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Article

Critical meta-analysis of problem-solving serious games: Clear signs of pedagogists' disengagement and over-optimistic expectations

Razieh Mohaqeqian[1], Morteza Rezaei-Zadeh[2], Mojtaba Vahidi-Asl[3]

[1]*Department of Educational sciences, Faculty of Education and Psychology, Shahid Beheshti University, Tehran, Iran.*
[2]*Department of Educational Sciences, Faculty of Education and Psychology, Shahid Beheshti University, Tehran, Iran; Flexible Learning Centre, Faculty of Science and Engineering, University of Limerick, Ireland. Corresponding author, Morteza.RezaeiZadeh@ul.ie*
[3]*Department of Software and information systems, Faculty of Science and Engineering, Shahid Beheshti University, Tehran, Iran.*

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Abstract:

Problem-solving is placed at top of the ten most important life skills recommended by World Economic Forum. Serious game has been one of the dominant tools for educating people in different subjects over the last 10 years. This study aims to critically analyse previous empirical studies conducted on Problem-Solving Serious Games (PSSG). Using Constant Comparative Method (CCM) framework, 737 studies in this area are listed; and after applying several filters, 36 studies are refined and finally chosen. The analysis shows that serious games not alone improve people's problem-solving ability, it also positively impacts on their problem-solving motivation, problem-solving measurement ability, critical thinking, and learning attitude. However, there is a lack of pedagogists' engagement with PSSG studies. As a result, those studies suffered from lack of educational rationale behind and lack of right direction in choosing their participants, research methods, focus, genre, and expected outputs. Theoretical and practical implications of this critical analysis are outlined at the end of this paper, shedding light on the future directions of PSSG studies. the main conclusions of this study are as following: 1. An inter-disciplinary approach led by pedagogists is needed to design, develop, and examine PSSGs effectively. 2. The over-optimistic viewpoint about serious games in general and PSSGs in specific should be moderated by looking more closely at the negative marginal and side effects of implementing these games on gamers.

1. Introduction

World Economic Forum conducted a survey asking chief human resources and strategy officers from leading global employers what are the most important competencies for living in the future complex world. The results of this survey highlighted the 10 most important competencies for future jobs; and 'problem-solving' placed at the top of the [1]. Furthermore, World Health Organisation (WHO) ranked problem-solving as the most important competency for living in 21st century [2].

Problem-solving is defined as the ability to identify and define a problem, exploring the causes and solutions of that problem, and preventing the negative consequences of that problem [3]. It is also defined as the ability to approach a goal which is not easy to be obtained [4]. Another definition of problem-solving sees it as the highest level of thinking which starts by thinking about a problem. This thinking leads to the higher levels which aim to analyse the causes, impacts, and solutions of the problem [5]. There is a belief that the learning comes out of this problem-based thinking is the most effective and lasting learning which can be applied in different occasions [6].

Serious game has been seen as human brain's favourite learning and development method [7]. Therefore, serious games have been widely used for educational purposes in different fields and subjects [8]. Across different subjects, there is a growing attention in implementing stimulated environments such as serious games for enhancing people's transversal skills [9] including their problem-solving ability over the last decade [10]. Empirical studies over the last decades show that games can improve people's problem-solving ability in two ways.

First and in general, almost all of serious games help people to enrich their problem-solving ability because playing with these games requires them to deal with a number of complex scenarios and solve a number of problems to progress in the game [11]. Second, some games have been specially designed for triggering people's problem-solving ability. These games are effective tools for enriching this skill because it helps people to try different approaches for improving their problem-solving without being affected by the risks and possible negative effects of those exercises [12]. As an example, Glass lab in the United States widely uses the serious games to improve people's transversal skills in general and problem-solving in specific [13,14].

It seems that using the new technologies such as serious games for learning different skills – including problem-solving – is not an optional choice anymore. The new generation of students and workers named 'digital natives' prefer to use new technologies both for learning as well as doing all their day-to-day activities [15]. When it comes to learning, digital natives tend to 'learn by doing', love fast and frequent interaction with the content, and enjoy their learning journey. All these learning preferences are addressed in serious games [16]. That's why among other technologies, games are highly ranked and used by digital natives in their learning environments [17].

However, despite the wide expectations from serious games to improve people' problem-solving ability; there is a lack of critical analysis on: 1. Which research methods the Problem-Solving Serious Games (PSSG) studies used? 2. Who participated in the PSSG studies? 3. What have been the main focus of the PSSG studies? 4. Are these PSSG studies supported by the pedagogical theories? 5. Which game genres have been used in the problem-solving games? And 6. What have been the outcomes of implementing problem-solving games?

The current study focuses on the six literature gaps above. Investigating each of these gaps helps the future PSSG scholars to structure their studies more effectively. In terms of the first gap, highlighting the research methods being used by the previous studies, shows the possible missing methods which should be implemented in the future PSSG studies. Investigating the second gap reassures the future studies not to exclude some participant groups from the PSSG studies. From the

third gap's perspective, this study will highlight whether previous PSSG studies focused on the theory or product. This also has potential to direct the future studies towards the missing focus. The fourth gap is expected to have a great contribution to the PSSG studies. it is important to know whether PSSGs are designed by pedagogy experts or not. If PSSGs are to trigger students' problem-solving ability, they should be built based on pedagogical theories and principles. From the fifth gap's perspective, it is also important to know which game genres have been used by the previous PSSG studies. This shows the potential of those genres as well as suggesting the future studies to examine those genres which were not used so far. Last but not least, the findings of the sixth question above sheds light on the outcomes of implementing PSSGs, highlighting their importance and applications in the formal and informal learning environments.

2. Methodology

Structured literature review is deployed to analyse the previous empirical PSSG studies, exploring the six literature gaps above. Petticrew and Roberts [18] defined structured literature review as an interpretation of documents by summarizing, analysing, evaluating, and synthesizing those documents. To do a right interpretation, the literature review should be done correctly using a comprehensive protocol. The current study uses Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. Further details of the PRISMA method deployed by the current study are outlined in the below.

2.1 Search strategy

Based on the research questions of this study the key words for searching in the literature are chosen. These keywords are listed in Table 1. Furthermore, truncation search strategy is implemented to make more inclusive search results. As could be seen in Table 1, the root of the key words is being used and the ending is being replaced by an asterisk (*). This technique allows us to search and find various word endings simultaneously.

Based on the key words above, a comprehensive search was conducted to find the relevant papers. Two criteria were applied to the initial search process: 1. The search was limited to the papers published between 2010 and 2020. This was for having more up to date research papers. 2. The search was limited to the Web of Science, Scopus, ProQuest, and ERIC databases as they seem to be accredited and authentic academic databases covering almost all the journals in the areas of serious games and problem-solving [19].

Table1. Keyword search strategy

OR		OR		OR
Problem solving		Competenc*		Game*
Problem-solving		Capabilit*		Series games
Problem based learning		Skill*		Educational games
		Aptitude*		Learning games
	AND	Eligibilit*	**AND**	Digital games
		Abilit*		Computer games
		Proficienc*		Game based-learning
		Merit		Video games
				Simulation games
				Online games

2.2 Review process

A comprehensive review process was implemented to make sure that almost all the relevant and right papers are included in this reflective and critical review. Figure 1 illustrates this process.

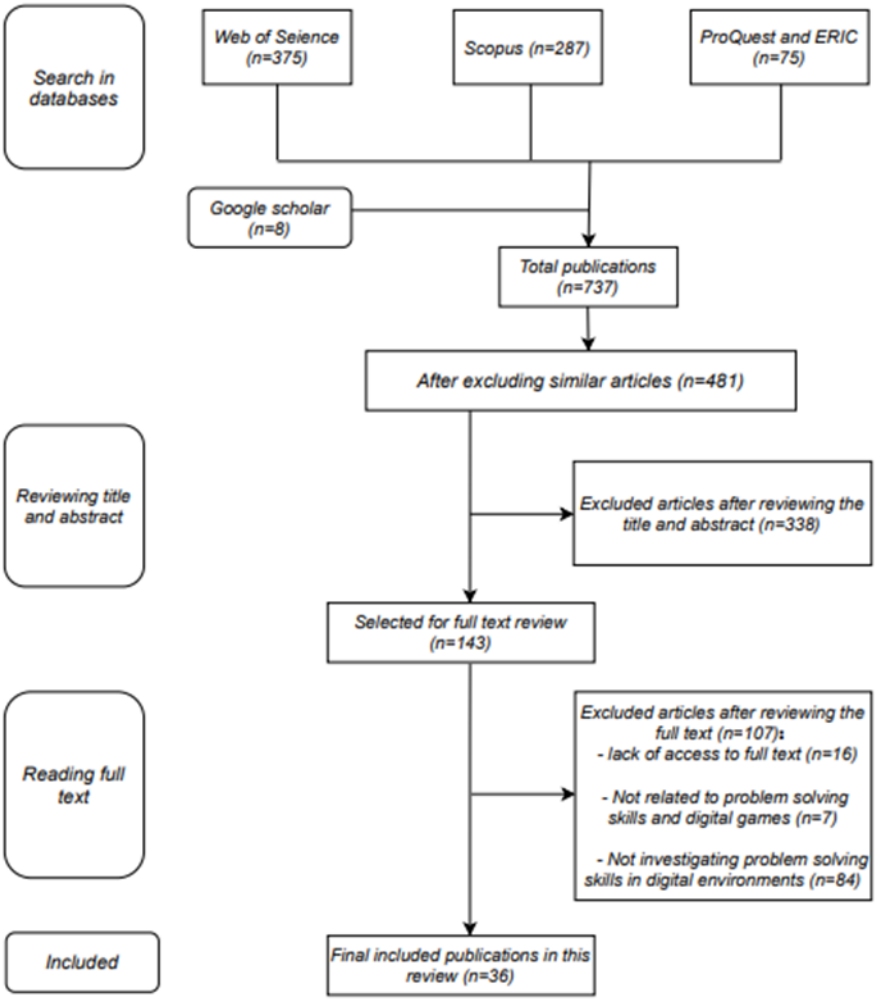

Figure 1. Flowchart of selection of publications

The four databases (Web of Science, Scopus, ProQuest, and ERIC) were used to search with the specified key words. Furthermore, Google Scholar was used to add a few more papers which were not indexed by the previous four databases. As a result, 737 papers identified, downloaded, labelled, and saved. 256 of these papers were repetitive in the different databases and were excluded from the final list. This repetition was happened because some of the papers were indexed by more than one database. The titles and abstracts of remaining 481 papers were reviewed in terms of their relevance to the purpose of this study. It was found that 338 of these papers were not specifically relevant to the scope of this study; and they were excluded from the list. Most of those papers explored the impact of games on students' ability to solve physics or chemistry questions / cases and they were not relevant to problem-solving ability as a transversal skill.

The remaining 143 papers were reviewed with more depth and details. Then, another 107 papers were excluded again from the list because they were not relevant to the video games. In fact, those 107 papers explored the impact of physical games on the problem-solving ability. Finally, 36 papers were found as completely relevant to the scope of this study. Those 36 studies explored the impact and the interdependency between the video/digital games and people's problem-solving ability. Those papers were entered in this structured review process.

Table 2 shows the aggregated list of inclusion and exclusion criteria used in the different stages of refining manuscripts to reach the final list of the papers included in the current study.

Table2. Inclusion and Exclusion Criteria of papers for entering to this study

Inclusion Criteria	Exclusion Criteria
- Related to problem-solving skill	- Unrelated to problem-solving skill
- Related to digital games	- Unrelated to digital games
- Published in and after 2010	- Published before 2010
- Published in peer-reviewed scientific journals, conferences and dissertations	- Published in book chapters, newspapers, general magazines, reports and editorials

As can be seen in Table 2, four sets of inclusion – exclusion criteria were used to refine the papers from 737 papers to 36 papers in the three stages above.

Table 10 in the appendix section of this manuscript briefs the 36 papers included in the current study.

3. Findings

As could be seen in Figure 2, the findings of this study are presented in six categories. These six categories are in line with the six literature gaps reported in this paper.

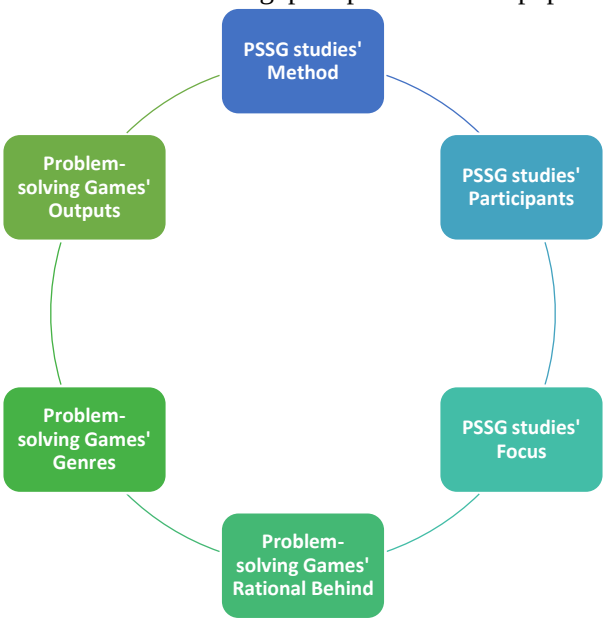

Figure 2. Six categories of findings of this study

Each of these six categories looks at the PSSG literature from a different angle. These findings are presented in the following sections.

3.1 The research methods of the previous PSSG studies

All the papers included in this study were carefully reviewed and analysed. Before looking at their research methods, the main themes explored and examined by the papers were extracted. To do so, the research questions / hypothesis were examined and the theme of the paper was written based on the nature of those questions / hypothesis. As a result, 5 themes emerged, and all the papers categorised under those 5 themes.

The first theme aims to measure the impact of serious games on people's problem-solving ability. Those studies do not focus on the other potential impacts of the serious games. They only aim to quantify the impact of games on their users' problem-solving ability, if there is any. The second theme (Exploring the potential of serious games for improving people's problem-solving ability), looks at the PSSG studies from a mechanism perspective. They want to explore how PSSGs tackle problem-solving. The third theme uses PSSGs only as a measuring tool and not as a developmental tool. They used various PSSGs to measure people's problem-solving ability. The fourth theme is more different with the other themes. Studies placed at that category try to design and develop serious games for enhancing users' problem-solving ability. In fact, they did not use other available PSSGs and they designed and developed their own PSSG. The fifth theme looks at the game design process as a potential opportunity for enhancing people's problem-solving ability. They believe that while people participate in designing a game (regardless of its purpose and genre) and developing the game mechanics, their problem-solving ability could be enhanced. And they try to examine and quantify this potential impact.

Table 3 shows the different research methods implemented by the different themes of the previous PSSG studies.

Table 3. Research methods implemented by the PSSG studies

Research Theme	Research Method			Quantitative Studies	Qualitative Studies	Mixed Studies
	Quantitative	Qualitative	Mixed			
Measuring the impact of serious games on people's problem solving ability	13	-	1	Haferkamp & Kraemer [20], Zhang, Yang, & Li [21], Yang [22], Adachi & Willoughby [13], Eseryel et al. [23], Hou & Li [24], Hooshyar et al. [25], Gurbuz et al. [14], Castronovo et al. [26], Emihovich [27], Hamlen [28], Dindar [29], Gadallah & Turner [30].	--	Wang & Wang [31].
Exploring the potential of serious games for improving people's problem solving ability	-	7	2	--	Voulgari & Komis [32], Warren et al. [33], Hwang & Chen [34], Echao & Romero [35], Dochie, Herman, & Epure [36],	Eseryel, Ifenthaler, & Ge [39], Chang et al. [40].

Research Theme	Research Method: Quantitative	Qualitative	Mixed	Quantitative Studies	Qualitative Studies	Mixed Studies
					Danby et al. [37], Muhamad et al. [38].	
Using serious games to Experimentally measure people's problem solving ability	-	-	1	--	--	Shute et al. [11].
Designing and developing serious games for improving people's problem solving ability	-	2	4	--	Shih et al. [41], Monjelat, Mendez, & Lacasa [42].	Sanchez & Olivares [43], Hwang, Wu & Chen [44], Hsu & Shih [45], Ang et al. [46].
Enhancing people's problem solving ability through participating in designing serious games	4	1	1	Akcaoglu [47], Hwang, Hung, & Chen [48], Chu & Hung [49], Ruggiero & Green [50].	Melander Bowden [51].	Akcaoglu & Green [52].
Total	17	10	9			

The percentages of using each of the three research methodology categories in the PSSG studies are shown in Figure 3.

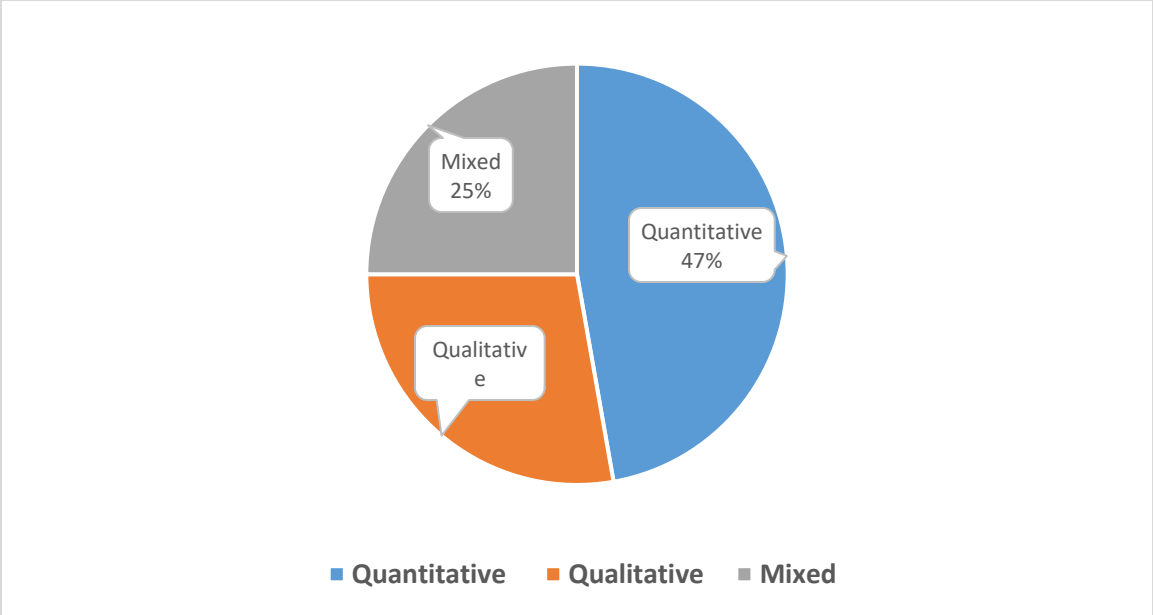

Figure 3. Research methods implemented by the PSSG studies

According to Table 3 and Figure 3, 47 per cent of the PSSG studies have been done using quantitative research methods. There is a lack of qualitative and mixed method studies in this area. Only 28 per cent of the PSSG studies implemented qualitative and 25 per cent applied mixed methods. This is against the fact that exploring complex issues such as PSSG can be better done using qualitative and mixed methods [53]. Quantitative methods are fitted to the studies with a positivism episteme while qualitative and mixed methods cover a combination of different research epistemes such as interpretivism, positivism, and post-positivism [54]. Therefore, the overall methodological recommendation of this study for the future PSSG studies is to -unlike the previous studies – consider qualitative and mixed methods for organising and conducting their studies. It is important to note that choosing the research method depends on the research's aims and questions and they should be taken into account while deciding for the research methods and techniques.

Looking more closely at Table 3, the methodological gaps in each of the 5 main themes are highlighted. For example, it is shown that there are no quantitative studies in the areas of 'exploring the potential of serious games for improving people's problem-solving ability', 'using serious games to experimentally measure people's problem-solving ability', and 'designing and developing serious games for improving people's problem-solving ability'. While qualitative research methods are appropriate to investigate these research themes, they are not enough for a comprehensive study of those themes. A combination of quantitative and qualitative research methods works better here.

3.2 The participants of the previous PSSG studies

It is also important to see who the participants of the previous studies were. In order to analyse the participant groups took part in the previous PSSG studies, the same themes were generated in the first findings section are being used here as well.

Table 4 summarises the analysis done by this study in relation to the participants of the PSSG studies in relation to each of the PSSG study themes.

Table 4. Groups participated in PSSG studies

Research theme	Participants			Studies (Under School Age Children)	Studies (School students)	Studies (University students)
	Under school age	School students	University students			
Measuring the impact of serious games on people's problem solving ability	0	8	6	--	Zhang, Yang, & Li [21], Yang [22], Adachi & Willoughby [13], Eseryel et al. [23], Hou & Li [24], Hooshyar et al. [25], Gurbuz et al. [14], Dindar [29].	Haferkamp & Kraemer [20] , Wang & Wang [31], Castronovo et al. [26], Emihovich [27], Hamlen [28], Gadallah & Turner [30].
Exploring the potential of serious games for improving people's problem solving ability	1	3	4	Danby et al. [37].	Eseryel, Ifenthaler, & Ge [39], Hwang & Chen [34], Muhamad et al. [38].	Voulgari & Komis [32], Warren et al. [33], Chang et al. [40], Dochie, Herman, & Epure [36].
Using serious games to Experimentally measure people's problem solving ability	0	1	0	--	Shute et al. [11].	--
Designing and developing serious games for improving people's problem solving ability	1	5	0	Shih et al. [41].	Sanchez & Olivares [43], Hwang, Wu & Chen [44], Monjelat, Mendez, & Lacasa [42], Hsu & Shih [45], Ang et al.[46].	--
Enhancing people's problem solving ability through participating in designing serious games	1	5	0	Melander Bowden [51].	Akcaoglu [47], Hwang, Hung, & Chen [48], Chu & Hung [49], Ruggiero & Green [50], Akcaoglu & Green [52].	--
Total[1]	3	22	10			

These numbers are summarised in Figure 4.

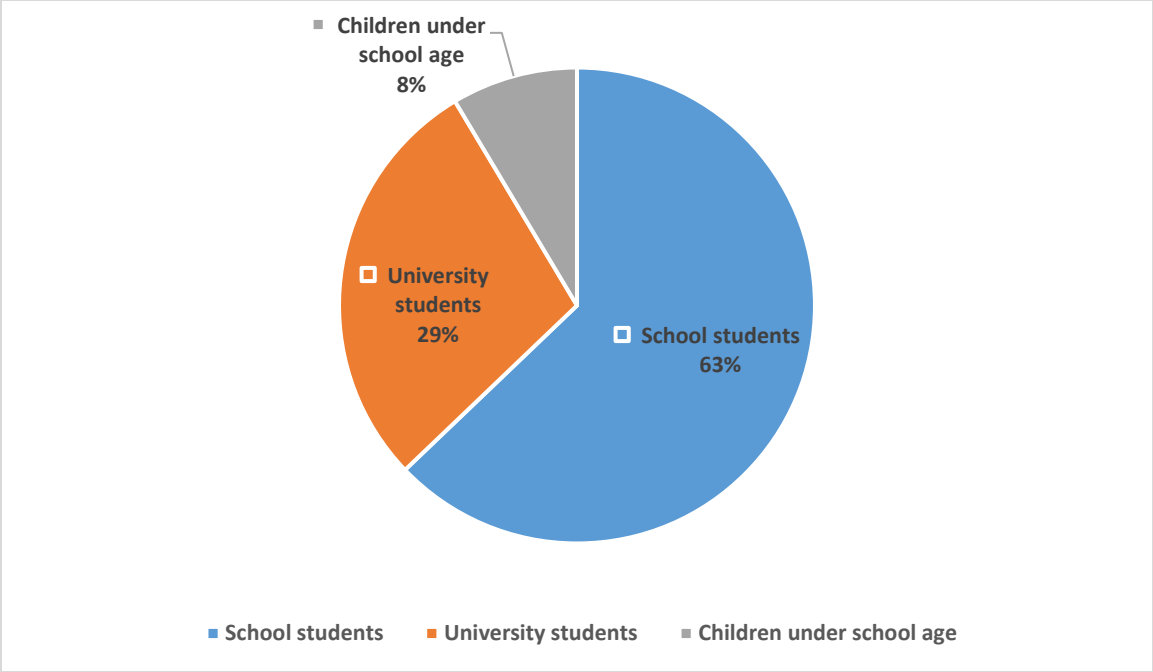

Figure 4. Groups participated in PSSG studies

As can be seen in Table 4 and Figure 4, school students aged between 6 and 18 have been the most engaged group of participants in PSSG studies. In fact, 63 per cent of the previous PSSG studies were conducted on school student populations. This shows the importance of this participant group, but it also highlights the gap in engaging the other participant groups in these studies.

According to the table above, children who are under the school age are mostly ignored by the previous PSSG studies. Given the fact that the age of using serious games has been significantly reduced over the last years, this should be seen as an important literature gap for the future studies.

3.3 The focus of the previous studies

Same to the previous section, the themes emerged in the methodology part of this study are being used for analysing the focus of those studies as well. Those 5 themes are being used here as the focus of the studies. however, two additional analytical layers are being added; and as a result, two main paradigms and five sub-paradigms are being emerged. The common features of the PSSG studies placed in the theory-focused paradigm are: 1. They did not design or produce any problem-solving game, 2. They have been done using interviews and questionnaires, 3. They always talked about the potential and not actual impacts / dimensions of the serious games. Despite the Theory-focused PSSG studies, the product-focused ones worked with actual games to explore their interdependency with problem-solving ability from different perspectives.

The current analysis – ac could be seen in Table 5 - shows the paradigm and the focus of the previous PSSG studies.

Table 5. The main paradigm / focus of the PSSG studies

Paradigm	Sub-paradigm	Focus	No. of studies	Studies
Theory-focused	Measuring games'	Measuring the potential impact of serious games on people's problem-solving ability	14	Haferkamp & Kraemer [20], Zhang, Yang, & Li [21], Yang [22], Adachi & Willoughby [13], Eseryel et al. [23], Hou & Li [24], Hooshyar et al.

Paradigm	Sub-paradigm	Focus	No. of studies	Studies
	potential impact			[25], Gurbuz et al. [14], Wang & Wang [31], Castronovo et al. [26], Emihovich [27], Hamlen [28], Dindar [29], Gadallah & Turner [30].
	Exploring game's potential	Exploring the potential of serious games for improving people's problem-solving ability	9	Voulgari & Komis [32], Eseryel, Ifenthaler, & Ge [39], Warren et al. [33], Hwang & Chen [34], Echao & Romero [35], Chang et al. [40], Dochie, Herman, & Epure [36], Danby et al. [37], Muhamad et al. [38].
Product-focused	Measuring people's problem-solving	Using serious games to experimentally measure people's problem-solving ability	1	Shute et al. [11].
	Producing games	Designing and developing serious games for improving people's problem-solving ability	6	Shih et al. [41], Sanchez & Olivares [43], Hwang, Wu & Chen [44], Monjelat, Mendez, & Lacasa [42], Hsu & Shih [45], Ang et al. [46].
	Enhancing problem-solving	Enhancing people's problem-solving ability through participating in serious games design	6	Akcaoglu [47], Hwang, Hung, & Chen [48], Chu & Hung [49], Ruggiero & Green [50], Akcaoglu & Green [52], Melander Bowden [51].

Table 5 shows the most- and less-focused subjects in the area of PSSG studies. In a high level analysis, 23 studies conducted in a theoretical paradigm, while only 13 studies placed in the product-focused paradigm. This shows that the previous studies shown more interest in the theoretical analysis of PSSG subjects and there is a lack of research for designing and developing serious games which can tackle people's problem-solving ability. This deficiency has different causing factors which will be addressed in the conclusion section of this study.

As can be seen in that table, the highest number of the previous studies (14 studies) focused on testing serious games in terms of their impact on people's problem-solving ability. It's important to know that those games were not specifically designed to tackle problem-solving as they were general entertaining games. However, researchers were curious about their impacts on people's problem-solving ability. While it is interesting to investigate those entertaining games' impact on problem-solving ability, it is disappointing to see there is no specific problem-solving game included in that group of studies.

The second bunch of theoretical studies focused on games' potentials for enhancing people's problem-solving ability. They did not use / examine any game or did not implement experimental studies. Instead, they mostly implemented interviews and focus groups to see what are 'potential impacts' of games on people's problem-solving. The problems with these studies are: 1. Some of these interviews conducted with people with insufficient knowledge and experience about the serious games' capabilities and deficiencies. 2. It is difficult to talk about the potential benefits and damages of serious games without actively playing with these games. 3. Those studies have been mostly exaggerating about the positive impacts of serious games on people's problem-solving ability, ignoring their damages to the players' cognitive and physical health.

The first category of practical studies includes one study which tries to measure the level of people's problem-solving ability through a game. In fact, game was used as a measurement tool for assessing people's problem-solving ability. This was an interesting study because game is a virtual environment

for simulating people's decisions and behaviour in the real life. However, the problem with that study was the game used for this measurement was not specifically designed for problem-solving purposes.

The second and third categories of practical PSSG studies cover designing and developing serious games for improving people's problem-solving ability. These games were designed in two ways: 1. The games were designed by professionals to enhance people's problem-solving ability. 2. The games designed by students to improve their problem-solving ability through their participation in game design process. The output of both categories above has been developing a game. But the first category's games are supposed to improve people's problem-solving through playing with them, while the second category's games are supposed to improve people's problem-solving through designing them.

The advantage of these two practical categories of PSSG studies was to focus on designing and developing a game as a product. Despite the theoretical studies which focused on the potential games, these studies went further and produce an actual game. But the disadvantage of these studies was that there was a clear disengagement of pedagogists in designing those games. Almost all of those studies ran and led by computer science experts who are not familiar with human behaviour change theories and principles.

3.4 Problem-solving games' rational behind

There is always a concern about whether serious games have been designed based on the pedagogical principles and theories or not [55]. This is because serious games need to have strong rational behind if they want to be impactful on enhancing their gamers' competencies (Ibid). This rational behind should come from the learning theories as these theories are mostly talking about how to change humans' competencies and behaviour [56].

The studies included in this analytical review are examined in terms of their pedagogical rationale behind. The main question here was to see whether those studies are being backed up by an education theory or not. As the PSSG papers reviewed, the learning theories behind them were emerged, if there was any. Table 6 shows the learning theories used as the underlying framework for designing problem-solving serious games.

Table 6. Link between PSSG studies and the learning theories

Learning theory	No. of the studies	Previous studies
Cooperative learning	8	Voulgari & Komis [32], Shih et al. [41], Hsu & Shih [45], Eseryel et al. [23], Echao & Romero [35], Chang et al. [40], Danby et al. [37], Melander Bowden [51].
Experiential learning	5	Akcaoglu [47], Hwang, Hung, & Chen [48], Chu & Hung [49], Ruggiero & Green [50], Melander Bowden [51].
Peer-learning	1	Hwang, Hung, & Chen [48].
Not specified	22	Haferkamp & Kraemer [20], Zhang, Yang, & Li [21], Sanchez & Olivares [43], Eseryel, Ifenthaler, & Ge [39], Warren et al. [33], Hwang, Wu & Chen [44], Monjelat, Mendez, & Lacasa [42], Yang [22], Adachi & Willoughby [13], Hooshyar et al. [25], Hwang & Chen [34], Gurbuz et al. [14], Wang & Wang [31], Castronovo et al. [26], Emihovich [27], Dochie, Herman, & Epure [36], Hamlen [28], Dindar [29], Gadallah & Turner [30]. Ang et al. [46]. Muhamad et al. [38]. Akcaoglu & Green [52].

The three education theories identified as the main rational behind of the PSSGs are briefed as following: 'Cooperative learning' is a learner-centred instructional strategy in which a small group of learners is responsible for its own learning and the learning of all group members to acquire and

practice the elements of a subject matter in order to solve a problem, complete a task or achieve a goal [57]. Experiential learning puts learners' experience at the central place in all considerations of teaching-learning environment [58]. Peer learning refers to students' learning with and from each other by explaining their ideas to others and by participating in activities in which they can learn from their peers [59].

Looking more closely at Table 6, it could be found that:

- Cooperative learning and experiential learning are the two learning theories which are mostly being used by the PSSG studies for designing problem-solving games. This is mostly because these theories are talking about how to manage learners' interactions with each other and how to help them to learn from their previous experiences [57]. These two topics (interacting with each other and learning by doing) are the two dominant themes in the video games as well. Therefore, it is understandable why they have been considered by the previous PSSG studies.
- There are so many other educational theories and models which have great potential to be used as a framework for designing, testing, and implementing serious games which have not been considered yet. For example, transformative learning is a learning theory which talks about how people can learn based on a dilemma. This theory seems to be very suitable for structuring the games which are usually formed around a problem.
- More importantly, 60 per cent of all the problem-solving games have been designed with no pedagogical rationale behind. This is an important figure which shows that there is a huge gap in the PSSG literature in relation to the dis-engagement of the pedagogists and pedagogical theories in the area of serious games design. A part of this gap is understandable because some of the previous studies did not design or produce any PSSG, but it's useful to have a pedagogical lens even for the theoretical elaboration on the PSSG studies.

3.5 Problem-solving games' genres

Serious games are categorized into different genres based on their gameplay mechanics, in-game tasks, and rules that players must attend. There is a strong relation between game genres and their impact on gamers' competencies [60]. Each of these genres has a specific impact on gamers' competencies; and therefore, should be chosen carefully by considering which competencies are targeted to be improved in gamers. For example, simulation is effective in enhancing people's spatial ability [61], while role playing is impactful in improving people's decision-making ability [62].

As could be seen in Table 7, problem-solving games use different genres such as simulations, role playing, board games, and puzzles.

Table 7. Game genres implemented in the problem-solving games

Game genre	No.	Studies
Simulation	6	Haferkamp & Kraemer [20], Sanchez & Olivares [43], Monjelat, Mendez, & Lacasa [42], Wang & Wang [31], Chang et al. [40], Castronovo et al. [26].
Role-playing	2	Eseryel, Ifenthaler, & Ge [39], Emihovich [27].
Online board	1	Hwang, Wu & Chen [44]
Puzzle	1	Emihovich [27].

As could be seen at Table 7, four genres have been used by the PSSGs: Simulation, Role-playing, Online boards, and Puzzles. In the simulation genre, players have to succeed within some simplified recreation of a place or situation to achieve a particular goal. In role playing genre, game players assume the characteristics of another person or creature. Online board games are web-based or app-based versions of board games such as Pachisi, Noughts and Crosses, Hnefatafl. The main advantage of online board games over the traditional ones is that they allow different groups of people to play together without physically being in the same space. Finally, puzzles are video games that emphasise solving a puzzle in different formats [63].

Looking more closely at Table 7, it could be seen that:

- Simulation is the most popular genre of the problem-solving games. This shows the importance and the effectiveness of simulation genre in improving gamers' problem-solving ability.
- Many other game genres such as Sandbox, Real-time strategy (RTS), Multiplayer online battle arena (MOBA), Shooters, Action-adventure, Survival, and Platformer have mostly been ignored by the previous PSSG studies. Since each of these genres has a potential impact on problem-solving ability, their usage in the problem-solving games would be considered. Further studies needed to investigate how these different genres tackle gamers' problem-solving ability.
- Only 10 studies included in this review addressed their genre. The other studies did not talk about their genres. This shows that game genre's importance is being ignored by most of the previous studies.

3.6 Problem-solving games' impacts

Analysing the previous studies shows that serious games affect people's problem-solving ability both directly and indirectly. These impacts gradually emerged as the papers included in this study analysed. Table 8 lists PSSG's direct and indirect impacts on their users' problem-solving ability.

Table 8. The impacts of problem-solving games

Type of impact	Impact	No. of studies	Studies
Direct impact on problem-solving	Improving people's problem-solving ability	25\	Haferkamp & Kraemer [20], Shih et al. [41], Zhang, Yang, & Li [21], Sanchez & Olivares [43], Yang [22], Warren et al. [33], Monjelat, Mendez, & Lacasa [42], Adachi & Willoughby [13], Hsu & Shih [45], Eseryel et al. [23], Akcaoglu [47], Hwang, Hung, & Chen [48], Hou & Li [24], Chu & Hung [49], Hooshyar et al. [25], Gurbuz et al. [14], Wang & Wang [31], Ruggiero & Green [50], Dochie, Herman, & Epure [36], Castronovo et al. [26], Emihovich [27], Ang et al. [46], Danby et al. [37], Muhamad et al. [38], Melander Bowden [51].
	Improving people's problem-solving motivation	5	Hwang, Wu & Chen [44], Eseryel et al. [23], Hwang, Hung, & Chen [48], Hooshyar et al. [25], Hwang & Chen [34].
	Improving people's algorithmic thinking	3	Gurbuz et al. [14], Chang et al. [40], Akcaoglu & Green [52].
	Enhancing people's self-awareness about their problem-solving ability	2	Eseryel, Ifenthaler, & Ge [39], Shute et al. [11].
	Improving people's ability to understand a problem	2	Hwang & Chen [34], Hamlen [28].

Type of impact	Impact	No. of studies	Studies
Indirect impact on problem-solving	Improving people's cooperative learning	4	Hsu & Shih [45], Eseryel et al. [23], Danby et al. [37], Melander Bowden [51].
	Improving people's learning attitude	2	Hwang, Wu & Chen [44], Hooshyar et al. [25].
	Improving people's technology acceptance	2	Hwang, Wu & Chen [44], Hooshyar et al. [25].
	Improving people's critical thinking	1	Hwang & Chen [34].
	Improving people's cognitive skills	1	Zhang, Yang, & Li [21].
	Improving people's learning ability	1	Hwang & Chen [34].

Direct impacts are those outcomes of serious games which directly tackle people's problem-solving ability. Indirect impacts, on the other hand, are those outcomes of implementing problem-solving serious games which are not directly relevant to problem-solving ability. This categorisation shows the wide variety of direct and indirect impacts of implementing serious games on developing people's problem-solving ability.

In relation to the direct impacts, it is interesting to see that games not only improve people's problem solving ability, but also their motivation to solve a problem, their ability to understand a problem, the self-awareness about their problem-solving ability, and their algorithm thinking. These are great complementary components of problem-solving ability.

Once a technology solution – such as video games – is chosen to improve a human attribute, an indirect impact such as 'improving people's technology acceptance' is also achieved. This technology acceptance helps them to use different technologies in a more effective way in the process of solving their problems. These video games are also proven to have a great impact on their users' learning attitude and ability. This learning is a necessary pre-requisite of solving the problems. The PSSG studies also proved that the serious games improve people's cognitive ability and critical thinking as two other important pre-requirements of problem-solving.

One of the literature gaps in the area of PSSG studies is that the indirect impacts of PSSGs are not examined well. While 37 studies focused on the direct impacts of PSSG on gamers' problem-solving ability, only 11 studies addressed the indirect impacts of those games. Given the fact that video games have so many side and marginal effects, this needs to be more seriously considered in the future PSSG studies. it is completely predictable that while PSSGs could positively impact gamers' problem-solving ability, they also come with so many other positive and negative impacts on the gamers.

Another pitfall of the previous studies is that even those 11 studies which addressed the indirect impacts of PSSGs on gamers, they only looked at the positive marginal impacts of those games, such as: improving people's cooperative learning, improving people's learning attitude, improving people's technology acceptance, improving people's critical thinking, improving people's cognitive skills, and Improving people's learning ability. This is despite the fact that according to the previous studies, serious games have so many negative side-effects as well and we should not ignore them while we are exploring their impacts on different subject-matter skills (For example, see: [64-66]).

4. Conclusion

This study is about reflecting on the previous studies conducted on the serious games relevant to problem-solving ability. Figure 5 summarises the information obtained by this review.

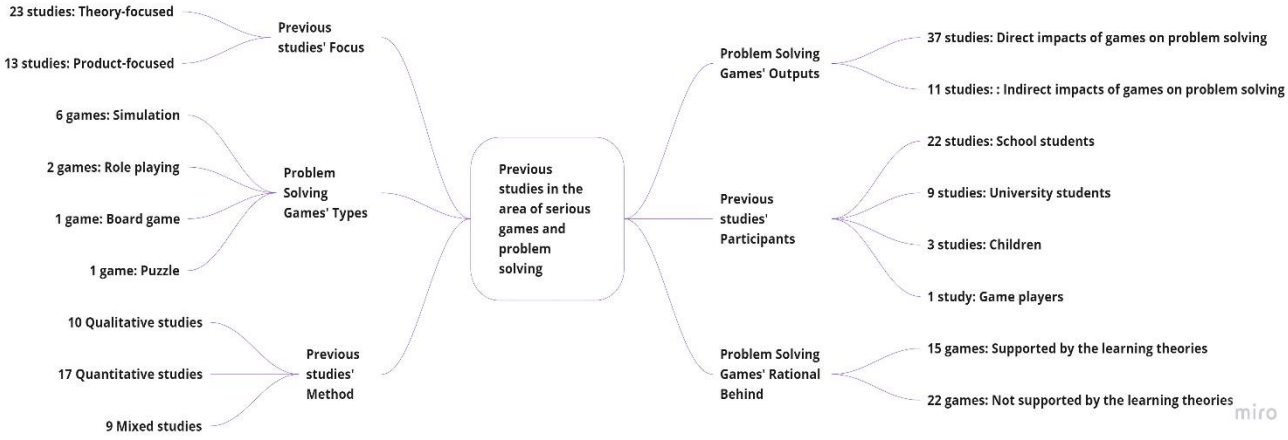

Figure 5. The summary of the findings of this study

As could be seen in Figure 5, the current study analysed previous studies around PSSG from six different perspectives. Based on the findings of this study in those six categories, the contributions of this study could be summarised as below:

As the first contribution of this study, the literature gaps in the area of serious games and problem-solving ability are highlighted by this study. These literature gaps could be seen in different areas, including: the participants, research methods, focus, rational behind, impacts, and tools used in the previous studies about PSSG. Identifying these gaps is important since they work as directions for the future studies around PSSG, otherwise the future studies will create the wheels from the scratch! As Abbasi Kasani et al. [67] mentioned, one of the main drawbacks of research about technology-enhanced learning is that they have not being built based on the findings and gaps of the previous studies.

As the second contribution of this study, several questions raised about PSSG studies' subjects, participants groups, focus, outputs, and tools. These questions are about why some of these parameters have been mostly addressed or ignored by the previous PSSG studies? For example, why 63 per cent of the previous studies used school students as the participants of their empirical studies? Why only 25 per cent of the previous studies implemented mixed research methods for conducting their research? Why only 36 per cent of the previous studies chose a hands-on approach for designing and developing PSSGs? Why 60 per cent of the previous PSSGs used simulation as their main tool? We tried to start responding to these questions in the previous section of this paper, but there are further rooms to discuss and deeply dive onto these questions by the future studies.

As the third contribution of this study, it is found that most of the previous PSSG studies are suffering from the lack of support by educational theories. While PSSG is a learning subject, more than 59 per cent of the PSSG studies did not link their findings to the learning theories at all. This is an important finding which needs to be discussed in further detail. This clearly shows that the previous PSSG studies were not conducted or led by educational experts, because most of the pedagogists wrongly think that being engaged in designing serious games is out of their remit [68], they think they do not have enough competence for playing a role in designing serious games [69], they have fear of technology since they are digital immigrants [70], or because designing serious games has been

traditionally the role of computer science experts and not pedagogists [71]. These are all potential reasons for why most of the previous studies were not backed up by the learning theories.

But regardless of the reason, such a disconnection between PSSG studies and learning theories has had serious consequences, such as: serious games' failure in developing their target competencies [55], developing inappropriate behaviour in gamers [56], increasing gamers' stress [68], parents' disappointment and worry about the negative impacts of serious games on their children [72], and increasing parents' fear of technology [73].

Figure 6 summarises all these literature findings about pedagogists' disengagement in designing serious games.

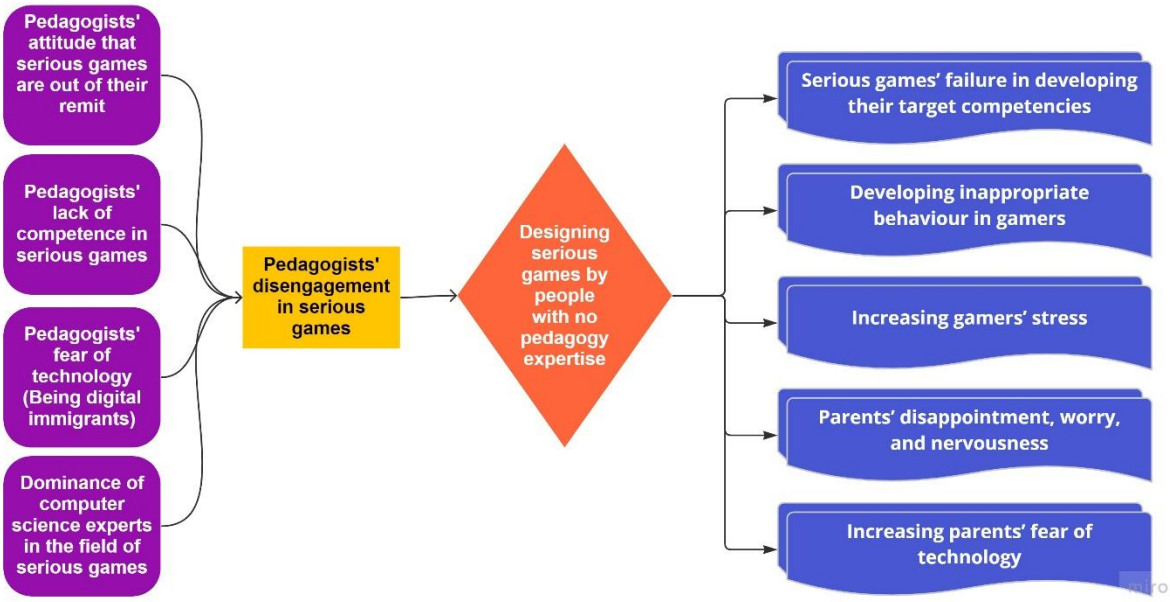

Figure 6. The reasons and consequences of pedagogists' disengagement in designing problem-solving games

As could be seen in Figure 6, pedagogists' disengagement in designing and implementing serious games has different causes and effects. For understanding the importance level of this disengagement, we should look at its consequences listed at the right side of the figure above. They are significant negative impacts which could be expected out of the serious games when they are not designed by pedagogists. In order to reduce these negative consequences, pedagogists should be effectively involved in designing, piloting, implementing, and evaluating serious games [57]. This involvement cannot be happening unless the four causing factors of their disengagement (shown at the left side of Figure 6) are being solved.

The conclusion of this study shown in Figure 6 needs to be more completed by adding other possible causes of pedagogists' disengagement with serious games, and the impact level of those four factors on pedagogists' disengagement need to be empirically measured.

As another conclusion, the current study highlights the importance of inter-disciplinary studies in the field of PSSGs. In order to have an effective PSSG, a few different disciplines should be involved: Education, Computer science, and Behavioural sciences. This inter-disciplinary cooperation could contribute to reducing the six gaps identified by this study. Table 9 summarises how each of these disciplines could reduce the PSSG studies' gaps.

Table 9. The inter-disciplinary approach for reducing PSSG studies' gaps in the future

PSSG Studies' Gap	Discipline	Discipline's contribution in reducing that gap
Lack of using qualitative and mixed methods in PSSG studies	Education / Behavioural science / Computer science	Each of these three disciplines have their own specific research methods and models. When an inter-disciplinary research is designed, the specific research methods of the disciplines involved should be considered.
Lack of engaging under school age children and university students in PSSG studies	Education / Behavioural science	Education and Behavioural science experts could lead PSSG studies for engaging under school age children and university students. They know the importance and specific requirements of these age groups and know how to participate them in PSSG studies.
Lack of product-focused research in PSSG studies	Computer science	Without computer science experts' engagement, almost all of the PSSG studies will be purely theoretical. Designing a game on the paper or interviewing people about a game is just the beginning. Without having a product-focus in PSSG studies which can result in producing PSSGs, these studies are not impactful.
Lack of educational rationale behind the PSSG studies	Education	Education experts could bring a range of learning theories and principles for enriching PSSGs' mechanics and procedures. Without these pedagogical guidelines, we could not expect PSSGs to improve gamers' knowledge and skills.
Lack of using different game genres in the PSSG studies	Computer science	Among so many game genres, only 4 genres are being used by the previous PSSG studies. Computer science experts could introduce and implement a wide range of game genres in the future PSSG studies.
Lack of studying the negative side-effects of PSSGs on gamers	Behavioural science / Education	Behavioural since and education experts could pay more attention to the negative marginal impacts of PSSGs on gamers' behaviour, learning, well-being, and health.

As it could be seen in Table 9, the six literature gaps in PSSG studies cannot be addressed without an inter-disciplinary approach. Each of the four disciplines involved in PSSG studies have a specific contribution in these studies.

Last but not least, it is figured out by this study that the previous PSSG studies have had an over-optimistic view on serious games in general and problem-solving serious games in specific. Given the fact that serious games have shown so many side-effects on gamers, these potential negative impacts should be examined in PSSGs as well. We might think in the near future about whether serious and video games are worth it or not!

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Table 10. The data of included publications in this systematic review

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Voulgari & Komis [32]	Investigating the potential of massively multiplayer online games (MMOG) to create a problem-based learning environment.	Qualitative	Online game players	Collaborative learning	---	Numerous factors such as game mechanics, task design, collaboration and competition, and game content are essential to creating an effective environment for problem-based collaborative learning.
Haferkamp & Kraemer [20]	Evaluating a serious game for training soft skills in crisis management teams.	Quantitative	Students and crisis management experts	---	Simulation - Educational	The simulated virtual environment is suitable for training in problem-solving and cooperation in crisis situations.
Shih et al. [41]	Designing and implementation of a digital game to develop problem-solving skills.	Mixed method	Children	- Cooperative learning - Bloom's taxonomy of cognitive	Adventure - Educational	Different styles of collaboration, positive interactions, and positive interdependence of the children improved their performance in William's adventure game.
Zhang, Yang, & Li [21]	The effect of VR / 3D action video games on players' cognitive skills and problem-solving.	Qualitative	Students	---	Action	Video games have a positive effect on basic cognitive skills such as cognition, perceptual learning, problem-solving and so on.
Sanchez & Olivares [43]	Designing and implementation of three mobile games to develop problem-solving skills.	Quantitative	Chilean 8th grade students	---	Simulation - Educational	The experimental group gained a higher understanding of their collaboration skills and received a higher score in the implementation of the problem-solving program than the control group.

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Eseryel, Ifenthaler, & Ge [39]	Assessing students' progress in solving complex problems in a game-based learning environment.	Mixed method	Students	---	Role-playing-Educational	An integrated model was proposed to assess the complex problem-solving in digital game-based learning.
Yang [22]	Evaluation of the effectiveness of digital game-based learning (DGBL) to improving problem-solving skills.	Quantitative	Students	---	Educational	The DGBL strategy was effective in improving students' problem-solving skills, while the control group did not improve. Also, no significant difference was observed between the two groups in terms of academic achievement.
Warren et al. [33]	Evaluating the effectiveness of a problem-based game to improving problem-solving skills.	Qualitative	Undergraduate students	---	Educational	The skills learned through game can be transferred to the professional world.
Hwang, Wu & Chen [44]	Designing and implementation an online game to improve web-based problem-solving activities.	Mixed method	Elementary students	---	Online board game Educational	The proposed online game not only enhanced students' learning attitudes, motivation, and technology acceptance, but also improved their learning in web-based problem-solving activities.
Monjelat, Mendez, & Lacasa [42]	Designing and implementation of a video game (sim city) to develop problem-solving skills.	Qualitative (ethnography)	High school students	---	Simulation - Educational	Commercial video games used in the educational system are valuable resources for developing problem-solving processes.
Adachi & Willoughby [13]	Investigating the relationship between the use of strategic video games and problem-solving skills.	Quantitative	High school students	---	- Role-playing - Strategy	Stronger strategic video games predict problem-solving skills and academic grades more than weaker strategic video games.

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Hsu & Shih [45]	Designing and development of adventure educational games for collaborative problem-solving activities.	Mixed method	Students	Collaborative learning	Adventure - Educational	Adventure educational activities in physical form, digital form, or both, made a significant difference in improving collaborative activities and problem-solving abilities.
Eseryel et al. [23]	Investigating the relationship between motivation, interaction and complex problem-solving in game-based learning.	Quantitative	High school students	Collaborative learning	Educational	Problem-solving motivation, interaction, and learner problem-solving skills are strongly influenced by how game tasks are designed.
Akcaoglu [47]	Learning problem-solving through game design.	Quantitative	Middle school students	Learning by doing	---	Game design can be a good activity for children to learn and practice problem-solving skills.
Hwang, Hung, & Chen [48]	Investigating the effect of game development approach (based on peer assessment) on problem-solving skills.	Quantitative	6th grade students	- Learning by doing - Peer assessment	---	The proposed approach can improve students' academic achievement, learning motivation, problem-solving skills, as well as their understanding of the use of computer games.
Hou & Li [24]	Evaluation of the various dimensions of a digital problem-solving adventure game.	Quantitative	Students	---	Adventure - Entertainment	The suggested game is useful for students with insufficient computer skills and allows them to gain in-depth knowledge of the subject.
Chu & Hung [49]	Investigating the effect of digital game development approach on problem-solving skills.	Quantitative	6th grade students	Learning by doing	---	A learning approach based on game development can effectively enhance students' problem-solving skills.
Hooshyar et al. [25]	The impact of online game-based formative assessment to improving problem-solving skills.	Quantitative	Students	---	Educational	The proposed system increased students' learning motivation, attitudes and degrees of technology acceptance, as well as improved their skills in problem-solving activities.

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Shute et al. [11]	Measuring problem-solving skills via stealth assessment in an video game.	Mixed method	Students	---	Strategy-Entertainment	Your Brainz game has enough credibility to assess students' problem-solving skills.
Hwang & Chen [34]	The effect of game design on students' problem-solving skills.	Quantitative	Elementary students	---	---	The game design approach improved the learning performance of students and increased their motivation. In addition, students' perceptions of problem-solving and critical thinking improved significantly.
Echao & Romero [35]	the literature review on serious games and problem-solving skills	Qualitative	---	Collaborative learning	Educational	The production of serious games is an interdisciplinary activity that can help develop 21st century competencies such as problem-solving, creativity and teamwork skills.
Gurbuz et al. [14]	Examining the effect of the Weather Forecast Game on problem-solving abilities.	Quantitative	Elementary students	---	Educational	The results of pre-test and post-test of the Weather Forecast game show that algorithmic thinking and problem-solving skills of students increased
Wang & Wang [31]	Investigating the effect of the Hotel Giant 2 game on improving problem-solving skills.	Mixed method	Hospitality students	---	Simulation - Educational	Using games is useful for improving the problem-solving performance of hospitality students.
Ruggiero & Green [50]	Investigating the effect of digital game design approach on problem-solving skills.	Quantitative	Students	Learning by doing	---	The findings of this study lead to improved problem-solving skills in four areas: problem identification, planning, implementation, and evaluation.
Dochie, Herman, & Epure [36]	Using gamification for assessment of problem-solving skills.	Qualitative	Students	---	Educational	Interactive content and scenario-based learning were used to assess problem-solving skills, and gamification elements such as points and leaderboards were used to motivate learners.

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Chang et al. [40]	An analysis of student collaborative problem-solving activities mediated by collaborative simulations.	Mixed method	High school students	Collaborative learning	Simulation - Educational	Callaborative simulation games have the potential to help students to facilitate the formation of a path to problem-solving.
Castronovo et al. [26]	Developing Problem-Solving Skills in Construction Education with the Virtual Construction Simulator.	Quantitative	Architectural engineering students	---	Simulation - Educational	Implementing educational simulation games can improve the problem-solving skills needed for construction.
Emihovich [27]	Investigating the effect of two types of video games (Warcraf) and (CogniFit) on problem-solving skills.	Quantitative	Graduate students	---	- Role-playing - Puzzle Entertainment	Warcraf role-playing game significantly improved students' problem-solving skills compared to CogniFit.
Hamlen [28]	Investigating the relationship between general problem-solving styles and problem-solving approaches in video games.	Quantitative	Undergraduate students	---	Entertainment	Problem-solving styles used in video games can be a reflection of real-life problem-solving styles.
Ang et al. [46]	Designing a game to practice social problem-solving skills.	Mixed method	Elementary students	---	Educational	The results of learning and user acceptance of this game have been reported positively.
Danby et al. [37]	Investigating children's cooperation and problem-solving skills in digital gameplay.	Qualitative	children aged 3–7 years	Collaborative learning	Educational	The children work together to progress using a variety of strategies, including training each other, monitoring each other's actions, and solving problems.
Dindar [29]	Investigating the effect of video games on complex problem-solving skills.	Quantitative	High school students	---	Entertainment	There is no correlation between any of the game variables (game experience, game time, game frequency) and problem-solving skills or academic achievement.

Author(s) & year	Purpose of the research	Research method	Participants	Learning theory	Game genre and game type	Maine findings
Gadallah & Turner [30]	Investigating the relationship between types of video games and critical thinking and problem-solving skills.	Quantitative	Graduate students	---	Entertainment	There is no significant relationship between video games and students' problem-solving skills and critical thinking.
Muhamad et al. [38]	Examining the implementation of game-based learning system on improving problem-solving skills.	Qualitative (meta-analysis)	Students	---	Educational	The game-based learning system provides an opportunity to develop problem-solving skills using an appropriate educational design theory.
Akcaoglu & Green [52]	Teaching systems thinking through game design.	Mixed method	Middle school students	---	---	Participants were able to use the skills learned during the course to solve problems in different areas.
Melander Bowden [51]	Learning problem-solving skills through collaborative activities in a game design project.	Qualitative	Children	- Collaborative learning - Learning by doing	---	Designing the game in this collaborative project led to the use of different problem-solving strategies by children and improved their problem-solving skills.