
		20	I felt good interacting with other players during the game.
	Fun	21	I had fun with the game.
		22	Something happened during the game (game elements, competition, etc.) which made me smile.
	Focused Attention	23	There was something interesting at the beginning of the game that captured my attention.
		24	I was so involved in my gaming task that I lost track of time.
		25	I forgot about my immediate surroundings while playing this game.
	Relevance	26	The game contents are relevant to my interests.
		27	It is clear to me how the contents of the game are related to the course.
		28	This game is an adequate teaching method for this course.
		29	I prefer learning with this game to learning through other ways (e.g. other teaching methods).
	Perceived Learning	30	The game contributed to my learning in this course.
		31	The game allowed for efficient learning compared with other activities in the course

Data collected using the MEEGA+ measurement instrument are analyzed in terms of frequency distribution (through frequency graphs) and central tendency (median) for each quality factor and their dimensions. The MEEGA+ model provides a spreadsheet for analysis of the data collected, assisting in the organization of the data and automatic generation of graphs for the visualization of the evaluation results.

Findings of a statistical analysis of the MEEGA+ model, analyzing 62 case studies on 24 different games (7 digital games and 17 non-digital games) for teaching computing indicate an excellent internal consistency of the MEEGA+ measurement instrument (Cronbach's alpha α=.927) (Petri et al., 2018). Results of an exploratory factor analysis and item correlation, confirm the structure of the MEEGA+ model, indicating that the quality of games for computing education is evaluated in terms of usability and player experience.

Adopting Item Response Theory (Carlson & Davier, 2017), which allows to express the relationship between observable variables (questionnaire items) and latent traits (game quality) through mathematical models, a game quality scale has been proposed that aims to classify the evaluated game on a quality level. Based on the results of the analysis, three levels of quality are defined to classify the evaluated game: low, good, and excellent quality.

In order to guide the application of the model, the MEEGA+ method also defines a systematic evaluation process. The MEEGA+ process is organized into five phases: scoping, planning, execution, analysis, and presentation, as presented in Figure 2, and defines activities and work products.

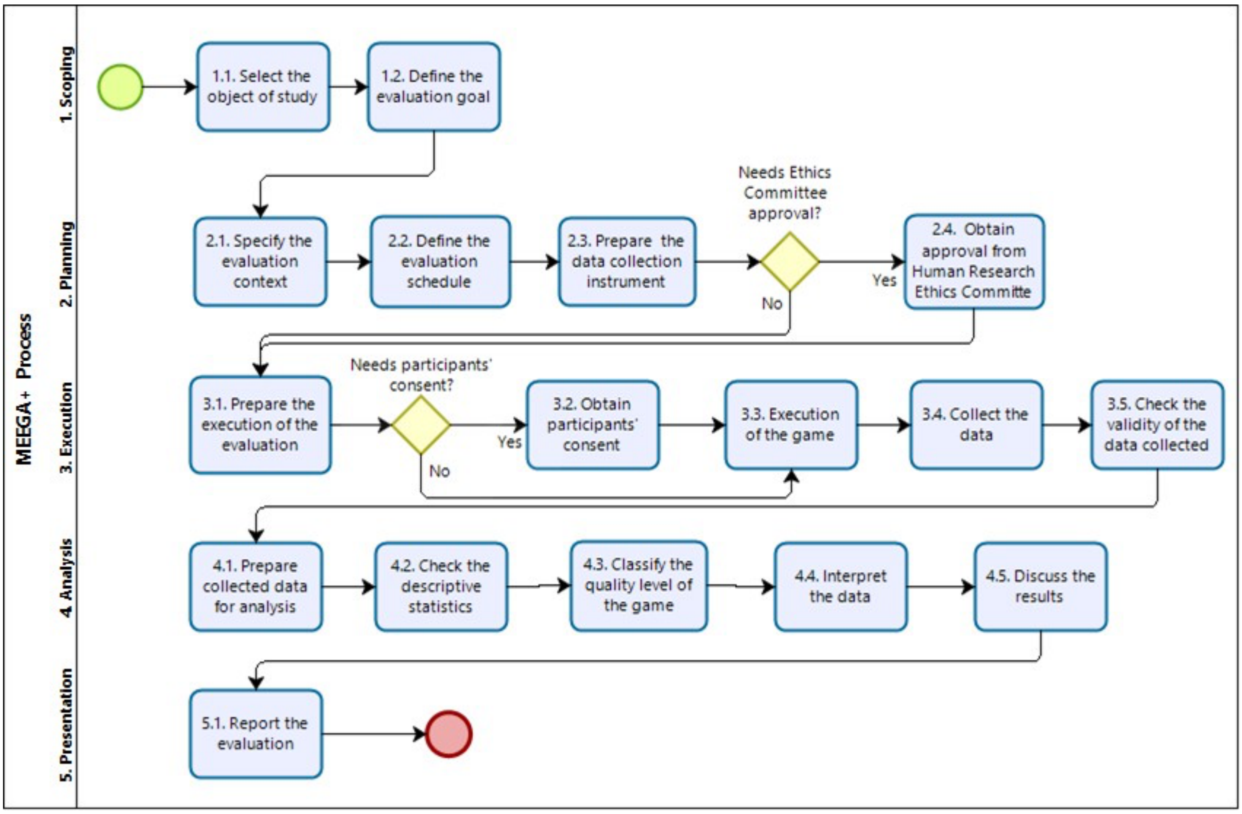

Figure 2: The MEEGA+ process

The material of the MEEGA+ method is available in English, Brazilian Portuguese, and Spanish at: http://www.gqs.ufsc.br/quality-evaluation/meega-plus/ under the Creative Commons License, including the questionnaire, analysis spreadsheet, R files, and usage instructions.

Observing the need to evaluate also the quality of games used for teaching computing in middle and high school as part of an increasing tendency to popularize computing, the measurement instrument of MEEGA+ has been adapted to this specific target audience through a participatory design approach as shown in Table 4 (Gresse von Wangenheim et al., 2020). The MEEGA+Kids questionnaire is available online in English and Brazilian Portuguese: http://www.gqs.ufsc.br/quality-evaluation/meega-plus/ under the Creative Commons License.

The response format is also a 5-point Likert scale with response alternatives ranging from strongly disagree to strongly agree. As part of a self-assessment of the perception of the learning effect of the game a descriptive question "What did you learn by playing the game?" was added.

Yet, differently to the MEEGA+ instrument in which the achievement of the learning goals is measured through a self-assessment by the students, this measurement is done as part of the MEEGA+KIDS questionnaire, through a set of multiple-choice questions assessing the achievement of the learning goals. These questions have to be carefully defined in accordance with the specific learning goals and the competence level to be achieved concerning the specific knowledge area to be learned.

Results from an analysis of data collected from six case studies, evaluating an educational game with responses from 90 middle school students, indicate satisfactory reliability and validity of the questionnaire (Gresse von Wangenheim et al., 2020). Concerning reliability, Cronbach's alpha α=.882 indicates a good internal consistency. Regarding construct validity, analyzing the Spearman correlation coefficient between the items, evidence of discriminant validity was obtained, showing that items of different quality factors do not correlate. Similarly, results show that most of the item pairs present a moderate or large correlation coefficient, providing a first indication of convergent validity.

Table 4: MEEGA+KIDS decomposition and questionnaire items

Quality factor	Dimension	Description
Usability	Aesthetics	The game design is attractive (game board, cards, etc.).
		The font and colors of the game match
	Learnability	Learning to play this game was easy for me.
	Operability	I think that the game is easy to play.
		The game rules are clear and easy to understand.
	Accessibility	The size and style of fonts used in the game are easy to read.
		The colors used in the game are meaningful.
Player experience	Confidence	The organization of the content helped me to become confident that I would learn with this game.
	Challenge	This game is appropriately challenging for me.
		The game provides new challenges (offers new obstacles, situations or variations) at an appropriate pace.
		The game does not become monotonous as it progresses (repetitive or boring tasks).
	Satisfaction	Completing the game tasks gave me a satisfying feeling of accomplishment.
		It is due to my personal effort that I managed to advance in the game.
		I feel satisfied with the things that I learned from the game.
		I would recommend this game to my colleagues.
	Social Interaction	I was able to interact with other players during the game.
		The game promotes cooperation and/or competition among the players.
		I felt good interacting with other players during the game.
	Fun	I had fun with the game.
		Something happened during the game that made me smile.
	Focused Attention	There was something interesting at the beginning of the game that captured my attention.
		I was so involved in my gaming task that I lost track of time.
	Relevance	The game's content is of my interest
		It is clear to me how the contents of the game are related to the course.
		I learned content of the course with this game
		I prefer learning with this game to learning through other ways (e.g. other teaching methods).
	Perceived Learning	Descriptive question - What did you learn playing the game?

3 Definition and execution of the systematic mapping

In order to elicit how the MEEGA/MEEGA+ model is used for the evaluation of games, we performed a systematic mapping following the procedure defined by Petersen et al. (2008).

3.1 Definition of the review protocol

The main research question is "How is the MEEGA/MEEGA+ model used to evaluate games"?

This research question is refined into the following analysis questions:

AQ1. Which studies have used the MEEGA/MEEGA+ model for the evaluation of games? And what are the characteristics of games evaluated in terms of knowledge domain, type of game, and educational stage?

AQ2. Has the MEEGA/MEEGA+ model been adapted in these studies?

AQ3. Has the reliability/validity of the MEEGA/MEEGA+ model been evaluated in these studies?

Inclusion and exclusion criteria. We included only peer-reviewed articles in English, Portuguese, and Spanish published since 2010, when the model was initially created. Academic works such as dissertations etc. have not been included. We included any study applying the MEEGA model or one of its evolutions (MEEGA+, MEEGA+Kids) for the evaluation of games, either educational or not. Articles reporting evaluations of instructional strategies other than games have been excluded. We included studies conducted on any educational stage (K-12, higher education, undergraduate), extracurricular, teacher or professional training, etc. On the other hand, articles that do not apply the model for the evaluation of a game were excluded. Articles presenting other evaluation models and or tools or development checklists were not considered.

Quality criteria. Only articles that present substantial information in order to allow the extraction of relevant information regarding the analysis questions were considered. Other artifacts, not presenting substantial information, such as summaries or one-page abstracts, blogs, and videos were excluded.

Data source. The search was conducted in major digital repositories, including ACM Digital Library, IEEE Xplore, Scopus, SpringerLink, ScienceDirect, ERIC, Web of Science, and Wiley as well as the SBC Openlib (Digital Library of the Brazilian Computing Society) with access through the Capes Portal. In addition, Google Scholar searches were conducted to complement the search, in order to minimize the risk of omission (Piasecki et al., 2018).

Definition of search terms. According to the research question, the search string was defined by identifying the core concepts, as shown in Table 5. With respect to the model, the names of each of the versions were included.

Table 5: Search terms and translations

Core Concept	Keywords in English	Portuguese translation	Spanish translation
MEEGA model	MEEGA, MEEGA+, MEEGA+Kids	MEEGA, MEEGA+, MEEGA+Kids	MEEGA, MEEGA+, MEEGA+Kids
Game	Game	Jogo	Juego

Using these keywords, a generic search string has been defined in each language and the search strings have been adapted in conformance with the specific syntax of each of the repositories limited to the period 2010 - 2024.

3.2 Search Execution

The search was conducted from February to March 2024 by the authors. Initial searches resulted in a total of 1.348 results (Table 6). At the first stage, we selected potentially relevant articles based on the title, abstract, and keywords returned as the result of the searches in each repository in accordance with the inclusion and exclusion criteria. In the second step, we analyzed the complete articles of potentially relevant ones in accordance with the established inclusion/exclusion and quality criteria.

Table 6: Overview on the selection of relevant articles

Repository	**Search idiom**	**No. of search results**	**No. of potentially relevant articles**	**No. of relevant articles**
ACM Digital Library	ENG	30	19	11
	POR	9	4	4
	ESP	0	0	0
ERIC	ENG	1	1	1
	POR	0	0	0
	ESP	0	0	0
IEEE Xplore	ENG	5	5	5
	POR	0	0	0
	ESP	0	0	0
SBC Openlib	ENG	2	2	2
	POR	0	0	0
	ESP	0	0	0
Science Direct	ENG	9	7	5
	POR	0	0	0
	ESP	0	0	0
SCOPUS	ENG	121	91	56
	POR	16	13	13
	ESP	3	1	1
SpringerLink	ENG	57	14	7
	POR	6	1	0
	ESP	0	0	0
Web of science	ENG	26	21	17
	POR	0	0	0
	ESP	0	0	0
Wiley	ENG	11	0	0
	POR	0	0	0
	ESP	0	0	0
Google Scholar	ENG	618	167	92
	POR	384	98	86
	ESP	50	27	19
Total (without duplicates)				**166**

Articles reporting evaluations of instructional strategies, other than games, such as simulations using MEEGA have been excluded from this mapping (e.g., (Omidvarkarjan et al., 2023)). We also excluded any articles presenting other evaluation models and or tools (such as (Omari et al., 2020)) or development checklists (e.g., (Frazão et al., 2021). Articles that were not fully accessible via Portal Capes were not considered. We also excluded academic works, such as dissertations or PhD theses. As a result, we encountered 166 articles, presenting 170 studies on 178 different games.

4 Data analysis

To answer the research question, we present the findings with respect to each of the analysis questions based on the relevant information extracted from the articles. Extraction was performed, revised, and discussed with the co-authors until a consensus was reached. As not necessarily all information is presented explicitly in the articles, certain characteristics were inferred based on the information available in the articles.

The large majority of the studies using MEEGA/MEEGA+ have been conducted in Brazil, the origin of the model (Figure 3). But we can also observe several applications in Europe and Asia as well as to a smaller extent in North America.

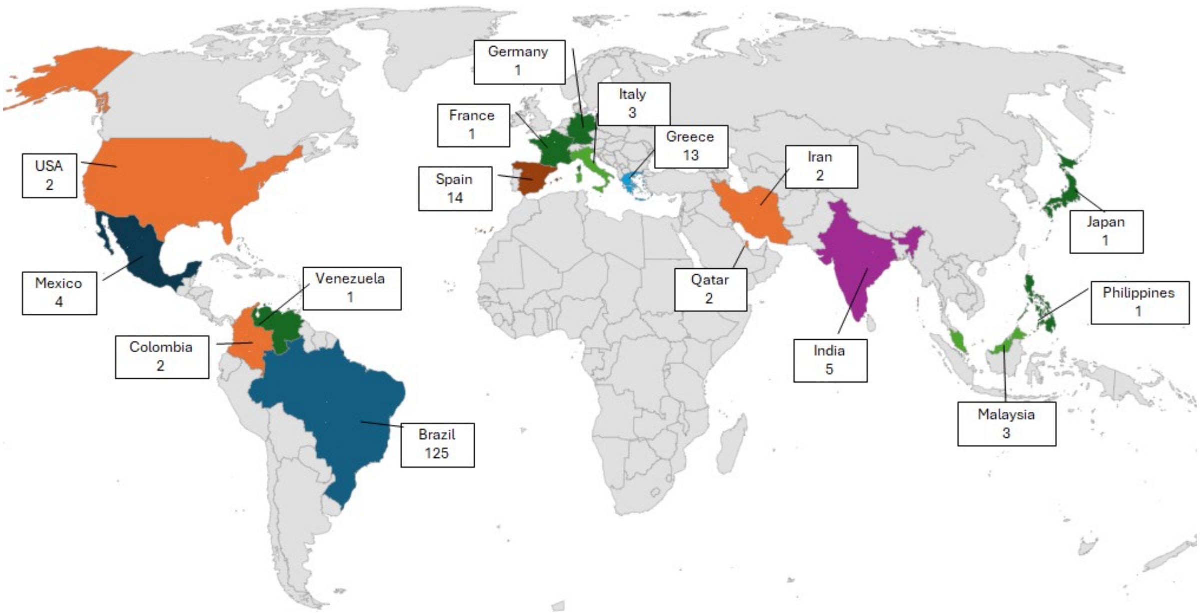

Figure 3: Distribution of studies per country

We can also observe a constant increase in the number of applications since 2015, only with an exceptional reduction in 2021, most probably due to the pandemic (Figure 4).

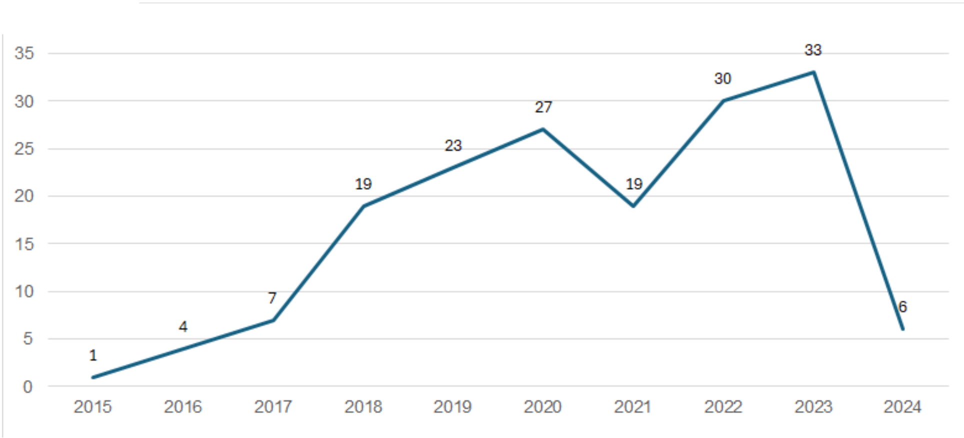

Figure 4: Distribution of publications per year

4.1 Which studies have used the MEEGA/MEEGA+ model for the evaluation of games?

The initial MEEGA model was developed for the evaluation of games teaching Software Engineering and was later extended for the teaching of any computing concepts as the MEEGA+ method. Most evaluations have been reported on games teaching various computing concepts, with a majority related to Software Engineering but also covering other areas such as computational thinking, algorithms & programming, data structures, and cryptography, among others. But, surprisingly the model has been adopted very broadly for the evaluation of games of the diverse knowledge areas, including traditional scholarly knowledge areas such as mathematics, chemistry, physics, history and literature, and linguistics (Figure 5). Yet, a considerable amount of evaluations have also been conducted on games from other knowledge areas such as healthcare, i.e., COVID-19, Tuberculosis, and Diabetes, as well as engineering, business and finances, environmental science to even military content. And, considering that many of these evaluations have been conducted using the MEEGA+ method as is, it seems that it can be applied to even a much broader application scope of games than the one it has been originally proposed for.

Figure 5: Frequency of studies per knowledge domain

As originally intended the model has basically applied only for the evaluation of serious games in educational contexts. The only exception is a study presented by Reis et al. (2020), who as part of an exploratory pre-study analyzed four mobile games for entertainment before developing their game to identify strengths and weaknesses of mobile games.

Game genres for which evaluations are reported range from quiz games (such as Kahoot), role-playing or strategy games, escape rooms, simulation as well as puzzle or battle games. The majority of the evaluations are reported with respect to single-player games, including 2D and 3D games as well as ones using augmented reality. These digital games include games to be played on the computer as well as mobile games, yet no study regarding console games was encountered. On the other hand, we also observed several applications of non-digital games (26%), including board games, card games or paper & pencil games. Hybrid games, such as Screener (Noël et al., 2024) a board game supplemented with online resources, or the GreaTest game (Silva et al., 2020a), a card game with a mobile companion have also been evaluated using MEEGA+.

In terms of the target audience, little more than half of the studies (53.8%) target the evaluation of serious games with undergraduate students, while also a considerable number of evaluations have been reported with K-12 students. Some of the games to be applied in extracurricular contexts have also been evaluated with the specific audience targeted by the games, such as, e.g., young people with autism disorder or military personnel (Figure 6).

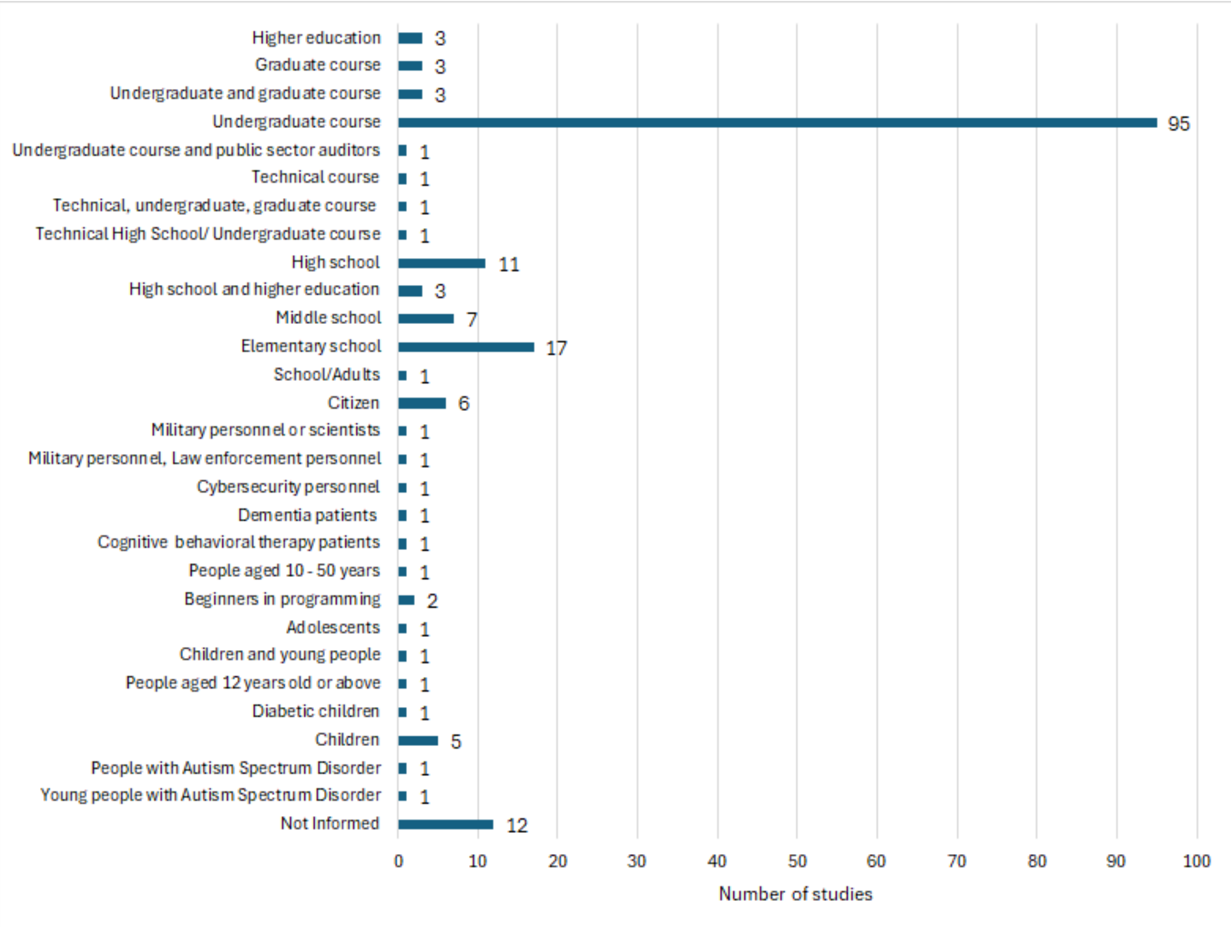

Figure 6: Distribution of studies per target audience

4.2 Has the MEEGA/MEEGA+ model been adapted in these studies?

Most studies adopted the revised version of MEEGA+ (71%), with mostly only older studies adopting the original MEEGA method (23%). Some studies involving students at K-12 also used the MEEGA+Kids questionnaire (5%), tailored specifically for this target audience. One study (Calderón et al., 2023) used the MEEGA+ and MEEGA+Kids at the same time.

Most studies adopted the MEEGA/MEEGA+ model as-is. However, 15 studies adapted the model, generally by modifying the questionnaire items. Only Moosa et al. (2020) modified the response scale from a 5-point Likert scale to a 3-point Likert scale in order to facilitate its understanding by children aged 8-11 years and Zarif-Yeganeh et al. (2024) also adopted a 3-point Likert scale without further justification.

Adaptations include a specific focus on just some dimensions of the MEEGA+ model (Nasharuddin et al., 2019; Tulha et al., 2019; Mendes et al., 2018; Oliveira Jr. & Barbosa, 2023a; Oliveira Jr. & Barbosa, 2023b; Silva et al., 2022), or the exclusion of questions with respect to games that have been applied outside the context of an educational course (Azevedo et al., 2022). Others excluded items related to digital games when applying the instrument for the evaluation of non-digital games, such as Guedes & Moreira (2023). Lima et al. (2022) also indicated that changes in the wording of the items have been made in order to fit the specific context.

Some added questions on the applicability of the game in the classroom (Rodrigues et al., 2020; Tulha et al., 2021), the playability of the game (Borges et al., 2019), the specific influence of the mobile game component of a hybrid game (Silva et al., 2020a) or to reinforce items on intrinsic motivation and reduced cognitive load (Venigalla et al., 2022).

Others also completed the instrument with items regarding the complete instructional unit, covering additional educational strategies besides the game (Gomes & Lelli, 2021). García et al. (2020) added questions to capture more details on the perception of learning (as well as additional questionnaires to also collect feedback from the teachers). Several also added questions on previous knowledge with respect to the concepts to be learned, e.g., on intercultural competence (Paz et al., 2018), Brazilian dialect (Classe et al., 2022a; Classe et al., 2022b), learning levels (Silva & Fernandes, 2020), global software development (Vizcaíno et al., 2023), flood risk (Pileggi et al., 2020), construction (Hassan et al., 2021), Covid-19 (Venigalla et al., 2022; Phutela et al., 2022), children's knowledge on abuse (Fava et al., 2022) or to analyze the perception of anxiety using standardized questionnaires (Ken et al., 2023) or physical activity (Nasharuddin et al., 2019).

Several studies combined the MEEGA+ model with the usage of the EGameFlow model (Fu et al., 2009), such as (Pileggi et al., 2020; Brasil et al., 2023; Pires et al., 2020; McGill et al., 2018). Similar to MEEGA+, this model is based on Sweetser's & Wyeth's framework (Sweetser & Wyeth, 2005) providing a scale that assesses user enjoyment of e-learning games. The scale includes the dimensions of immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement. These dimensions are used to measure user enjoyment focusing on e-learning games, while the MEEGA+ is adopted to evaluate both digital and non-digital educational games.

Some also report the adoption of additional questionnaires to assess emotional responses. For example, Macena et al. (2020) complemented the evaluation using the Self-Assessment Manikin (SAM) (Bynion & Feldner, 2017), a non-verbal pictorial assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli in various contexts. Others, such as (Nascimento et al., 2023; Araújo et al., 2023; Bastos et al., 2023; Honda et al., 2022) used Emoti-SAM (Hayashi et al.

2016), an adaptation of the SAM developed specifically for assessing emotions in digital environments.

Focusing on the evaluation of the usability of the games, some also adopted the SUS (System Usability Scale) (Brooke, 1996), including (Pires et al., 2020; Honda et al., 2022; McGill et al., 2018). Other studies, such as Pessoa et al. (2019) and McGill et al. (2018) also emphasize the usability aspect adopted heuristics, including Panas Game Usability Heuristics (Watson et al., 1988) or Nielsen's Usability Heuristics (Nielsen, 1995). McGill et al. (2018) also used the Technology Acceptance Model (TAM) (Davis, 1989), to evaluate the acceptance and use of the game, whereas Rosa and Gloria (2020) and Rosa (2022) applied the NASA Task Load Index (NASA-TLX) (Human Performance Research Group, 1986) that rates perceived workload in order to assess a system.

Several studies also created their data collection instrument based on existing ones, including MEEGA+ as a source, such as (Alf et al., 2023; Low, 2024; Rosa & Gloria,2020; Katsaounidou et al., 2019), including the Game Experience Questionnaire (IJsselsteijn et al., 2007). Filippas & Xinogalos (2023) added questions based on the acceptability, usability, and didactic utility and the game environment. Some studies also analyzed data on players' actions and errors made during the gameplay (Junior et al., 2023).

Basically, all studies collected data through questionnaires. We only encountered one study that complemented the data collection by interviews (Silva et al., 2020b). Few studies report the usage of the game quality scale, including only (Venigalla et al., 2022), (Venigalla & Chimalakonda, 2020), (Hassan et al., 2021), (Azevedo et al., 2022), (Oliveira et al., 2023), (Sampaio & Pereira, 2022), (Petris & Silva, 2023).

4.3 Has the reliability/validity of the MEEGA/MEEGA+ model been evaluated in these studies?

The large majority of the reported studies were conducted as a case study, as originally proposed by the MEEGA/MEEGA+ model and process. Three studies were designed as experiments. Ken et al. (2023) evaluated the game ReWIND for treating anxiety disorders, through a randomized controlled trial with 40 participants, of whom half were randomly assigned to play ReWIND while the others executed a non-game task. Besides measuring anxiety levels, both groups also answered the MEEGA+ questionnaire after task completion, and the results were compared. Zarif-Yeganeh et al. (2024) performed a study with three randomized groups (control, game, and multimedia), using a pre-and post-test design with 155 students, and compared the perceived player experience and usability across the groups. McGill et al. (2018) present the planning of an evaluation of the game "If Memory Serves" to support teaching pointers in computing education through an experiment using MEEGA+ together with a set of other measurement instruments.

Two studies were also conducted as quasi-experimental studies. Alf et al. (2023) used two different types of simulation games, one on general management and another one on change management. Yet, both groups played the game, with the experimental group participating in a reflection assignment while the control group did not. Data collected with the MEEGA+ instrument was used to compare the students' learning as well as perceived player experience. Angulo et al. (2022) used "JUSECA", a serious game for understanding algorithms, with the experimental group while the control group answered the same algorithms used in the game but in an exercise guide. The performance of both groups (experimental and control) was measured through an ad-hoc performance evaluation, with three questions about writing algorithms, and MEEGA+ was applied to evaluate the game in terms of user experience and usability.

The majority of the studies were conducted with a small sample size of only 11-20 participants or less (Figure 7). Very few studies report larger sample sizes with more than 100 participants, including Georgiadou & Xinogalos (2023) who performed a study with 213 participants, and González-Tablas et al. (2020) with 223 participants.

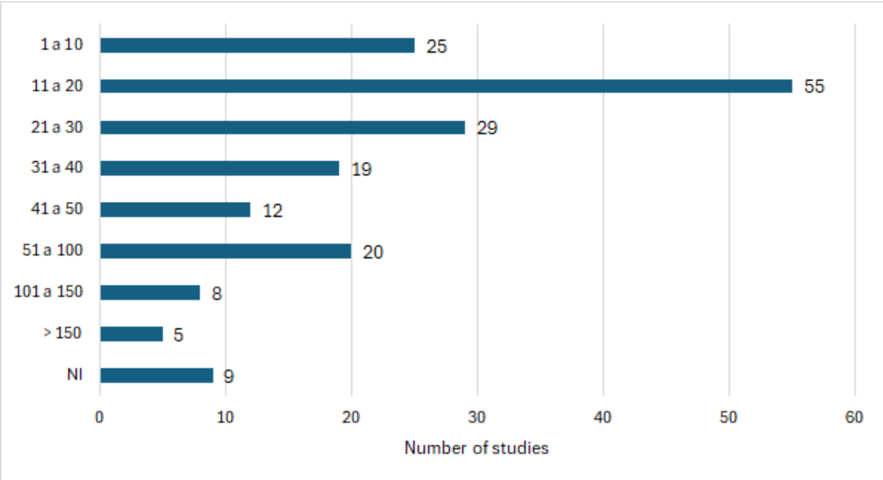

Figure 7: Number of studies per sample size

We also observed that some studies were conducted with participants different from the target population. For example, Georgiadou & Xinogalos (2023) evaluated a game for teaching safe internet use and digital intelligence competencies to be applied in primary school with prospective ICT teachers, similar to Oliveira Jr. & Barbosa (2023a), who evaluated a game teaching probability in elementary school with elementary school teachers. Filippas & Xinogalos (2023) evaluated the "Elementium" game for familiarizing junior high school students with basic chemistry with adults aged 18-39 years. Skraparli et al. (2023) evaluated a game on programming code targeting people aged 12 years old or above with undergraduate students. Macena et al. (2020) evaluated the game "Operação Lovelace" for learning algorithms with participants aged 17-24 years while aiming at elementary students. Azevedo et al. (2022) evaluated the "Dengueside Survival" game targeting also children only with university students and Sampaio & Pereira (2022) evaluated a game aiming at autistic children only with computing professionals and a teacher.

Reliability. Even when considering that the reliability of the MEEGA/MEEGA+ instrument has been evaluated beforehand through a large-scale study, surprisingly few studies re-evaluated the reliability of the instrument on their data collected (Table 7). These studies calculated Cronbach's alpha in order to analyze the reliability of the data collection instrument. Findings indicate good to best reliability with the majority of the values > .80, with only one exception, which may be due to the type of game or some other factor that may have caused this result.

Table 7: Overview on reliability evaluations

Reference	Game	Knowledge area	Sample size	Reliability findings
(Abreu et al., 2023)	EgC-EndGame for Corruption	Social sciences/ Law and ethics	24	Cronbach alpha = .96
(Classe et al., 2022a; Classe et al., 2022b)	Uai! Que isso sô!	Linguistics	64	Cronbach alpha=.93
(Freitas et al., 2018)	Invade the System	Computing	27	Cronbach alpha=.874
(Kritz et al., 2020)	Xô Corona	Health	21	Cronbach alpha = .85
(Macena et al., 2022)	Hello Food	Computing	15	Cronbach alpha = .95
(Mendes et al., 2018.)	Hanoi tower	Computing	36	Cronbach alpha = .826
	Crossing Code	Computing		Cronbach alpha = .712
	Boolamp	Computing		Cronbach alpha = .825
	Invade the System	Computing		Cronbach alpha = .874
	Code Dungeon	Computing		Cronbach alpha = .861
	Caça Bugs	Computing		Cronbach alpha = .651
(Oliveira Jr. & Barbosa, 2023a)	Probabilidade em Ação (non-digital version)	Mathematics	17	Cronbach alpha = .802
(Oliveira Jr. & Barbosa, 2023b)	Probabilidade em Ação (digital version)	Mathematics	19	Cronbach alpha = .913
(Schoeffel, 2021)	XP Enigma	Computing	20	Cronbach alpha = .8831
(Zarif-Yeganeh et al., 2024)	Pharm-PSY	Health	50	Cronbach alpha = .84

Validity. Three studies also report the evaluation of the validity of the evaluation model (Table 8). Abreu et al. (2023) analyzed the convergent validity of the questionnaire conducting a confirmatory factor analysis based on data collected from 24 participants, calculating average variance extracted (AVE) and composed reliability (CR). Findings reveal that the majority of the items present an average variance extracted (AVE) > .5, indicating the items to be valid. Exceptions are items related to fun, challenge, and trust presenting lower values and, therefore, may not be considered valid, also confirmed by analyzing the factor loadings. The composite reliability (CR) also showed reliable values for most items (>.7), except again for items related to fun, challenge, and trust.

Table 8: Overview on validity evaluations

Reference	Game	Sample size	Validity findings
(Abreu et al., 2023)	EgC-EndGame for Corruption	24	Confirmatory factor analysis: AVE >.5 for most items and CR>.7 for most items (exceptions are related to fun, challenge and trust).
(Abreu & Classe, 2022)			
(Oliveira Jr. & Barbosa, 2023a)	Probabilidade em Ação (Non-digital version)	17	KMO = 0,606 and Bartlett Sphericity Test = 67,007 Exploratory factor analysis: Factor loadings of all items >.675
(Oliveira Jr. & Barbosa, 2023b)	Probabilidade em Ação (digital version)	19	KMO = 0,699 and Bartlett Sphericity Test = 136.761 Exploratory factor analysis: Factor loadings of all items >.736
(Oliveira Jr. et al., 2022)			

Oliveira Jr. & Barbosa (2023a) also analyzed the validity of the measurement instrument composed of 8 items through an exploratory factor analysis applying the MEEGA+ model for the evaluation of a non-digital version of a game. The verification of the Kaiser-Meyer-Olkin (KMO) = 0.606 and the Bartlett Sphericity Test = 67.007 ($p < 0.001$) regarding the analysis of the non-digital version of the game based on a sample of 17 participants, confirmed the possibility to conduct an exploratory factor analysis. Findings with factor loadings of all items > .675 show that they are highly correlated with one of the three factors: aesthetic aspects, aspects related to learning, and aspects related to operability and accessibility.

Oliveira Jr. & Barbosa (2022) also analyzed the validity of the measurement instrument composed of 7 items through an exploratory factor analysis applying the MEEGA+ model for the evaluation of a digital version of a game. The verification of the Kaiser-Meyer-Olkin (KMO) = 0.699 and the Bartlett Sphericity Test = 136.761 ($p < 0.001$) regarding the analysis of the non-digital version of the game based on a sample of 19 participants, confirmed the possibility of conducting an exploratory factor analysis with extraction by principal axes and Varimax rotation with Kaiser normalization. Factor loadings of all items > .736 indicate that the items are highly correlated with one of two factors: aesthetics/operability or learning.

5 Discussion

Findings show that the MEEGA/MEEGA+ model has been adopted for a large number of game evaluations since its first publication in 2011. Various researchers justified the application of the MEEGA/MEEGA+ model instead of other alternative models with a similar focus due to the ease of its application providing reliable and valid results even as part of a case study, without the need for a more rigorous research design, which may not be feasible due to certain contextual constraints or in the typical case of small sample size may not yield any significant results.

The wide variety of applications of the MEEGA/MEEGA+ model, not only in terms of knowledge domain but also in terms of type of games and educational stages, provides an indication of the broad applicability of the model initially designed for the evaluation of games for teaching Software Engineering (MEEGA) and then extended to Computing (MEEGA+).

We also observed that the model has been applied for a large variety of types of games including quiz games, puzzles, escape rooms, RPGs, simulations, etc. However, we encountered difficulty in finding information on the game type in the articles, maybe due to the lack of a well-accepted taxonomy of game types or a lack of a more uniform format of reporting and characterizing the games. An improvement suggestion could therefore be to include a more structured game characterization as part of the MEEGA+ model, which may facilitate a more complete and consistent reporting on the games being evaluated. And, although the model has been applied mostly for the evaluation of digital games, it has also been adopted with a considerable number of non-digital ones, typically in this case excluding the questions that are specific to digital games.

The results also indicate that the model can be used on diverse educational stages ranging from elementary school to higher education as well as with target audiences outside an educational context, such as community health agents, military experts, or citizens in general. A more recent adoption of the MEEGA model with children, also demonstrated a well-accepted use of the MEEGA+Kids version, specifically tailored for this target audience.

The model is mostly used as-is also indicating that the support that it provides for the analysis of the quality of serious games by evaluating learning and learning experience is considered adequate. Few studies simplified the model generally in terms of evaluation items, e.g., when applying the model with children before the availability of the MEEGA+Kids version or when applying the game in a nonformal educational context with citizens, e.g., by excluding items related to an educational context. Some also focused only on specific quality factors of the model, such as usability.

On the other hand, several studies also used additional evaluation models, such as EGameFlow or questionnaires on specific aspects such as usability or technology acceptance in addition to the MEEGA/MEEGA+ model. These completions may point out an improvement potential to complete the MEEGA/MEEGA+ model including such quality factors/items and/or the development of different versions for different objectives of emphasis.

Only two studies modified the response scale from a 5-point Likert scale to a 3-point Likert scale in order to facilitate its understanding by children. We also observed that in some cases the visualization of results has been changed from the visualization of frequencies to percentages, yet sometimes without a clear indication of the total number of data points, thus obscuring important information. We also observed that some studies report measures for the Likert scale of the model, such as averages/means, which are generally considered inappropriate for this kind of scale, for which the median should be used as the measure of central tendency (Jamieson, 2004).

Very few studies have analyzed the reliability of the data collection instrument with their data, yet their findings also indicate good to best reliability (Cronbach alpha > .80) with only one exception demonstrating a lower reliability. This confirms the results of the large-scale studies on the MEEGA instrument (Petri et al., 2017b) indicating a Cronbach alpha = .915 based on data from the evaluation of software engineering games and the MEEGA+ instrument (Petri et al., 2018) with a Cronbach alpha =.928 and the initial analysis of the MEEGA+Kids instrument (Cronbach alpha = .882) (Gresse von Wangenheim et al., 2020) based on data from the evaluation of computing games. By analyzing the reliability of the instrument for the evaluation of games in different knowledge areas, including social sciences, linguistics, health, and mathematics, these findings provide a first indication that the model may also be considered reliable in a more general context.

Three studies have also examined the validity of the evaluation model. However, considering the very small sample sizes in these studies ranging from only 17 to 24 participants, leaves the obtained results questionable, as, e.g., Hair et al. (2009) indicate that it is difficult to perform a factor analysis with a sample smaller than 50 observations, suggesting that, preferably, the size should be greater than or equal to 100.

Threats to validity. In order to mitigate the impact of factors that may affect the validity of our mapping, we adopted several strategies. A common bias is that positive results tend to be published more than negative ones, yet this should be a minor factor since we focus on the application of the MEEGA/MEEGA+ model and not the quality of the games being evaluated. Another risk is the omission of relevant articles. In this regard, the search string was carefully constructed to include all potentially relevant articles by including all variations of the model name and being translated into different idioms. Furthermore, searches were conducted in several major digital repositories, not limited to a specific knowledge area, such as computing. In addition, knowledge area, such as computing. In addition, Google Scholar searches were conducted to complement the search, in order to further minimize the risk of omission (Piasecki et al., 2018). Threats to the selection of relevant applications of the model and data extraction were mitigated by defining and documenting a strict protocol, with the careful establishment of inclusion/exclusion and quality criteria and applying these criteria carefully during the selection until consensus among the authors was obtained. Data extraction was performed by one author, inferred when not explicitly stated in the article, and carefully reviewed by the co-authors.

6 Conclusion

The findings of this systematic mapping show that the MEEGA/MEEGA+ model is a widely adopted alternative for evaluating educational games for teaching not only software engineering or computing but a large variety of knowledge areas, including mathematics, chemistry, physics, history and literature, and linguistics as well as healthcare, engineering, business and finances, environmental science among others. So far, the model has primarily been used as-is, suggesting that it provides adequate support for the analysis of the quality of serious games by evaluating learning and learning experience. Furthermore, its ease of use as part of a case study while still yielding reliable and valid results has been cited as one of the major reasons for its preference to other alternative evaluation models. This shows that especially the improved version of MEEGA+ is a well-accepted model for the evaluation of serious games in order to assist game creators and instructors to improve such games as well as to support decisions on their application within instructional units.

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