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Empirical Research Paper

Computer-based games in project management education: A review

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ABSTRACT

The work-readiness of Project Management (PM) graduates has been highly discussed topic during the last decade. Employers consistently seek graduates capable of thriving in the ever-changing, intricate, and challenging project environment. Computer-based games offer the potential to replicate real-life project environment, allowing students to learn how to navigate the challenges posed by projects. PM higher education has started to utilise computer-based games in the curriculum to improve highly sought after technical and soft skills of students. While significant studies have been conducted on gamification within PM, the review of their contributions and key characteristics has been missing, hence, necessitating this study. This study explores the research trends and contributions of publications related to computer-based games in PM higher education. As a result, it provides valuable insights and recommendations for educators, game designers and researchers to effectively integrate computer-based games within PM higher education. The findings of this review hold value for educators aiming to use computer-based games as an integrated learning concept, game developers striving to create more effective games and researchers interested in indulging deeper into the realm of computer-based games for PM.

1. Introduction

The demand of project professionals is on the rise. Project Management (PM) related jobs account for 3% of the global employment which is equal to approximately 90 million jobs worldwide. By 2030, it is expected to increase to 3.2%, equating to 102 million jobs (PMI, 2021a, 2021b). At the same time, 13 million project professionals will be at their retirement stage by 2030. To close this gap, there is a need of at least 25 million project professionals. If this talent gap is not bridged, the industry will experience a potential loss of up to US$345.5 billion in global GDP by 2030 (PMI, 2021a).

In response to the escalating demand for skilled project professionals (Tumpa et al., 2021), higher education institutions bear the responsibility of preparing PM graduates for the evolving landscape of projectification (Borg and Scott-Young, 2020; Thomas and Mengel, 2008). However, the current state of PM education is fraught with challenges in making graduates work-ready for the complexities of projects (Pant and Baroudi, 2008; Thomas and Mengel, 2008; Tumpa et al., 2023; Zou, 2008). PM education attracts a lot of criticism, particularly for being unable to develop soft or transferrable skills (Jena and Satpathy, 2017; Pant and Baroudi, 2008; Ramazani and Jergeas, 2015). While pointing towards this, Crawford (2006) argued that in contemporary times, the development of PM practitioners can be seen as "both narrow and shallow", falling short of the demands of complex projects (p. 624).

In navigating the intricacies of the project environment, graduates in this field require a spectrum of competencies, encompassing not only technical skills but also essential soft skills like communication, problem-solving, collaboration, and strategic thinking (PMI, 2022; Thomas and Mengel, 2008). The top three skills crucial for a successful PM career—communication, project leadership, and stakeholder engagement—are challenging to impart effectively through traditional lectures, hindering practical application and fostering a teacher-centric learning approach (Jaccard et al., 2022). As PM students learn about scope, time, cost, and quality management, they also need a comprehensive understanding of the issues and challenges in relation to these aspects. Higher education institutions are making their efforts to embrace innovative education practices and moving away from traditional lecture-based learning. However, teaching both technical skills and soft skills through innovative pedagogical approaches poses some

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challenges as it requires meticulous preparation and planning (Jena and Satpathy, 2017). Traditional way of learning seems to be disengaging, monotonous and unexciting.

Utilizing games as a pedagogical approach to teach various aspects of PM addresses challenges inherent in traditional teaching and learning methods (Jääskä et al., 2021). Game-based learning creates opportunities for students to apply PM concepts in a simulated, risk-free environment, fostering active engagement, critical thinking, problem-solving, collaboration, and creativity (Giannakos et al., 2020; Manzano-León et al., 2021). Review studies have highlighted the growing adoption of games in various disciplines such as the use of games in science education (Cheng et al., 2015; Li and Tsai, 2013); in learning Artificial Intelligence and Machine Learning (Giannakos et al., 2020); in STEM education (Gao et al., 2020); and in health and physical education (Papastergiou, 2009). These studies provide valuable insights into the benefits and challenges of integrating games into specific disciplinary contexts and contribute to the growing understanding of the potential of games in higher education. The inclusion of educational games in the curriculum boosts motivation, improves learning, helps acquire knowledge, and generate experiences (Calderón et al., 2019).

There are a number of concepts in relation to educational games available in the PM education research such as gamification, game-based learning and serious games. While some studies used these words interchangeably, this study will treat them distinctly. In education, gamification involves including game elements such as leaderboards, badges, points, roles, and levels which are used to improve students' engagement with the content, increase their motivational levels and promote learning (Plass et al., 2015). Game-based learning, on the other hand, incorporate an actual game in the learning and teaching which teaches skills and knowledge to students (Wiggins, 2016). Serious games are referred to games utilised for learning purposes. They are also called educational or simulation games in the literature. In this study, the term "game", implies both non -digital games and digital games used for educational purposes. "Computer-based game" used in this paper refers to games played on computers to experience real-life experiences of project environments in a simulated environment. In this paper, the prime focus is on computer-based games in PM education. The exclusive focus on computer-based games is for a number of reasons. As technological advancement progresses, educators aim to implement technology-based innovative pedagogical practices which is known as "Education 4.0". Education 4.0 leverages technologies to improve pedagogical practices. There is a huge spark in the integration of digital technologies in education due to its potential to enhance students' problem-solving skills, make connections with real-life scenarios, collaborate and engage with other students (Getenet et al., 2024). With an aim to improve the teaching and learning practices, many higher education institutions have initiated the implementation of digital technologies in the pedagogical practices (Okoye et al., 2023). At the same time, Generation Z has strong inclination to use technology for educational purposes as it claims their interest and keeps them engaged in learning (Szymkowiak et al., 2021). Hence, considering rapid advancements of technology and students' interest in it, this paper explored the potential uses of computer-based games in PM education.

There is an increasing trend in the use of games in PM higher education (Jaccard et al., 2022). Many studies have explored the contribution of games in PM education (Aarseth et al., 2017; Calderón et al., 2017; Jaccard et al., 2022; Rumeser and Emsley, 2019a). The existing literature suggests that the use of games can help students practise some aspects of PM such as stakeholder engagement, cost management, uncertainty management, project control and decision-making. With significant number of studies published on this topic, a review is needed which can highlight the research growth and indicate the contributions to date. More so, such a review is needed to highlight the gaps left behind by previous studies which can be filled by future studies. This study also proposes recommendations for game designers and instructors to design games and execute them successfully.

To the best of the authors' knowledge, a notable gap exists in terms of reviewing the utilisation of computer-based games in the context of PM. Conducting such a study would help consolidate the current research findings on the computer-based games in PM discipline. Such study will be a timely move as technology use is rapidly increasing in every aspect of daily life, like never before. Accordingly, the aim of this review study is to provide a detailed understanding of the current research on the use of computer-based games in PM education. The following objectives will guide this investigation.

- Objective 1: To discern and analyse research trends encompassing the use of games in higher education, with a specific focus on PM higher education.
- Objective 2: To identify the dominant themes in the existing literature in relation to computer-based games in PM higher education and provide recommendations for game designers and instructors.

This review would be valuable to both academics and game designers providing insights for the development and implementation of computer-based games in PM higher education. To gain a comprehensive understanding of the research field, the study will first investigate the applications of games in higher education across all fields, before focusing specifically on the games in PM followed by computer-based games in PM higher education. The paper is structured as follows: review methodology consists of systematic literature search, approach for scientometric review and thematic analysis. Afterwards, the findings from scientometric review focusing on games in higher education and PM higher education are presented. Subsequently, recommendations for instructors and game developers are provided. This is followed by conclusion section where the limitations of this review study are highlighted.

2. Review methodology

This review methodology comprised a systematic literature search, followed by a scientometric and thematic analysis. The systematic literature search was performed following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement (Moher et al., 2009). The PRISMA Statement, designed to enhance transparent and comprehensive reporting of systematic reviews, provide evidence-based, minimal recommendations. Serving as a road map, it aids authors in articulating the procedures undertaken, the findings and, in the case of a review protocol, outlines the planned course of action (Sarkis-Onofre et al., 2021).

To ensure transparency and thorough reporting within the systematic literature review, this study is guided by the benchmarks set by the PRISMA Statement. The scientometric review employs the 'science mapping' approach, while an inductive thematic analysis is conducted to identify dominant themes and recommendations. An overview of the review approach and the resulting outcomes is shown in Fig. 1.

2.1. Systematic literature search

To ensure the transparency and repeatability of the search strategy, a well-defined sampling methodology is crucial (Kitchenham and Charters, 2007). Accordingly, a rigorous approach of searching and selecting relevant publications is implemented in this review, as delineated in Fig. 2, aligning with requisites of the PRISMA statement. The identification of relevant publications unfolds in a comprehensive three-stage process. In the first stage, a systematic search is executed to pinpoint studies concerning the use of games in higher education. Subsequently, in the second stage, the identified studies on games in higher education are narrowed down to the subject area of PM. In the third stage, the search of the literature was narrowed down to computer-based games in PM higher education. To ensure a comprehensive inclusion of relevant games in the PM discipline, a combination of systematic search and

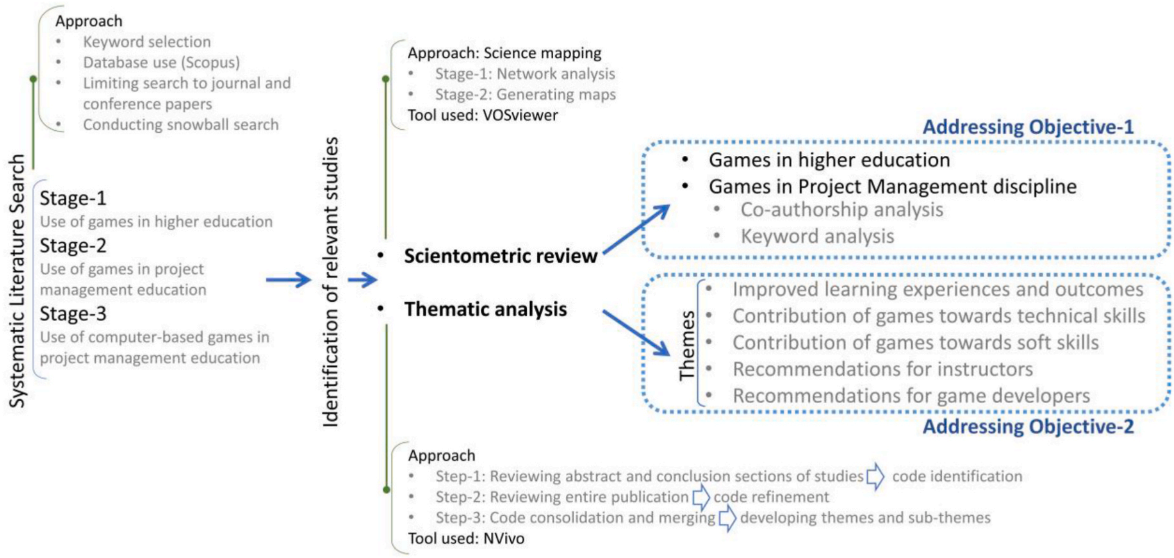

Fig. 1. Review framework.

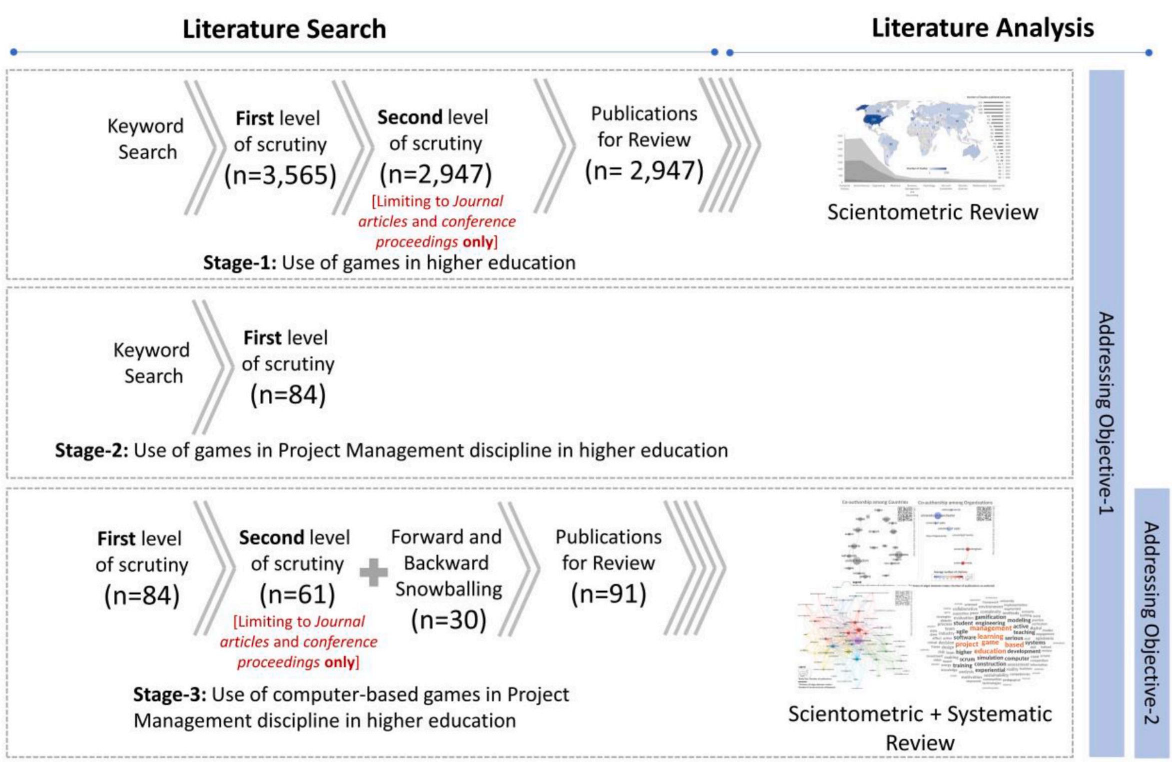

Fig. 2. Methodology used for literature search and analysis.

forward/backward snowball search method is employed. The systematic search helps identify primary studies, while the snowball search involves examining the references cited in the identified studies (backward snowball search) and exploring subsequent studies that have cited the identified studies (forward snowball search).

2.1.1. Stage 1: use of games in higher education

To identify the studies conducted on the topic of games in higher education, a search inquiry was conducted in Scopus. Scopus was selected for its stature as one of the largest transdisciplinary search engines, renowned for its comprehensiveness compared to Web of Science, PubMed and Google Scholar (Tober, 2011). For stage 1, the search query encompassed a diverse range of game types. A range of keywords were used to locate relevant literature. The keywords were identified based on the scoping review conducted on computer-based games in PM higher education. A scoping review was undertaken to justify the gap which aided the accumulation and refinement of the keywords. The following keyword string was used for this search:

TITLE-ABS-KEY (("serious game" OR "computer game" OR "simulation-based game" OR "simulation game" OR "game-based learning" OR "educational game" OR "computer simulation game" OR "digital game" OR "video game" OR "online game") AND ("learning" OR "training" OR "education") AND ("higher education" OR "university"))

The search at this stage resulted in the identification of 2947 studies.

2.1.2. Stage 2: use of games in PM education

To conduct a specialized review of 'PM'-related studies employing games in higher education, some modifications are introduced in the search code previously used (in stage 1). By including specific terms related to PM and its key areas in the search code, the focus of the search is narrowed down to studies that explore the use of games within the field of PM in higher education. This modification aims to target and retrieve studies that are directly relevant to the specialized review of PM discipline. The revised keyword string is as follows:

TITLE-ABS-KEY (("serious game" OR "computer game" OR "simulation-based game" OR "simulation game" OR "game-based learning" OR "educational game" OR "computer simulation game" OR "digital game" OR "video game" OR "online game") AND ("learning" OR "training" OR "education") AND ("higher education" OR "university") AND ("PM"))

This stage resulted in the identification of 84 studies in total. The outcome of stage 1 and 2 effectively fulfil objective 1.

2.1.3. Stage 3: use of computer-based games in PM education

To identify the studies specifically centred on computer-based games in higher education within the field of PM, an additional search and filtration operation was carried out with focus on 84 studies retrieved in stage 2. To conduct a comprehensive review of studies in this area, the search was limited to journal and conference articles written in English, resulting in a filtration outcome of 61 studies. Relevant studies citing the shortlisted 61 studies and relevant studies cited within the shortlisted 61 studies were identified by conducting forward and backward snowball search. This snowball search resulted in the extraction of additional 30 studies. This increases the number of overall studies for detailed review to 91. Each of these 91 studies were reviewed thoroughly to determine which studies focused on computer-based games. These 91 studies were reviewed to identify research trends in the subject area (fulfilling objective 1). Out of the initial 91 studies, 44 studies were identified that delve into the utilisation of computer-based games in higher education related to PM. Subsequently, these selected 44 studies underwent a rigorous critical review to unveil prominent themes, effectively fulfilling objective 2. Table A1 in the Appendix lists the 44 studies with information regarding the aims, methods, and future directions.

2.2. Approach for scientometric review

Scientometric analysis involves the application of bibliometric techniques, tools, and data to examine literature. For scientometric review in this review, the 'science mapping' approach is utilised. Following the review methodology recommended by Börner (2010), the study followed a structured process, including stages such as tool selection, data acquisition, pre-processing, data analysis, modeling, visualization, and communicating the results. In this study, science mapping was conducted in two successive stages. The initial stage focused on creating network analyses using keyword co-occurrence and co-authorship analysis. In the second stage, network analysis was used to generate maps that displayed valuable network metrics. These measures revealed the evolution of research in the subject area, showing intellectual, conceptual, and social aspects, as well as identifying trends and patterns. To choose suitable scientometric tools for this study, the strengths and limitations of popular software were assessed, resulting in the selection of VOSviewer, which provides the essential features for visualizing scientometric networks (Eck and Waltman, 2014; Van Eck and Waltman, 2010).

2.3. Approach for thematic analysis

In this study, NVivo, a qualitative data analysis tool known for its capability to analyse qualitative data and perform literature reviews (Beekhuyzen, 2007), was used to organise and analyse findings and prevalent themes from studies related to the use of computer-based games in PM education. An initial review of selected studies was conducted using NVivo's word frequency analysis feature. This analysis allowed for the identification of key terms and concepts that emerged prominently across the literature, facilitating the exploration of common themes and patterns within the research area.

In a two-step process, identifying the most common terms in the selected studies informed the inductive reasoning process, leading to a more focused and in-depth review of those studies. In the initial step, the abstract and conclusion sections of the chosen studies were thoroughly examined to create themes/codes in NVivo that represented the contributions and findings of these studies. In the second step, the entire publications were reviewed to further refine the existing codes in NVivo and to create new codes if required, a process approach by Braun and Clarke (2006). The process commenced by familiarising with the data followed by generating codes on NVivo. The resulting codes from NVivo were combined and consolidated to identify and discuss the recurring themes to address the review objectives. Once the themes were identified, they were reviewed to ensure that the codes represent the themes.

In order to address the second objective of this review, the findings derived from the relevant papers were categorised in five themes. The themes are associated with a number of sub-themes. The themes include improved learning experiences and outcomes, contribution of games towards technical skills, contribution of games towards soft skills, recommendations for instructors and game developers.

NVivo kept an electronic record of the complete coding process, ensuring consistency and transparency in data analysis and interpretation. The subsequent section presents a comprehensive overview of the findings resulting from the review process.

3. Scientometric review: analysis of research trends

The research trends for the reviewed publications are presented in this section in two parts. First, the review findings regarding the larger body of knowledge related to the use of games in higher education are presented and subsequently, the review findings regarding the studies on games in PM education are presented, fulfilling objective 1.

3.1. Games in higher education

In response to the first objective of this study, it is crucial to gain insights into the broader research trends across various disciplines that have implemented games for learning purposes in higher education. This understanding provides a foundation before delving into an in-depth examination of the studies regarding games in PM education. The review presented in this section is based on the Stage 1 of the literature search mentioned in the methodology section. Noteworthy highlights from the 2947 studies relevant to Stage 1 are briefly outlined as follows.

- The top 20 most frequent keywords from these publications are about games, learning, education, and motivation.
- A gradual increase in number of publications on the subject area is observed from 2005 onwards (refer to Fig. 3).
- The top eight subject areas in which studies related to games have been conducted include Social Sciences (n = 1664; 56%), Computer Science (n = 1629; 55%), Engineering (n = 846; 28.7%), Medicine (n = 280; 9.5%), Business, Management and Accounting (n = 167; 5.7%), Psychology (n = 158; 5.4%), Arts and Humanities (n = 150; 5%), and Decision Sciences (n = 110; 3.7%) (see Fig. 3). Across the last two decades, highest growth in the publication volume on the topic of games is seen within the discipline of social sciences, computer science, and engineering.
- Among the identified studies, 1547 (52.5%) are journal articles and 1400 (52.5%) are conference articles (47.5%). Studies on this topic are predominantly published in Proceedings of the European Conference on Games Based Learning (n = 194; 6.5%).

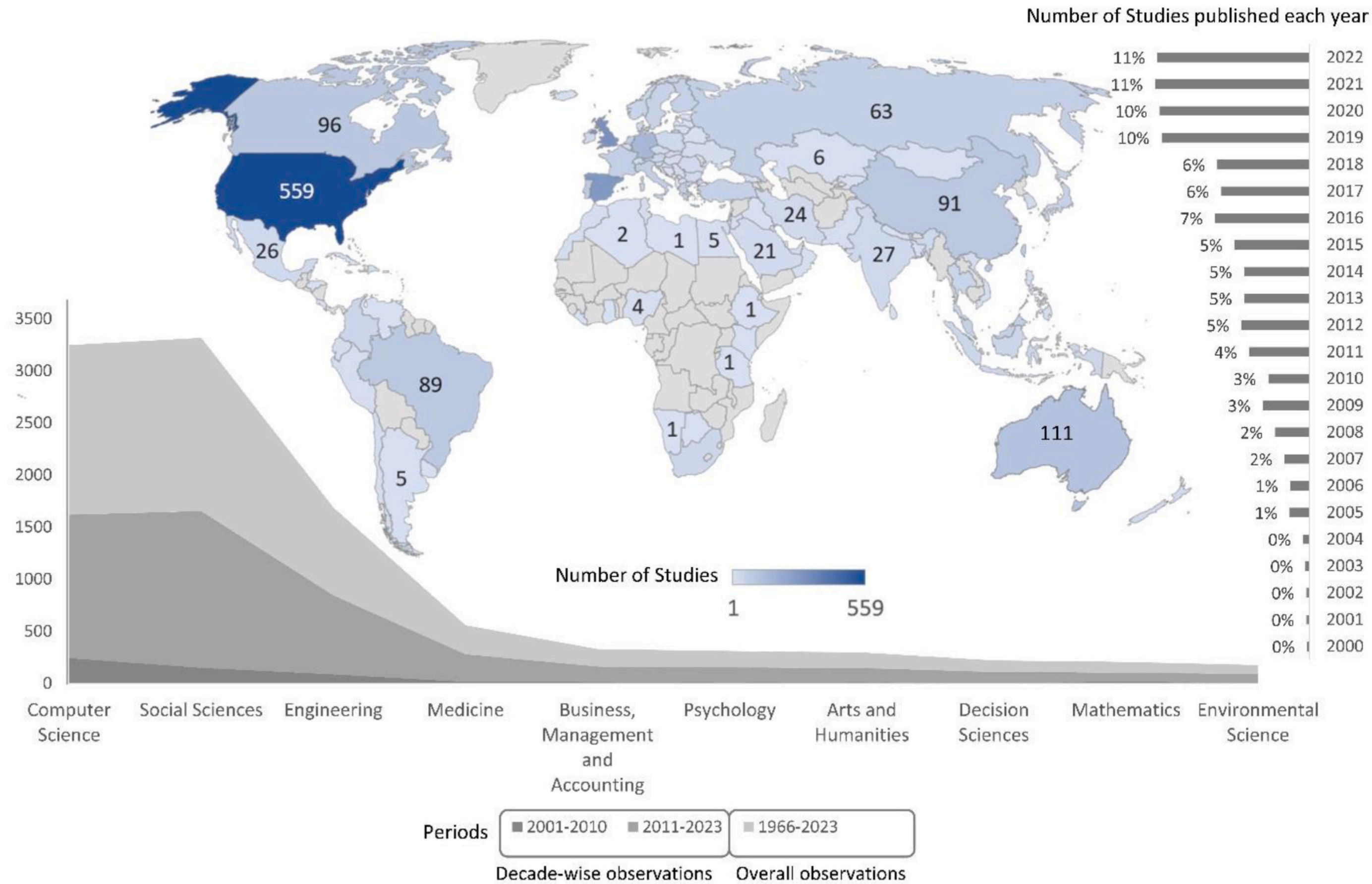

Fig. 3. Trends in publication of studies related to the use of games in higher education.

- The top eight institutions in terms of the number of publications include University of the West of Scotland (n = 26), Delft University of Technology (n = 24), Universidad Complutense de Madrid (n = 24), Coventry University (n = 23), Universidad de Granada (n = 21), Tampere University (n = 18), National Taiwan University of Science and Technology (n = 18), Stockholms universitet (n = 17). Among these 8 universities, 7 are based in the European region.
- The top eight regions in terms of the number of publications include United States (n = 559; 19%), United Kingdom (n = 305, 10.3%), Spain (n = 277, 9.4%), Germany (n = 155, 5.3%), Australia (n = 111, 3.8%), Canada (n = 96, 3.3%), Taiwan (n = 93, 3.2%), and China (n = 91, 3.1%) (see Fig. 3). Region-wise analysis presented in Fig. 3 consider the regional belonging of all authors (that is authors in first, second, and subsequent positions) in each publication.

3.2. Games in PM discipline

To fulfil the first objective of the study, we delve into the research trends in the use of games in PM discipline in higher education. This objective is primarily addressed through a scientometric review approach, which systematically maps the knowledge landscape concerning the use of games in the PM discipline. The review presented in this section is based on the Stage 2 of the literature search, as outlined in the methodology section. The analysis encompasses a detailed account of the research trends within the subject area, including an examination of keywords co-occurrence and the co-authorship of documents. Table 1 showcases the most prominently cited publications in this domain. These studies are published from 2007 onwards and have addressed diverse topics within the PM arena including safety, sustainability, scrum management approach, and earned value analysis. Instead of theoretical development, these highly cited studies are more inclined towards the practical aspects of game use in PM domain. The high citation of these studies may indicate that in terms of publication volume there is more research focus on the contribution of the subject topic

Table 1
Top cited publications on the use of games in PM.

Publications	Number of citations		
	WoS	Scopus	Google Scholar
Lin, K.Y., Son, J.W. and Rojas, E.M., 2011. A pilot study of a 3D game environment for construction safety education. *Journal of Information Technology in Construction (ITcon)*, *16*(5), pp.69-84.	NA	99	170
Von Wangenheim, C.G., Savi, R. and Borgatto, A.F., 2013. SCRUMIA—An educational game for teaching SCRUM in computing courses. Journal of Systems and Software, 86(10), pp.2675-2687.	57	85	172
Tejedor, G., Segalàs, J., Barrón, Á., Fernández-Morilla, M., Fuertes, M.T., Ruiz-Morales, J., Gutiérrez, I., García-González, E., Aramburuzabala, P. and Hernández, À., 2019. Didactic strategies to promote competencies in sustainability. Sustainability, 11(7), p.2086.	64	78	131
von Wangenheim, C.G., Savi, R. and Borgatto, A.F., 2012. DELIVER! – An educational game for teaching Earned Value Management in computing courses. Information and software Technology, 54(3), pp.286-298.	54	65	128
Dondi, C., & Moretti, M. (2007). A methodological proposal for learning games selection and quality assessment. *British Journal of Educational Technology*, *38*(3), 502-512.	48	63	155

towards practice instead of theoretical development.

Following are the key attributes of these studies using games in the context of PM in higher education.

- While there is a notable surge in publications during the current decade, a sustained upward trajectory in the number of publications in this area is not evident (refer to Fig. 4).
- Among the identified studies, 38 (42%) are journal articles and 53 (58%) are conference articles (see Fig. 4).
- Studies on this topic are mostly published in Proceedings of the European Conference on Games Based Learning (n = 8; 8.7%), ASEE Annual Conference and Exposition Conference Proceedings (n = 3; 3.3%), IEEE Global Engineering Education Conference (n = 3; 3.3%), Project Leadership And Society (n = 3; 3.3%), and Sustainability (n = 3; 3.3%) (see Fig. 4).
- Top institutions in terms of the number of publications include University of Manchester (n = 6), Universidad de Cádiz (n = 5), Oulun Yliopisto (n = 4), Universidade Federal de Santa Catarina (n = 4), Universiteit Twente (n = 4), and Curtin University (n = 4).
- Top regions in terms of the number of publications include United Kingdom (n = 17), USA (n = 15), Brazil (n = 9), Australia (n = 8), Finland (n = 8), and Spain (n = 8) (see Fig. 4).
- Authors who have contributed at least three journal publications in this area include Borgatto, A.F., Calderón, A., Emsley, M., Jääskä, E., Ruiz, M., Rumeser, D., Scott, D., and Von Wangenheim, C.G. Other than one of these academics, all the rest belong to Europe-based institutions.
- The top 20 most frequent keywords from these publications include PM (n = 79), Students (n = 40), Education (n = 30), Teaching (n = 29), Serious Games (n = 27), Game-based Learning (n = 23), Engineering Education (n = 20), Simulation (n = 16), Computer Games (n = 14), Software Engineering (n = 13), Curricula (n = 11), Education Computing (n = 11), Computer Aided Instruction (n = 10), Higher Education (n = 10), Learning (n = 10), Software Design (n = 10), and Software PM (n = 10).

The detailed scientometric review of these 84 studies is provided in the following sections.

3.2.1. Co-authorship among countries and organisations

Understanding the established scientific collaboration networks within a specific field facilitates access to funding, specialization, and expertise. It also enhances productivity and assists scientists in avoiding isolated efforts. Through the analysis of co-authorship networks, almost every aspect of these scientific collaboration networks can be effectively monitored (Glänzel and Schubert, 2004). With this consideration, the co-authorship networks in the subject area are investigated (see Fig. 5).

In the case of reviewed publications, an institutional collaboration network is generated, as illustrated in Fig. 5. The size of the nodes is adjusted to represent the number of documents originating from each institution, where larger nodes denoted a higher number of publications and vice versa (see Fig. 5). This visualization reveals the degree of collaboration among institutions and their impact on research in this field. Interestingly, some renowned institutions shown in the network did not appear to engage in collaboration (see Fig. 5), indicating isolated research activities within these institutions. Most institutions appeared to work independently, except for Curtin University, the University of Nottingham, and the University of Twente, which seemed to engage in collaborative efforts. This suggests a lack of knowledge exchange among researchers in the other active institutions, which is an issue that needs attention.

Citation count may be considered as the research impact of a study. A high citation count may imply a greater number of subsequent studies following a predecessor study and hence, a higher research impact. In the collaboration network (see Fig. 5), while certain institutions like the 'University of Manchester' had a high number of associated studies, they received a relatively low average number of citations. Conversely, some institutions such as the 'University of Nottingham' and 'Curtin University' had relatively high citation counts but fewer studies associated with them.

A country-wide collaboration network is also shown in Fig. 5 to highlight the regions leading the research in the subject area and to map their research collaboration. Based on the number of publications, the most contributing countries within the network are highlighted (see Fig. 5). In the collaboration network, the UK (n = 17) ranks highest. Strongest research link is noticed between the UK and Australia. After the UK, most studies are conducted in the US (n = 15). However, studies conducted in the US are not in collaboration with academics from other regions. To elevate the collective knowledge within the field, institutions located in the countries that make significant contributions must reconsider their research strategies to promote collaboration. When compared to the potential connections possible in the network, the actual connections have been limited. Consequently, there is a deficiency in cross-case and comparative studies on this subject that could corroborate ideas and findings across various contexts.

3.2.2. Keyword co-occurrence analysis

Keywords serve as indicators of the fundamental content found in published studies and illustrate the extent of research undertaken within a particular field (Su and Lee, 2010). For the shortlisted 84 studies, a word cloud of their keywords is developed using NVIVO as shown in Fig. 6. The most frequently used words (see Fig. 6) indicated the focus of

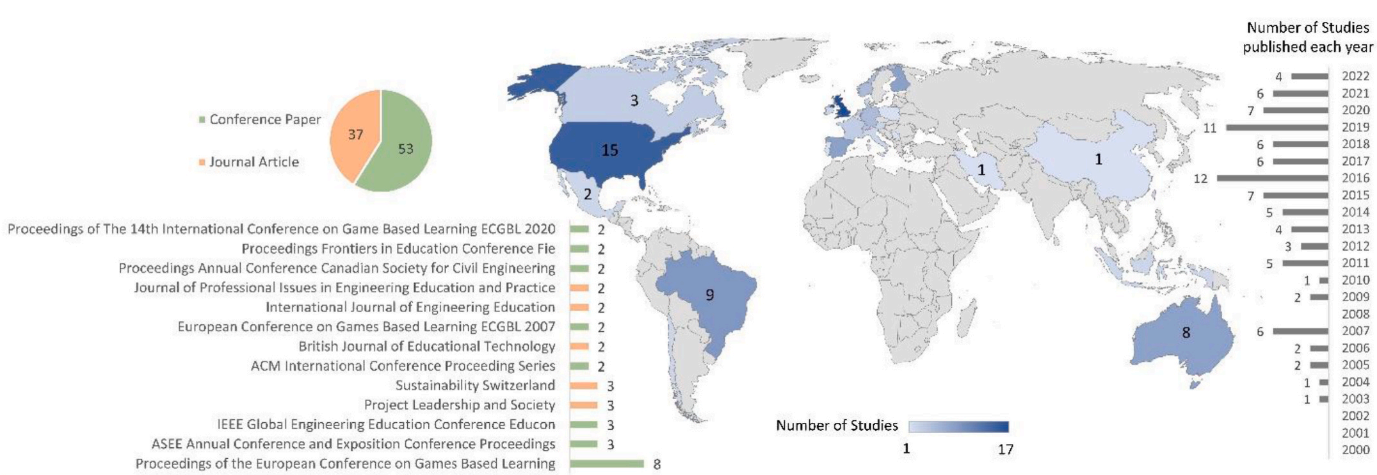

Fig. 4. Trends in publication of studies related to the use of computer-based games in PM area.

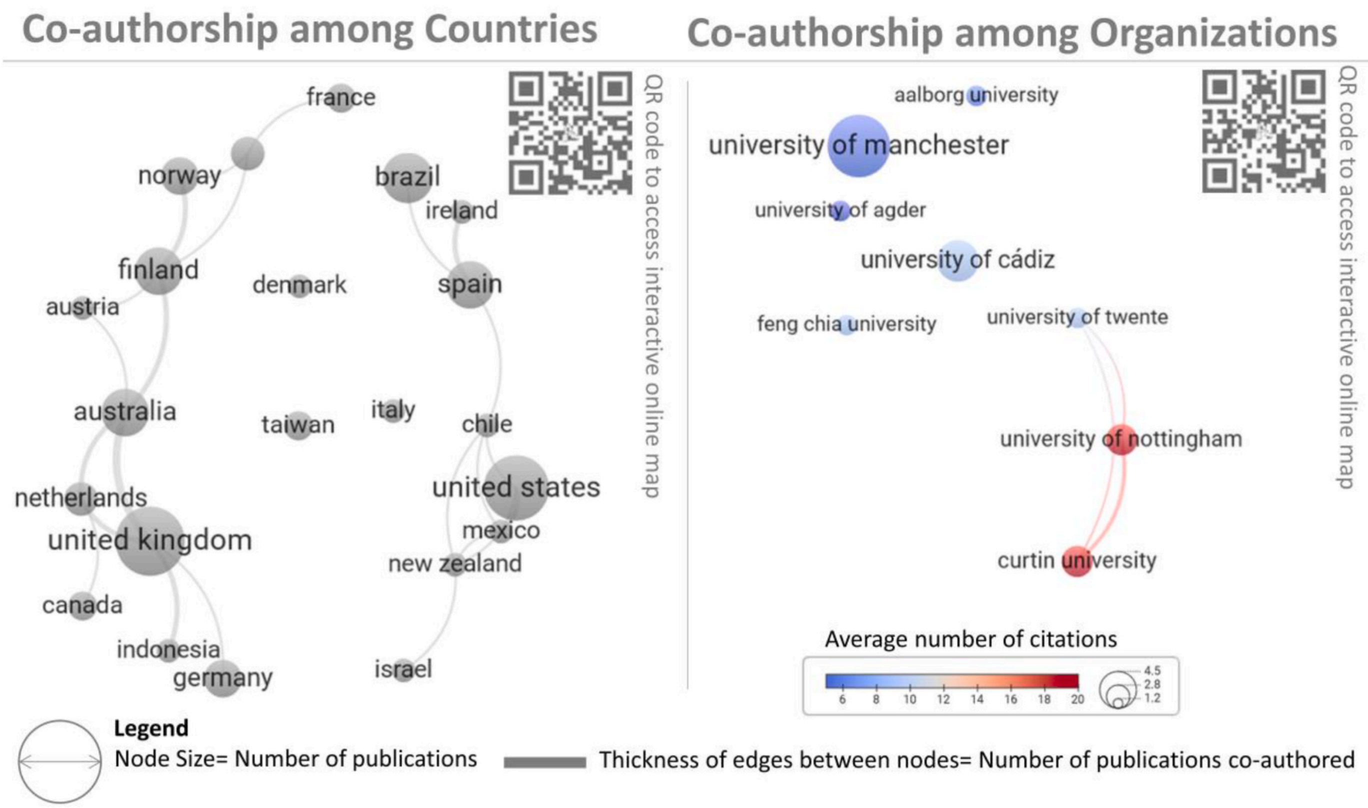

Fig. 5. Collaboration network of countries and institutions in the research area.

Fig. 6. Word cloud indicating the frequently occurring keywords among reviewed studies.

studies i.e., "gaming", "PM", and "learning". Keywords indicate a significant focus of the selected studies in learning, training, and pedagogy.

A network comprised of interconnected keywords provides a precise representation of the generation of scientific knowledge, showcasing the research subjects covered, the patterns and interconnections among these topics, and their intellectual organization (Eck and Waltman, 2014). In this network, the strength of the connection between two keywords is determined by the number of publications in which both keywords are present (Eck and Waltman, 2014). The keyword network, as generated from VOSviewer, indicates the proximity and the robustness of the links among keywords (see Fig. 7). The assessment of the primary research domains and their interconnectedness, as shown in Fig. 7, unveils several noteworthy discoveries, shedding light on issues and deficiencies in the existing literature regarding this subject. Despite the broad spectrum of research subtopics within the field, Fig. 7 highlights a particular emphasis on certain areas, including "engineering education," "construction management," "software PM," and "human resource management."

4. Results of thematic analysis

To fulfil Objective 2, this section critically examines the prominent themes in relation to the computer-based games in PM higher education. The themes were derived from the reviewed literature. An inductive thematic analysis was conducted on NVivo. The selected articles were read thoroughly and coded on NVivo. The codes were then grouped into themes. The results were grouped into five themes. The first three themes involve how computer-based games improve learning experiences and outcomes, contribute towards improving technical skills and soft skills. The last two themes revolve around proposing recommendations for instructors and game developers. Each of the is associated with a number of sub-themes. The themes and sub-themes identified from reviewed studies (see Table 2) are discussed as follows.

4.1. Improved learning experiences and outcomes

One of the dominant themes in the reviewed literature is the ability of computer-based games to extensively contribute to students' improved learning experiences and academic performances (Long et al., 2009; Saenz and Cano, 2009; Zwikael and Gonen, 2007). These games also play a crucial role in the development of innovative instructional designs for PM education (Calderón et al., 2017; Lalic et al., 2021). While computer-based games improve students' knowledge acquisition, they turn the delivery of traditional PM education into a contemporary teaching method by facilitating student interaction, involvement and engagement with learning content (Barros et al., 2006; Calderón et al., 2017; Hussein, 2015; Hussein and Ravnå, 2015; Jääskä et al., 2021; Lalic et al., 2021). This increased engagement and interaction leads to a

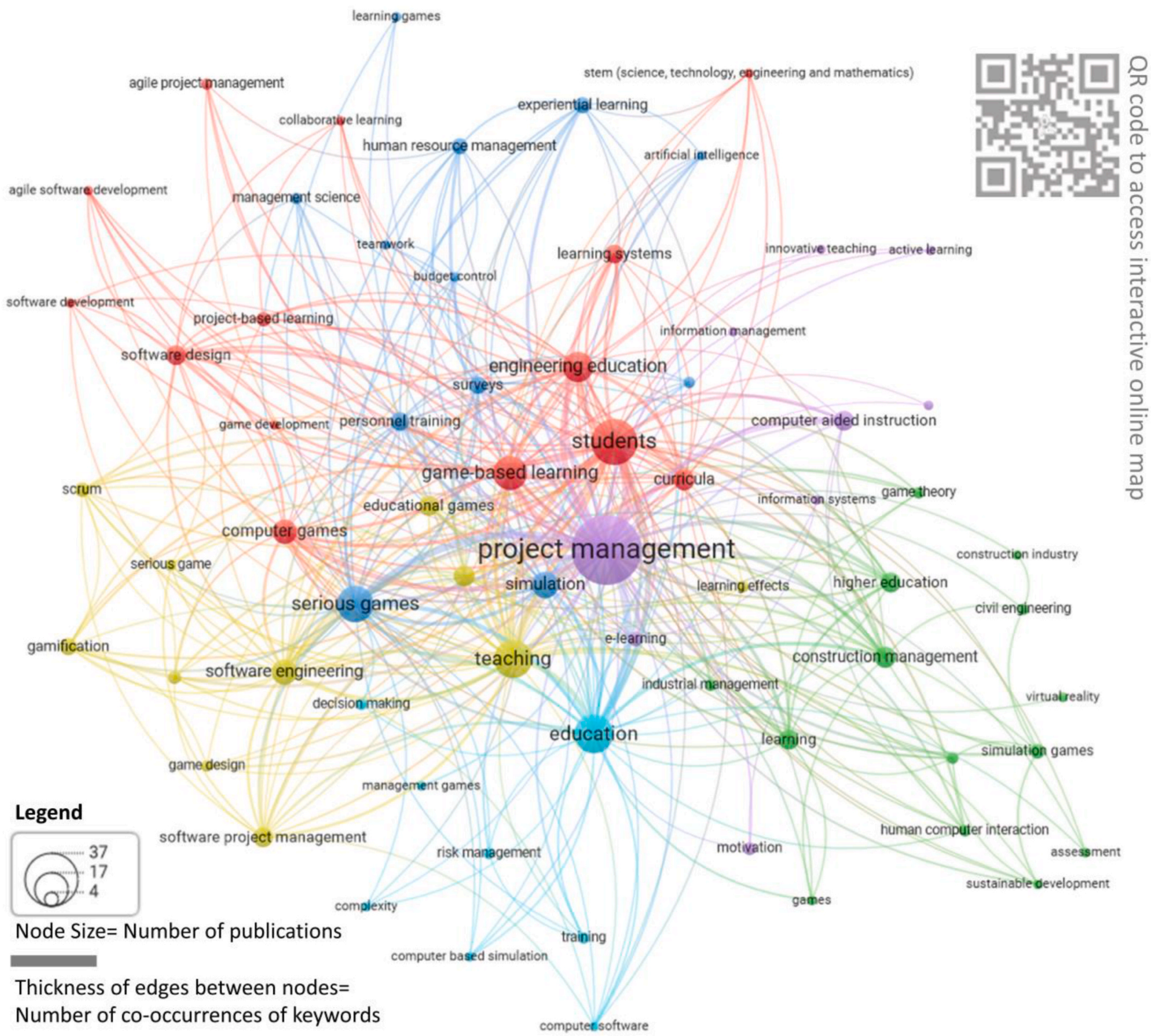

Fig. 7. Keyword network of publications related to games in PM discipline.

deeper understanding of the learning material (Hussein, 2015).

4.1.1. Collaborative learning environment

Computer-based games create a positive, valuable and enjoyable learning environment (Bayart et al., 2014; De Souza et al., 2017; Lee, 2016; Souza et al., 2018). As computer-based games motivate students in their learning, students achieve better learning goals and outcomes (Lalic et al., 2021). The inclusion of the games stimulates students' motivation and promote a practical, fun, inspiring and social environment (Calderón et al., 2017, 2019). For instance: C-Negotiation Game substantially improves students' motivation, effectiveness and satisfaction (Dzeng and Wang, 2017). While playing games, it creates excitement, enjoyment among students, and interaction between students and academics (Bayart et al., 2014). The interaction and engagement created through these games contribute to improved academic performance. In comparison to conventional teaching methods, games also promote better knowledge acquisition (Baccarini et al., 2012; Calderón et al., 2017, 2018, 2019; Dib and Adamo-Villani, 2014; Lalic et al., 2021) and have a positive impact on students' sense of involvement and participation in discussion (Hussein, 2015). Students in the study of Long et al. (2009) commended "Muck Game" and "Canal Game" as these games replaced the traditional methods of teaching construction and PM and engaged them in the learning processes. Furthermore, a collaborative learning environment is created when these games are implemented in the classroom where students can share their knowledge with others, promoting a collaborative learning environment.

4.1.2. Enhanced application of theoretical concepts through practical exercises

Experiential learning offers significant value to students' learning as it enables students to apply their learnt concepts into practice (Dantas et al., 2004; Taborda et al., 2017). Learning through conventional teaching methods can be challenging for Generation Z students. However, the use of computer-based simulation games provides them with an interactive and dynamic learning experience (Baccarini et al., 2012; Saenz and Cano, 2009). These games create a real-life project

Table 2
Emerged themes from the thematic analysis with its associated sub-themes.

Themes	Sub-themes	Articles
Improved learning experiences and outcomes (n = 35)	Collaborative learning environment Enhanced application of theoretical concepts through practical exercises Equipping students for real-world challenges	(Al-Jibouri et al., 2005; Baccarini et al., 2012; Barros et al., 2006; Bayart et al., 2014; Bonazzi et al., 2012; Calderón et al., 2017, 2018, 2019; Chaves et al., 2015; Dantas et al., 2004; De Souza et al., 2017; Denholm et al., 2013; Dib and Adamo-Villani, 2014; Dzeng and Wang, 2017; Ekyalimpa et al., 2014; Galvão et al., 2011; Hassan et al., 2021; Herrera et al., 2019; Hussein, 2015; Hussein and Ravnå, 2015; Jääskä et al., 2021; Lalic et al., 2021; Lee, 2016; Long et al., 2009; Petri et al., 2018; Rumeser and Emsley, 2017, 2018a, 2018b, 2019a, 2019b; Saenz and Cano, 2009; Souza et al., 2018; Vanhoucke et al., 2005; Zwikael and Gonen, 2007)
Contribution of games towards technical skills (n = 35)	Training for uncertainty and complexity in projects Simulating PM for different project stages Understanding knowledge areas of PM	(Al-Jibouri et al., 2005; Baccarini et al., 2012; Barros et al., 2006; Bayart et al., 2014; Bonazzi et al., 2012; Calderón et al., 2017, 2018, 2019; Chaves et al., 2015; Dantas et al., 2004; De Souza et al., 2017; Denholm et al., 2013; Dib and Adamo-Villani, 2014; Dzeng and Wang, 2017; Ekyalimpa et al., 2014; Galvão et al., 2011; Hassan et al., 2021; Herrera et al., 2019; Hussein, 2015; Hussein and Ravnå, 2015; Jääskä et al., 2021; Lalic et al., 2021; Lee, 2016; Long et al., 2009; Petri et al., 2018; Rumeser and Emsley, 2017, 2018a, 2018b, 2019a, 2019b; Saenz and Cano, 2009; Souza et al., 2018; Vanhoucke et al., 2005; Zwikael and Gonen, 2007)
Contribution of games towards soft skills (n = 20)	Enhancing decision-making skills Enhancing teamwork skills Enhancing problem-solving and leadership skills	(Bayart et al., 2014; Calderón et al., 2017, 2018, 2019; Denholm et al., 2013; Hassan et al., 2021; Jääskä et al., 2021; Lalic et al., 2021; Lee, 2016; Mawdesley et al., 2011; Misfeldt, 2014; Naik and Jenkins, 2019; Petri et al., 2018; Rumeser and Emsley, 2017, 2018a, 2018b, 2019a; Saenz and Cano, 2009; Schäfer, 2017; Zwikael and Gonen, 2007)
Recommendations for instructors (n = 23)	Balancing complexity for learning Instructors' prior knowledge and preparation Conducting debriefing sessions	(Al-Jibouri et al., 2005; Baccarini et al., 2012; Bayart et al., 2014; Bonnier et al., 2020; Calderón et al., 2019; Herrera et al., 2019; Hussein and Ravnå, 2015; Jääskä et al., 2021; Jaccard et al., 2022; Lalic et al., 2021; Lee, 2016; Letra et al., 2015; Long et al., 2009; Miler and Landowska, 2016; Misfeldt, 2014; Petri et al., 2018; Rumeser and Emsley, 2017, 2018a, 2018b, 2019a, 2019b; Saenz and Cano, 2009; Souza et al., 2018)
Recommendations for game developers (n = 23)	Realism User interface Game display Fun and challenging	(Al-Jibouri et al., 2005; Baccarini et al., 2012; Bayart et al., 2014; Bonnier et al., 2020; Hussein and Ravnå, 2015; Jääskä et al., 2021; Jaccard et al., 2022; Lee, 2016; Long et al., 2009; Miler and Landowska, 2016; Misfeldt, 2014; Petri et al., 2018; Rumeser and Emsley, 2017, 2019a; Souza et al., 2018)

Note: n = number of reviewed studies related to a theme.

environment and turn theoretical knowledge into practical, social and engaging activities (Dantas et al., 2004). Lee (2016) implemented Scrum-X through which students were able to apply Scrum methodology from Sprint planning and Sprint execution to Sprint review and retrospective. The game interface presents a graphical representation of data which enriches students' perceptions of learning and generates entertainment (Dantas et al., 2004). As the games create an engaging learning environment, it creates a desire in students to learn (Lalic et al., 2021). Students experience a differentiated learning experience which promotes an advanced understanding of the learnt lessons (De Souza et al., 2017). Computer-based games promote active involvement and participation of students which is critical to keep their interest in the learning material (Bayart et al., 2014). By using these games, students have the opportunity to apply theoretical concepts in practice, leading to the development of optimum experiential and fruitful learning, which in turn fosters satisfaction with learning process (Jääskä et al., 2021).

4.1.3. Equipping students for real-world challenges

Computer-based games can serve as an effective tool to prepare students for the real-life project environment. To improve students' project planning and executing skills, the best idea is to manage and work on real projects and learn from the mistakes. This may be a costly exercise. Therefore, computer-based games can be adopted as a learning activity in class which will help students experience project planning and execution without failing in real projects (Zwikael and Gonen, 2007). Computer-based games set an experimental environment which emulates the real-world project environment where students plan the project, execute their plan and experience the repercussion of violating important aspects of the projects (Dantas et al., 2004). As a result, simulation games can play a crucial role in providing hands-on experience in PM (Dzeng and Wang, 2017; Saenz and Cano, 2009).

Computer-based games provide academics with a more practical way of teaching PM techniques compared to traditional teaching methods (Zwikael and Gonen, 2007). For PM students, these games help increase theoretical knowledge, applied knowledge and competence levels (Dib and Adamo-Villani, 2014; Hassan et al., 2021). Students are considered future "knowledge workers" and simulation games transform their explicit knowledge into tacit knowledge (Bayart et al., 2014). This transformation allows students to develop a deeper understanding and practical application of PM principles.

4.2. Contribution of games towards technical skills

PM educators are in a constant struggle to facilitate lifelong learning of PM students by incorporating technology-based and transformative innovative practices in higher education (Ang et al., 2021). Especially, those students belonging to generation Z are known for their interest and affinity for interacting with technology (Baccarini et al., 2012). Technology-savvy students are motivated and engaged in information systems (Lee, 2016). To cater for this need, computer-based games have been implemented in PM education which is viewed as an effective learning tool for teaching PM in an effective way (Al-Jibouri et al., 2005; Rumeser and Emsley, 2018a). The reviewed literature suggests that PM technical knowledge is enhanced by including computer-based simulation games in the PM subjects. PM-related technical knowledge is provided to hone students' abilities to plan, execute, monitor, control and close a project successfully within the planned budget, schedule, scope, and quality.

4.2.1. Training for uncertainty and complexity in projects

The project environment can be extremely complex, and its impact on the project progress can be catastrophic. Dealing with complexity and uncertainty effectively is one of the skills of an efficient project manager (Ahmadi Eftekhari et al., 2022). The use of PM principles to deal with the complexity of projects has been extensively discussed in literature (Rumeser and Emsley, 2018a, 2018b, 2019a). Computer-based games have the ability to simulate the complexity of real-world projects, thereby enhancing students' learning experience by creating a learning environment for them to practice, dealing with intricate project scenarios. The complexity of project environment grows with increase in the communication channels, number of team members, activities, and decisions to be made. PM students can learn about complexity through Project crashing game (PCG) and program crashing game (PgCG) (Rumeser and Emsley, 2018a).

Computer-based simulation games serve as valuable tools in PM education by introducing students to the risks and uncertainties inherent in real projects, offering them a simulated experience (Denholm et al., 2013; Hassan et al., 2021). Moreover, these games effectively teach students how to identify, assess, mitigate and follow-up on project risks (Hussein and Ravnå, 2015). Games motivate the students to grasp the importance of risk planning (Petri et al., 2018). While traditional classroom environment for project risk management provides students with the theoretical understanding of risk identification, risk categorisation, and risk mitigation, the computer-based games can teach students practically how to react to uncertain events and improve their decision-making processes. These games expose students to the challenges emerged in the real-life projects and develop their understanding and experience in dealing with this uncertainty and in managing projects (Zwikael and Gonen, 2007).

4.2.2. Simulating PM for different project stages

There is growing evidence that simulation games improve the attainment of knowledge throughout the entire project lifecycle. According to PM Body of Knowledge (PMBOK) guide, project lifecycle encompasses initiating, planning, executing, monitoring and controlling, and closing. Simulation games can contribute to enhancing the overall understanding of each stage in the project lifecycle (Vanhoucke et al., 2005). While some computer-based games are able to teach students all stages of project lifecycle, other games have the potential to teach specific techniques or stages of a project's lifecycle (Calderón et al., 2017; Zwikael and Gonen, 2007). Through these games, students can visualise the consequences of PM strategies applied across all phases of a project (Rumeser and Emsley, 2018a; Saenz and Cano, 2009).

4.2.3. Understanding knowledge areas of PM

According to PMBOK, PM comprises ten distinct knowledge domains such as project integration, scope, time, cost, quality, human resource, communication, risk, procurement, and stakeholder management. The reviewed literature indicates that computer-based games contribute to a better understanding of these knowledge areas. For instance, Zwikael and Gonen (2007) claimed that computer-based simulation games have a positive impact on student's knowledge in various PM knowledge areas. Particularly, project risk, procurement, schedule, cost, and human resource management were discussed in the reviewed literature.

Computer-based simulation games have proven to be effective in contributing to students' knowledge development, especially for project schedules, cost and human resource management (Denholm et al., 2013; Hassan et al., 2021; Vanhoucke et al., 2005). Students participating in these games, reported gaining insights into real-life PM phenomena, such as managing project stakeholders, resources, costs, and dealing with uncertainty (Jääskä et al., 2021). Some computer-based games have been specifically designed to train junior project managers in the areas of cost, time, risk and human resources management, providing them with valuable practical experience (Calderón et al., 2017). Students can learn how they can achieve a target budget and schedule and how their decisions affect the schedule and budget of a project (Rumeser and Emsley, 2017). Computer-based games help students confront the complexity of project scheduling and to practically experience the concepts of project scheduling (Vanhoucke et al., 2005).

Procurement and negotiation are also key areas of PM, and there are some computer-based simulation games which specifically focus on teaching the decision-making process involved in these aspects. For example: the educational game, C-Negotiation Game is designed by Dzeng and Wang (2017) advanced students' decision making capabilities in relation to procurement and negotiation in construction projects. In these games, students take on different roles, such as the role of contractor or the supplier. As the contractor, a player's objective is to obtain the maximum profit through the fulfilment of procurement requirements by negotiating with the suppliers. Someone playing the supplier's role has the objective to sell the materials and acquire the most profit by negotiating with the approaching contractors (Dzeng and Wang, 2017). Furthermore, construction PM simulation game (CPMSG) enhanced the knowledge and skills of construction project planning, cost and risk management by 158% (Hassan et al., 2021).

Alongside a prevalent role of the computer-based games towards technical skills and education of PM graduates, such games also contribute towards soft skills discussed in detail in the next section.

4.3. Contribution of games towards soft skills

In addition to PM knowledge, computer-based simulation games also effectively nurture a range of other essential soft skills. Managing projects is a daunting task (Zuo et al., 2018). To deal with the challenges involved in projects, project managers need to possess the right set of both technical and soft skills in their skillsets (Moradi et al., 2020; Tumpa et al., 2022). In fact, previous research has shown that one of the main causes of project failure is a lack of soft skills of PM professionals (Zaman et al., 2022; Zuo et al., 2018). Many studies have indicated the significance of soft skills in PM. Soft skills are related to leadership, communication, conflict resolution, judgement, decision-making, team working, and emotional intelligence. These also involve contextual skills, cognitive skills, and personal skills (Stevenson and Starkweather, 2010). Sampaio et al. (2021) have recently pointed out that the behavioral competencies, encompassing qualities like leadership, communication, result orientation, emotional intelligence, ethics, creativity, and motivation, have a notable impact on the success of projects, particularly in terms of accomplishing project objectives, overall project performance (time, budget, and quality), and user satisfaction. Jaccard et al. (2022) empirically proved that PM-Game developed students' soft skills competencies which seems to be challenging to be achieved through the utilisation of traditional PM teaching approaches (Ramazani and Jergeas, 2015).

A detailed account of the skills cultivated through simulated games is outlined below.

4.3.1. Enhancing decision-making skills

In the reviewed literature, the most discussed soft skill which PM students develop by engaging in computer-based games was decision-making skill (Calderón et al., 2017; Hassan et al., 2021; Jääskä et al., 2021; Lalic et al., 2021; Lee, 2016; Misfeldt, 2014; Rumeser and Emsley, 2019a). Decision-making is a pivotal competency for successful project managers which wields a profound influence on project costs, schedules and overall value creation (Jääskä et al., 2021). Project managers in their day-to-day life need to make many challenging decisions. Therefore, instilling the capacity to effectively make decisions within complex project scenarios is of critical importance for PM students (Rumeser and Emsley, 2019a).

Computer-based games, especially simulation-based, are meticulously crafted to mirror the real-world project environments. As students repeatedly engage with these games, they learn from the mistakes in their previous decisions and its impacts on project performance. This iterative process empowers them to refine and enhance their decision-making abilities. These games operate in a dynamic and interactive realm, where players' actions dynamically shape the evolving scenarios. This dynamic nature compels students to adapt new strategies, tactics, attitudes, and perspectives (Lush, and Blanksma, 1995). Students engaging in Project Business Game, an educational simulation game, improved their decision-making skills to make critical decisions in project environment (Jääskä et al., 2021).

While playing a game, students experience content, topics, tools, conditions, and risks and need to make decisions about time, cost and quality. Simulation games offer students to make decisions without paying the real-world costs associated with mistakes, fostering a risk-free and safe environment for experimentation and learning (Saenz and Cano, 2009). In essence, the immersive nature of simulation games empowers PM students to master the intricate skills of decision-making, enhancing their readiness to confront the multifaceted challenges of real-world project scenarios.

4.3.2. Enhancing teamwork skills

Projects are inevitably teamwork endeavours (Ellis et al., 2022). Regardless of project nature, projects are undertaken in teams (Nauman et al., 2021). Collaboration, teamwork and communication are essential for any proficient project professional (Calderón et al., 2018). The reviewed literature provided strong evidence that computer-based simulation games develop PM students' team-building skills (Bayart et al., 2014; Calderón et al., 2019; Hassan et al., 2021; Jääskä et al., 2021; Misfeldt, 2014; Naik and Jenkins, 2019; Rumeser and Emsley, 2017, 2018a; Saenz and Cano, 2009). While playing the computer-based games, students communicate with other team members which improves their communication skills and team building skills (Calderón et al., 2017, 2019; Denholm et al., 2013; Petri et al., 2018). Team-Based Mixed Reality (TBMR) games such as PM Exercise, "Winning Margin" Business Simulation, Management of Change and Management of Product Design and Development significantly improved students' team-building skills (Denholm et al., 2013).

Additionally, teamwork cultivates a range of basic skills such as collaboration and communication required for project managers regardless of the industry they belong to (Jääskä et al., 2021; Naik and Jenkins, 2019). PM professionals spend 90% of their time in communication-related activities (Rumeser and Emsley, 2018a, 2018b). When computer-based simulation games are performed in a team, PM students holistically develop team building in their skill set as they interact with other team members, as well as communicate and participate in discussions.

4.3.3. Enhancing problem-solving and leadership skills

Clients requiring PM services have been advocating the need of preparing PM graduates for the increasing level of complexity, chaos, and uncertainty in projects (Thomas and Mengel, 2008). Higher education institutions have been paying much attention to prepare graduates for problem-solving and leadership skills. Unfortunately, these skills alongside other soft skills are the ones which cannot be instructed in a traditional classroom setting. The complexity of projects is on rise. For instance, the New South Wales government has been involved in a number of complex projects such as M12 Motorway and Western Sydney Orbital (State Significant Projects, 2022). The reviewed literature suggests that computer-based simulation games improve PM students' problem-solving skills (Calderón et al., 2017; Hassan et al., 2021; Misfeldt, 2014). By engaging in computer-based simulation games, students perform similar tasks multiple times in new settings/environments and by doing so they develop problem-solving skills (Lalic et al., 2021). During the game, students are confronted with issues as they are in real-life. After meticulous plans, challenges can and will appear in real-life projects. Simulation games present different kinds of risks and challenges for students. For instance, The Project Execution Game presents students with various unexpected events to enhance students' problem-coping skills (Zwikael and Gonen, 2007). These game-based scenarios help students solve problems and react to the challenges, change and adjust existing plans and develop critical thinking, collaborate with the team, show their leadership skills and make effective decisions (Jääskä et al., 2021; Zwikael and Gonen, 2007). These are considered crucial skills of project managers. In problematic situations, project managers need to demonstrate leadership qualities which have been regarded as highly demanded competencies (Ahsan et al., 2013; Drouin et al., 2021; Stevenson and Starkweather, 2010).

5. Thematic analysis: recommendations

Based on the reviewed literature, detailed recommendations for instructors and game designers for effective design and implementation of computer-based games are provided in this section.

5.1. Recommendations for instructors

Based on the reviewed studies, some strategies for the use of computer-based games in PM education have been identified which upon implementation can result in effective learning.

5.1.1. Balancing complexity for learning

Employers often express dissatisfaction regarding the work-readiness of PM graduates for the complexity of the project environment. The introduction of computer-based games can address this gap by introducing complex computer-based simulation games (Rumeser and Emsley, 2018a). When designing and implementing computer-based simulation games, academics should consider the complexity of the games. The complexity of the games influence students' learning experiences. The existing literature suggests that the complexity of the games should be dependent on the student's education and experience level. The delivered subjects also influence the complexity of the simulated games. If it is an advanced subject, the game can be more challenging and complex whereas less complex games can be used to teach basic PM principles to students who have minimum or no experience of working on projects (Calderón et al., 2019). While the increase in complexity challenges students to enhance their performance and motivation levels (Jääskä et al., 2021); too much complexity in the games may discourage students from engaging in games (Hussein and Ravnå, 2015). Therefore, it is recommended to design games in a way that they include various functions to address educational goals, however, the games should not be complicated more than necessary (Rumeser and Emsley, 2018a, 2019a). The complexity of the games, however, does not affect players' decision-making. The decision-making performance of PM students playing these games is improved when the games are both complex and non-complex.

5.1.2. *Instructors' prior knowledge and preparation*

Instructors play an influential role in successfully executing computer-based games in PM classes. Along with an instructors' traditional role, execution of simulation games requires additional preparation and administration from lecturers (Jääskä et al., 2021). Lecturers need to play active role and encourage students to participate in the games (Saenz and Cano, 2009). Successful integration of computer-based games is one of the critical success factors for achieving desired learning outcomes and instructors significantly contribute to this. If academics are not well trained, prepared or experienced in this area, that can lead to inappropriate execution and game usability issues experienced by players (Rumeser and Emsley, 2019a). Instructor's active involvement helps students to participate and engage well in games (Saenz and Cano, 2009).

Briefing the guidelines to the students before starting the game is a key to achieving the desired outcomes. The explanation needs to be clear so that students grasp the instructions (Rumeser and Emsley, 2018a, 2019b). In addition, lecturers need to explain the objectives of the games (Bayart et al., 2014). If not explained appropriately, this can result in students struggling to complete the game rather than focusing on the actual learning objectives (Rumeser and Emsley, 2019a).

In academia, instructors (such as lecturers and professors) are responsible for the learning of students. Inappropriate attention and preparation related to the execution of games may hamper students' experience of learning. A competent lecturer or trainer can contribute significantly to the learning objectives (Bonnier et al., 2020). Students' learning depends on the smooth pedagogical integration of the games (Bayart et al., 2014). The effectiveness of the computer-based games for learning is dependent on an instructor's prior knowledge and experience (Rumeser and Emsley, 2018b).

5.1.3. *Conducting debriefing sessions*

Debriefing sessions is one of the powerful tools for the successful implementation of the computer-based games in PM education (Bayart et al., 2014). Debriefing sessions contribute to students' better decision-making. Debriefing also helps in a number of ways such as reflecting on learnings and experiences; retaining new knowledge; collecting learning outcomes; and discussing strengths and weaknesses of PM strategy (Lalic et al., 2021).

Debriefing sessions can be conducted by peers and tutors and both of these sessions have been found effective (Jääskä et al., 2021). Tutors' feedback can be intermittent or at the end of the session. Intermittent feedback can help students adjust their strategies and make better decisions (Denholm et al., 2013). "Feedback can be found at every level and unit of an efficient educational system and is an overarching concept that helps explain and interpret the role of assessment in educational games. It has more educational value if it is formative and immediate" (Taras, 2005). However, students need to be provided with specific and comprehensive feedback (Rumeser and Emsley, 2019a). Listening from other groups (that is peer debriefing) is useful as this gives an alternative viewpoint to approach the same problem (Rumeser and Emsley, 2018b).

5.2. *Recommendations for game developers*

For the developers of computer-based games, it is critical that the games are designed in a manner that facilitates and encourages effective learning among students.

5.2.1. *Realism*

One of the key elements of designing computer-based games in PM education successfully is to ensure that the games are realistic. Games should be realistic to reflect the complex real-world situations. Games have the potential to develop skills which cannot be lectured (Rumeser and Emsley, 2019a). Although the game experience may not be the appropriate reflection of the real-life situations, it still gives students a representation of the situations which students may not experience if they were lectured the same content (Al-Jibouri et al., 2005; Misfeldt, 2014). Jääskä et al. (2021) suggested that computer-based games do not have to be realistic, but it has to be realism which can support the fulfilment of meeting the learning objectives. Appropriate case study description and purposeful stories are essential for students to understand the connection between game activities and real-world situations.

5.2.2. *User interface*

Simple and user-friendly interface is one of the success factors of effective computer-based game design (Bonnier et al., 2020). Non-complicated user interface improves the educational effectiveness as students easily understand the game mechanism (Jaccard et al., 2022; Miler and Landowska, 2016). Complex user interface may distract students to focus on learning objectives (Bonnier et al., 2020). If the dashboard and interface is too complex, it can reduce learnability and efficiency of use (Bonnier et al., 2020). It can also become cumbersome for students to understand the mechanism and time-consuming to play. An animated and colourful interface can be exciting and attractive for students (Baccarini et al., 2012).

5.2.3. *Game display*

The reviewed literature suggests a range of techniques for improving the game display which is attractive and convenient to use. PM related information is typically presented using Gantt charts, critical path and resource histogram views. Graphical representation of data improves the attractiveness of the information and clarity of the project attributes. Various icons can be used such as administrative work shown by a letter icon, and excavator icon can present construction work. Various eye-catching icons can be used to make the interface exciting and stimulating. For instance, if the project is running as planned, the display can show "smooth sailing" of a ship in sunny weather. On the other hand, if the project outcomes deviate from its planned targets, the weather can become stormier. In addition, delta sign can show the change in duration (Rumeser and Emsley, 2017).

The game settings may give the team an opportunity to choose their own avatar (profile picture) and the team's name. Some more features such as avatar feedback (angry and happy reactions of the project sponsor), collaborative features such as chat box can improve the motivation level of students as these functionalities make the games interesting and attractive (Rumeser and Emsley, 2019a).

5.2.4. *Fun and challenging*

A highly focused design feature is about making games fun and challenging (Lee, 2016; Misfeldt, 2014; Souza et al., 2018). The existing literature suggests that games should not be monotonous and have challenging factors. Games should create a competitive and exciting environment in the classroom which can have a differentiated and enjoyable learning experience (Bayart et al., 2014; Hussein and Ravnå, 2015). The purpose is to design a game which is fascinating with the reasonable challenges associated with it (Jääskä et al., 2021; Long et al., 2009). The idea is to create a learning environment which facilitates engagement and involvement with sound understanding of the technical skills (Petri et al., 2018).

6. Conclusion

A systematic literature review was conducted to identify the current trends in computer-based games in PM education research and provide recommendations to PM academics and game designers. The results suggest that computer-based games if appropriately designed, can contribute to soft and technical skills of PM graduates, which are must-needed for successful completion of projects. PM students can have better understanding of the complexity and dynamic situations of projects by engaging in computer-based games. However, the development and execution of computer-based games in the higher education settings requires considerable planning. Regarding this, the review provides recommendations to PM academics and game developers.

Although systematic literature review provides transparency and reliability of the process, this review is not without its limitations. Although data screening was performed by two authors, its rigor is limited by cognitive biases. Scopus which has a larger pool of social sciences than Web of Sciences was used as the database for systematic search of relevant studies. Studies not indexed in Scopus are not considered in this review. Also, this review is limited to studies published in English language only. Lastly, the scientometric review provides a snapshot of research developments. With significant advancements in this knowledge area in future, bibliometric analysis presented in this review will be outdated.

7. Future research avenues

The scientometric review of literature has indicated the weaknesses of the current literature on the subject matter. Following are the recommendations for future researchers to improve the body of knowledge in this area.

- The majority of the studies examined in this review were published in journals or conferences associated with PM, education, or gamification in education. It seems that the publications of computer-based games focusing on PM education are not widespread in reputable and specialized journals. Important recommendations to advance research in this field involve establishing specialized scientific journals focused on the subject and introducing dedicated sections or special issues related to this topic within well-known education or PM journals.
- Co-authorship strengthens scientific cooperation and adds to scholarly discourse (Ding, 2011). Co-authorship is synonymous with scientific cooperation, and its absence in a scientific network signifies reduced research productivity. Significant evidence indicates that collaborative efforts are more likely to get published in high-impact outlets and receive more citations (Glänzel and Schubert, 2004). Generally, researchers investigating the use of games in PM education are found to work in isolation. The results emphasize the critical need for researchers in this field to collaborate. Moreover, institutions are commonly observed to research independently. Most research in this domain is conducted in isolation, either by individual researchers or their respective institutions. A suggestion in this context is that future endeavours in this subject area could benefit from broadening collaborations with external parties to promote discussions, debates, and the cross-fermentation of research initiatives.
- Within the network of influential countries engaged in scientific collaboration (as depicted in Fig. 4), several nations exhibited limited collaboration connections with major research contributors such as the USA and UK, as well as other network members. The absence of research collaboration in these cases should be considered when these countries are revising their research policies. Developing countries were under-represented in the network which is detrimental to the learning experience of PM-related students in those countries.

CRediT authorship contribution statement

Roksana Jahan Tumpa: Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Formal analysis. **Tayyab Ahmad:** Writing – review & editing, Methodology, Formal analysis. **Leila Moslemi Naeni:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Conceptualization. **Jaakko Kujala:** Writing – review & editing, Supervision.

Declaration of Competing interest

None

Data availability

Data will be made available on request.

Appendix

Table A1
Details of the reviewed articles

ID	Publication	Research aim	Research method	Limitation/s	Future research avenues
1	Al-Jibouri et al. (2005)	Exploring the experiences of students on construction PM and control through a simulation model.	Quantitative*	The study is based on a single dam-construction civil engineering project.	Future studies may consider exploring students' experiences on diverse range of projects.
2	Baccarini et al. (2012)	Investigating students' learning about project risk management through design and development of a computer-based game.	Quantitative*	Study reporting on preliminary results and based on a small sample size.	Future studies to be conducted with larger sample size for more reliable results.
3	Barros et al. (2006)	Reporting on the reflection of academics on development of system dynamics-based games intended to improve knowledge of software PM students.	Quantitative*	Model requiring refinement to present more realistic project scenario.	Based on the new model, further empirical studies to be conducted. Future research to consider multiple factors such as training environment, usability, interaction, and multimedia presentation of the game.
4	Bonazzi et al. (2012)	Proposing a set of functional and technical design guidelines for PM students in a large classroom setting.	Quantitative*	Students' learning and acquired competency not tested	Future studies may be conducted with students playing different version of the same game through which students' knowledge and acquired competency can be tested.
5	Chaves et al. (2015)	Comparing the learning experiences of a serious game (DesigMPS) with game-based learning with a project-based learning method.	Quantitative*	Comparison in the learning experiences was only made with project-based learning method.	Future studies may consider comparison with other instructional methods. Furthermore, researchers can investigate which features of DesigMPS increase student motivation.
6	Dantas et al. (2004)	Exploring learning experiences of project managers through a simulation-based game.	Quantitative*	The simulation-based game is in its early development stage which may have	Future studies may consider the expansion of games including the use of more graphical tools which may increase

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Table A1 (*continued*)

ID	Publication	Research aim	Research method	Limitation/s	Future research avenues
				impeded the presentation of more realistic situations.	students' learning experiences and entertainment.
7	Ekyalimpa et al. (2014)	Proposing a framework for PM game considering previous games development.	Mathematical modelling	The proposed framework was not implemented in a classroom setting.	Future studies may consider implementing the proposed framework and check its reliability and authenticity.
8	Galvão et al. (2011)	Investigation of a persistent browser-based game (eRiskGame) focusing on risk management to teach PM professionals.	Quantitative*	The browser-based games are subject to internet connection. Browser-based games may lack complexity of real-world perspectives.	Future studies may consider making comparison between traditional teaching methods and eRiskGame. Future, students' learning experiences can be monitored in a longitudinal study considering various study levels.
9	Herrera et al. (2019)	Exploring students' learning experiences of lecture- and game-based learning in lean construction principles.	Quantitative*	The study did not take various contextual contexts such as educational institutions, countries and culture into consideration. The findings may not be applicable in areas other than lean construction.	Future studies may consider combining other games and analysing the differences when the game is implemented in other cultural settings.
10	Hussein (2015)	Investigating the effectiveness of blended learning environment through the inclusion of games to improve students' engagement	Quantitative*	A number of recommendations have been provided based on the study results. However, they were not tested in a classroom setting. Also, the recommendations are subject to classroom size.	Future studies may consider testing these recommendations in various classroom sizes with different cohorts.
11	Letra et al. (2015)	Presenting the effective design pattern of games to teach software PM topics.	Quantitative*	Findings cannot be generalised in other area such as software engineering.	Future studies can replicate this study for other subjects of software engineering.
12	Long et al. (2009)	Aiming to teach key concepts of construction PM to civil engineering students by using simulation games.	Quantitative*	Teachers' reflection on game execution was lacking	Future studies may consider integrating a mixed method approach to improve the robustness of results. Along with students' opinion, academics' reflection should also be considered in future research.
13	Mawdesley et al. (2011)	Aiming to improve self-directed learning experiences through the inclusion of simulation games in teaching and learning.	Quantitative*	Study findings are in the early stages with full results not available. The findings are based on students from one university in the UK.	Future studies may consider attempting cross university analysis including students from different levels (undergraduate and postgraduate).
14	Calderón et al. (2017)	Investigating the experiences of using a simulation game (ProDec) to improve motivation, experience and learning acquisition of software PM students.	Quantitative*	The study did not consider performing comparative analyses through controlled experiments. Limitations of this research also include generalisability across different courses, students' cohort and institutions.	Future studies may consider adopting a mixed method, use of controlled experiment or longitudinal studies. Consideration of different courses, students' cohort and institutions is another avenue for future research.
15	Miler and Landowska (2016)	Analysing how cognitive, behavioural and emotional aspects of educational games influence their educational effectiveness.	Quantitative*	Limitations in terms of sample size, convenience sampling approach, confounding variables, and subjective measurements.	Future studies to consider increasing the sample size with purposive sampling technique and reducing the potential subjective measurements.
16	Naik and Jenkins (2019)	Exploring learner's experiences of using game-based learning (Trello) for teaching Agile Scrum approach.	Quantitative	The study was performed on a small sample with undergraduate studies. Also, the learning was tested through marks achieved which may not be the full scale of learning assessment.	Future studies to consider both undergraduate and postgraduate cohorts for comparative analysis on a relatively large sample size. Also, future studies may explore the use of the games on other skills such as communication and problem solving.
17	Rumeser and Emsley (2017)	Scrutinising the use of simulation games to explore how learning styles affect students' learning methods when encountered with project complexity.	Quantitative*	The study was limited to explaining how students' learning styles affect learning method based on the various level of project complexity.	Future studies to consider exploring how PM learning methods and learning styles get affected by learning effectiveness. In addition, other project complexity factors such as schedule delays and scope changes can be incorporated in future research.
18	Rumeser and Emsley (2018b)	Aiming to examine students' preferred learning method when it comes to playing simulation games; Investigating if games with more complex simulation are more important than less complex ones.	Quantitative*	The study was limited to exploring students' preferred learning methods and their reasons for this in PM simulation games.	Future studies to consider both learning effectiveness and preferred methods. Other complexity factors such as staff diversity, and resources availability can be incorporated.
19	Rumeser and Emsley (2019a)	Exploring how project complexity influences decision-making in projects	Quantitative	While number of decisions, activities, projects, and interactions were included as complexity factor, other factors such as risks, uncertainties and scope changes were not included; Project success criteria limited to time and cost.	Future studies to incorporate other complexity factors into consideration along with measurement of learning and extending the cohort of students. Diverse range of success criteria such as quality and sustainability can also be included.
20	Dzeng and Wang (2017)	Investigating students' learning experiences on web-based negotiation game (C-Negotiation Game) to inform their procurement and negotiation decision in construction projects.	Quantitative*	The study focused on only one university	Future studies to consider including students from multiple universities.

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Table A1 (*continued*)

ID	Publication	Research aim	Research method	Limitation/s	Future research avenues
21	Petri et al. (2018)	Improve students' learning experience; Comparing the benefits of digital and non-digital games employed for software PM.	Quantitative*	Although a large sample size was used, the sample may be homogenous in nature. The generalisation of the findings can be influenced by course objectives, students' demographics and instructors' expertise.	Future studies to bring diversity in data and use a mixed method approach.
22	Rumeser and Emsley (2019b)	Developing game design and implementation guidelines improving the quality of PM serious games.	Mixed method (questionnaire and interviews)	Only including a small number of interviewees.	Future studies to empirically test target audience, feedback, game settings, and debriefing.
23	Saenz and Cano (2009)	Exploring the effectiveness of a simulation game such as PROSIGA in PM environment	Quantitative*	Lacking discussion that under which circumstances students achieve optimum experiential learning	Future studies to explain the conditions to achieve best learning experiences.
24	Lee (2016)	Investigating the experiences of students using Scrum-X, a computer-based simulation game to teach Scrum.	Quantitative*	Study being a pilot project lacks rigour and used a small sample size	Future studies may replicate the study on full scale based on a large sample size and adopting a mixed method approach.
25	Schäfer (2017)	Aiming to train electrical engineering and computer science students on Scrum using Minecraft game, a game-based learning.	Qualitative (reflection)	Study limited to having pseudo external stakeholders or customers. Scrum should have a real customer or external stakeholder.	Detailed preparation can be performed in future studies where an external stakeholder can be managed to provide students with more real-life experiences. Future studies can combine other applications, software projects and computer games.
26	Bayart et al. (2014)	Investigating how serious games can be used to enhance knowledge acquisition and students' academic performance.	Quantitative*	The study did not compare the academic performance and knowledge acquisition using a test group and control group protocol	Future studies to compare the results between students using serious games and students in traditional teaching approaches
27	Denholm et al. (2013)	Investigating the perception of post-graduate students on the effectiveness of serious games in class.	Quantitative*	Recommendations for designing and administering games are presented, however, lacking empirical evidence	The proposed recommendations can be empirically tested.
28	Calderón et al. (2019)	Exploring the use of serious games (ProDec) in software PM education.	Quantitative*	Method lacking nuances of qualitative data and analysis to better understand the utilisation of serious games in software PM.	Future studies can address the methodological challenge. Furthermore, students' experience can be explored with the combination of serious games and technologies such as virtual, augmented or mixed reality.
29	Jääskä et al. (2021)	Investigating the use of Project Business Game to improve project planning, stakeholder and cost management, risk management and decision-making skills	Quantitative*	Study involved a small sample size with students' perspectives only. Limited generalization as the findings are based on a single educational game solution.	Future studies can aim to include a large sample size considering multiple student groups with students' background, social skills, prior knowledge of learning subject and experience of games. Teachers' perspectives should also be considered in future studies.
30	Hussein and Ravnå (2015)	Aiming to develop a learning platform to understand the complexity of project risk management and to impart necessary skills	Qualitative (Debriefing)	Lacking the use of various complexity factors in the risk management template	Future studies may consider conducting a Delphi approach to add more elements to the risk management template and also consider other complexity variables
31	Hassan et al. (2021)	Aiming to design and develop a game for construction management to incorporate knowledge, skills, capabilities and overall PM competencies in individuals.	Quantitative*	Findings cannot be generalised for large-scale projects as the sample did not consider individuals involved in large scale projects.	Future studies can consider involving individuals in the sample from large-scale projects. Future research can simulate construction of dams, building factories, and other large-scale projects.
32	Bonnier et al. (2020)	Exploring students' and instructors' experiences of implementing serious games in PM education	Qualitative (focus group interviews)	Limited to single-player games	The inclusion of multiplayer games to facilitate informal and unstructured debriefing and reflection can be addressed in future research. In future studies, students' training should be incorporated before students start to play the games.
33	Calderón et al. (2018)	Using serious games to teach standard ISO 21500 in the context of software PM.	Quantitative*	Lacking in depth analysis of motivation, user experience, and learning outcomes	Future research to make use of controlled group to get insights into the differences in outcomes.
34	Misfeldt (2014)	Explaining how students' engagement in PM simulation games and competition can influence the learning outcomes and game experiences	Qualitative (interviews and focus groups)	Lacking discussion regarding impact of competition on simulation games and vice versa	The synergy or conflict towards competition and simulation games and students' attitude can further be explored; Along with students' opinion, academics' reflection should also be considered in future research.
35	Dib and Adamo-Villani (2014)	Developing a serious game for teach sustainable building design principles and practices to undergraduate students enrolled in Civil Engineering, Architecture and Building Construction Management Programs	Quantitative*	Only undergraduate students considered in study.	Future studies to explore the impact of the game on improving student motivation; In the future studies, comparative analysis can be performed between undergraduate and postgraduate students in terms of knowledge acquisition.

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Table A1 (*continued*)

ID	Publication	Research aim	Research method	Limitation/s	Future research avenues
36	Lalic et al. (2021)	Exploring impacts of game-based learning in gaining knowledge in agile PM	Quantitative*	Findings based on the application of game-based learning in one single course with a small sample size	Future studies to consider applying the game in different courses from different universities to improve the validity of findings. Game-based learning and traditional learning can be blended to see the impacts and changes.
37	Jaccard et al. (2022)	Identifying how serious games impact PM education and the best pedagogical practices to implement games	Qualitative (semi-structured observation)	Study findings were based on classroom observation which may have subjective assessments. Study entirely based on teachers' observation and discussion with students.	Future studies should adopt more structured quantitative or qualitative approaches to solidify the findings
38	Rumeser and Emsley (2018a)	Helping PM game designers and educators to embed complexity in games and understand its impacts on students' learning	Quantitative*	Findings only based on students' short-term reaction right after playing the games	Future research should aim to incorporate other complexity factors (such as unexpected delays and scope changes) to observe their impacts on students' learning. Pre-test and post-test, periodic observations, and long-term post-training surveys should be included in data collection. To achieve deep understanding, future research should adopt qualitative approach to collect data.
39	Vanhoucke et al. (2005)	Using a simulation game (Project Scheduling Game), to observe project managers' behaviour alongside their decisions, preferences, and strategies in a real-life project scheduling	Qualitative (case study)	Limited in exploring the use of game for project-related problems	Future research to incorporate other factors into the game such as time/cost trade-off problems, resource-constrained project scheduling problems, and time/resource trade-offs; In future research, project managers can provide the explanation of their decision and strategies to get better insights into their thinking.
40	Zwikael and Gonen (2007)	Aimed to present a new game: PEG – Project Execution Game to address real-world problems during project execution	Quantitative*	Did not consider the execution of the game through experiment and control groups; Findings based on data collected from one country limiting their generalisation	Future research to implement the same game to improve project planning capabilities, managing financial risks in a bank, or managing technological risks in an engineering company; Using experiment and control groups for future research; future studies can collect data from different countries and course levels
41	Dzeng and Wang (2016)	Exploring use of a web-based negotiation game, C-Negotiation Game, which helps students make decisions in a simulated environment for construction procurement and negotiation processes	Quantitative*	Data collection limited to a single class from one university limiting the generalisation of findings	More universities to be included to collect data for future research. The game was implemented in one single class. Future studies to understand the strategic difference between winners and non-winners.
42	De Souza et al. (2017)	For teaching SCRUM framework, an electronic board serious game, named SCRUMI was presented.	Quantitative*	Lack of rigour in Data collection and analysis owing to small sample size; Not clear how the game (SCRUMI) contributed to teaching SCRUM framework	Need to adopt robust method in future research; Need to include more discussion around the use of SCRUMI to teach technical details of SCRUM.
43	Misfeldt (2015)	Explored how game experiences and learning outcomes were influenced by a competitive game and simulation.	Qualitative (interviews)	Limitations regarding future exploration of game experiences and learning outcomes to identify their impacts on each other. Only students' perspectives were taken into consideration.	Influence of competitive game on simulation and vice versa can be part of future research; Teachers' observation can also be factored into the data to increase the results validity
44	Souza et al. (2018)	Explored the use of a digital serious game – SCRUMI – to teach SCRUM framework.	Quantitative	Lacks a robust methodology. Limited to basic descriptive analysis of students' response.	Need of conducting a detailed study with more advanced statistical analysis; Need of larger sample size

Note: Quantitative* = Use of Questionnaire survey in a quantitative approach.

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