

Work-in-Progress: A Scoping Review for Gamification in Construction Engineering

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Abstract

This paper is a work-in-progress that reports the latest findings of a scoping review for gamified solutions in construction engineering education. Despite considerable attention to creating game-based solutions for engineering education during the last two decades, the existing state-of-the-art advancements in this field for construction engineering is far from achieving its full potential and still little is known about systematic ways to direct research and development efforts in this domain. The first step towards developing systematic plans to advance research in this area is to analytically understand the extent, range, and nature of the existing research to identify research gaps and potential directions for future studies. This study addresses this need through a scoping review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Review (PRISMA-ScR). Throughout the research process, we have identified 103 relevant studies. We have been extracting and synthesizing a wide range of data from the identified studies. Using the collected and analyzed information, we identify the existing limitations and propose factors to be considered in the future research activities.

Introduction

The long history of experimental learning in construction engineering shows the significant potential of cognitive development through direct experience and reflection on what works in particular situations. Of course, the complex nature of the construction industry in the twenty-first century cannot afford an education through trial and error in the real environment. However, recent advances in gamification, especially digital games, can help educators develop game-based pedagogical strategies. These novel strategies allow students to explore various scenarios and learn from their experiences in controlled settings. Designing and implementing effective game-based pedagogical strategies is a complex and multidisciplinary endeavor that may be financially expensive and time-consuming. Despite the considerable investments in designing and developing gamified educational strategies in the last two decades, little is known about systematic approaches to direct future research and development efforts in this field for the construction sector. The overarching objective of this study is to address this gap in knowledge by conducting a scoping review to systematically analyze and map the research done in this domain. Particularly, this study addresses two questions: (1) what is known from the literature about gamified solutions for education and training in the construction industry? (2) what are the potential future research directions in gamification for education and training in the construction industry?

In this study, we address these questions using a scoping review. A scoping review is a relatively new approach to evidence synthesis through a comprehensive and structured literature search [1]. Despite a systematic literature review focusing on well-defined questions about a specific topic,

a scoping review tends to address broader questions [2]. Particularly, scoping reviews are applicable for examining the extent, range, and nature of research activities in a field and identifying the research gaps in the existing literature [3].

Search and synthesis method

In this study, we conduct the scoping review using a search protocol based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Review (PRISMA-ScR) [4]. Our search and synthesis process consists of six main steps as follows:

Step 1: Defining the eligibility criteria: Any technical document, including peer-reviewed journal papers, conference proceedings, and book chapters that discusses the application of gamification in construction engineering education and training, is included in the review if it is written in English. Considering the recency of the topic, we did not limit the search process based on the publication date.

Step 2: Determining the information source: To identify potentially relevant documents during the scoping review, we searched Scopus bibliographic database. This database, created by Elsevier, indexes a wide range of subjects from a long list of publishers. Gusenbauer and Haddaway (2020) investigated the capabilities and performance of many bibliographic databases using a wide range of factors, including their query options, Boolean operators, and dataset structures. The outcomes of their investigation identified Scopus as one of the reliable sources for systematic review.

Step 3: Designing search strategy: Our search strategy was based on the existence of various combinations of phrases related to gamification and the construction industry in the title, abstract, or keywords of a publication. Particularly, we used the following search query to list the potentially relevant studies:

("gamification" OR "gamified" OR "serious game") AND ("construction" OR "civil eng" OR "AEC")*

Step 4: Identifying the relevant documents: The search query, conducted on November 21, 2021, resulted in a list of 518 documents. By reviewing the abstracts of the listed publications, we identified 103 studies that meet our inclusion criteria and could be considered relevant to the topic.

Step 5: Reviewing the full manuscripts: In step five, we review the full manuscripts of the 103 relevant documents to extract the information that helps us address the research questions and objective of this study. During the review, we collected two sets of information from each document. The first set incorporates basic characteristics of the publications, including the type of the document (e.g., peer-reviewed journal paper), publishers, authors' affiliation, and publication year. The second set of information concentrates on the contents of the documents to

analyze the type and extent of their contributions to the body of knowledge. Particularly, this set of extracted information aims to address the following questions to provide a big picture for the depth of the existing research in gamified solutions in the construction industry.

- 1- Did the research use a commercially available game or create a new serious game for education or training in the construction domain?
- 2- Was the proposed serious game digital or physical?
- 3- What specific aspects of the construction process (e.g., safety, sustainability, economic decision-making) were targeted in the proposed gamified solutions?
- 4- If the primary purpose of the game was not education or training, what was it?
- 5- Did the research empirically assess the performance of the proposed gamified solution?
- 6- Did the research base the proposed gamified solution on a theoretical learning framework?

Step 6: Synthesizing the extracted information: In this step, we synthesize the extracted data from the documents to map and summarize the extent of the existing research in this area and identify the limitations, gaps in knowledge, and potential future directions for research and scholarly works.

Preliminary results

So far, we have extracted a wide range of data from the identified relevant publications in this work-in-progress study. We briefly review some parts of the synthesized information in this section. In terms of publication year, the oldest study was published in 2007. The evident upward trend in the number of publications in recent years (Figure 1a) shows the increasing attention that the research community is paying to this rapidly evolving topic. In terms of publication types, the identified 103 relevant documents consist of 41 peer-reviewed journal publications, 60 conference proceedings, and two book chapters (Figure 1b).

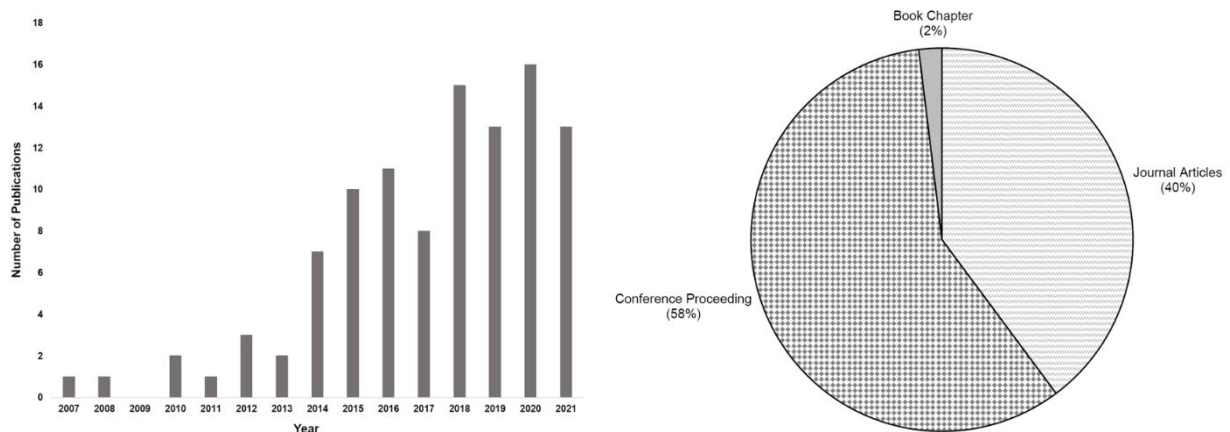


Figure 1: Distribution of the Documents Based on (a) Publication Year and (b) Publication Type

In terms of content and scope, the relevant documents can be categorized into three groups: 1) studies that proposed a gamified solution for education or training, 2) studies that offered gamified solutions for non-educational purposes, and 3) studies that contributed to this field but did not develop a specific gamified solution. The first group that proposed game-based educational solutions consists of 49 publications that targeted areas including occupational safety, construction methods, lean construction, sustainability, and project management. The second group that developed gamified solutions for non-educational purposes include eight publications. These studies aimed to facilitate operations in different areas including project management, economic decision analysis, and communication through gamified solutions. Although the primary goals of these studies are not education, they may have potentials to for education and training purposes. In total, these two groups of studies offer 57 different gamified solutions.

The remaining 46 studies that did not propose an explicit gamified solution can be categorized into four groups: (1) studies that only provide general discussions about the importance of gamification in construction engineering, (2) studies that focused on creating virtual environments using 3D simulations but their final products cannot be considered a game based on the scientific definition of a game introduced by Bernard Suits in 1978 [5], (3) studies that used some limited gamification elements (e.g., points) but did not create an interactive game environment in which users can explore different strategies to achieve a goal, and (4) publications that offer technical guidelines (e.g., how to create game objects using Building Information Modeling files) to design a gamified solution in the construction domain. Figure 2 summarizes the hierarchical categories and number of documents in each one.

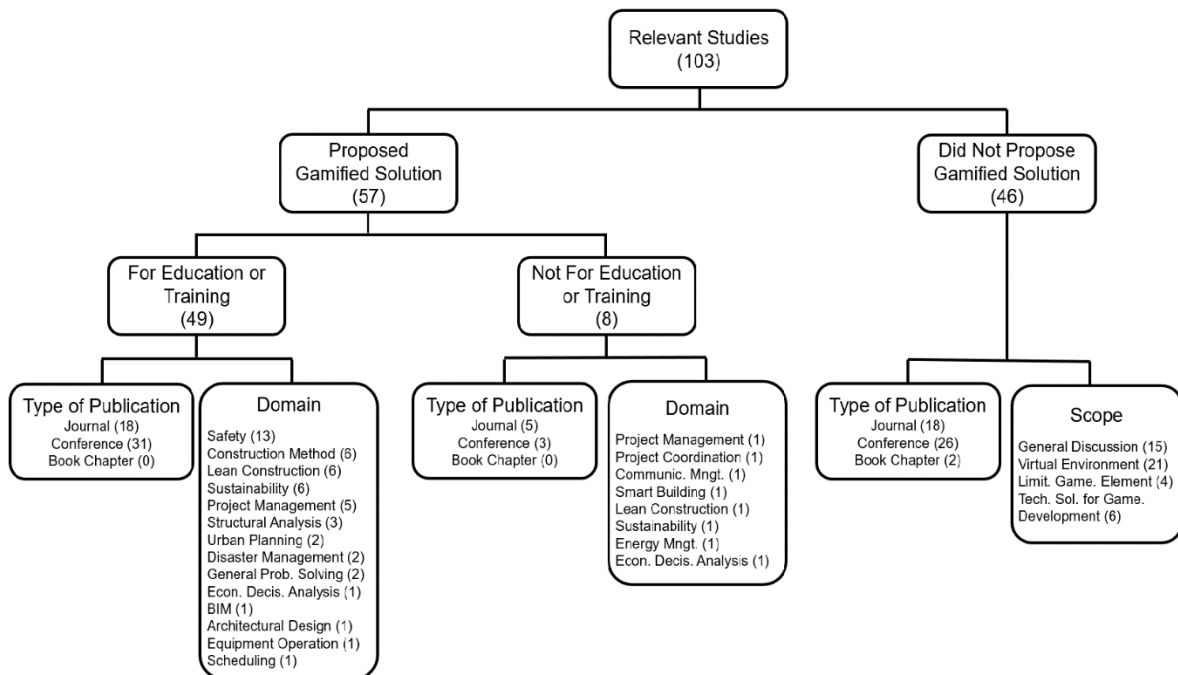


Figure 2: Categories of the Studies Based on Their Type of Contribution

Limitations and future directions

The synthesized data extracted from the relevant publications help us understand the extent of the existing works and identify four main factors to be considered in the future research activities.

- 1- **Extending gamification to various aspects of construction domain:** The existing gamified educational solutions have targeted a relatively limited number of areas such as safety, lean construction, and sustainable development. Many other aspects of construction projects, including heavy equipment planning, scheduling, value management, project delivery methods, cost management, and construction material science, have significant potentials to be taught through serious games.
- 2- **Designing gamified solutions based on learning theories:** Only five studies out of the 49 studies that proposed an educational gamified solution mentioned learning theories, and only three of them used a theoretical learning framework to design their proposed game-based learning method. This is a significant limitation in terms of systematic designing and developing game-based pedagogical strategies that needs to be addressed in future works.
- 3- **Using gamification to promote learning at scale:** Digital serious games for education can considerably contribute to learning at scale systems if they are equipped with Artificial Intelligence and Machine Learning solutions that actively monitor the performance of the users by analyzing the log files and provide customized feedback.
- 4- **Games for vocational training:** The 4th industrial revolution is changing every aspect of the construction industry. It is critical to train and prepare construction professionals to effectively work in the rapidly changing digital era. Recent studies including [6] indicated that adult professionals could learn better through modular learning materials that are integrated into their daily professional activities. Customized game-based vocational training modules that help professionals learn how to interact and work with new technologies can be a basis for future research and scholarly activities.

Conclusion

This paper summarized some aspects of the latest outcomes of the scoping review that we are currently conducting to understand the extent of the existing research in gamification for construction engineering education. Using the outcomes, we identify knowledge gaps and propose critical factors to be considered in future research activities. When it is complete, this study will set the stage for developing systematic plans to direct future research and scholarly works to design and implement game-based pedagogical strategies for education and training in the construction industry.

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