
Further Development of BIM Education: A Literature Review of Game-Based Learning Approaches and a Proposal for a Game-Based Solution in Facility Management

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ABSTRACT

The fact that Building Information Modelling (BIM) is still so little used in Facility Management (FM) is not due to one reason alone, but is related to various obstacles. One of these is that many building operators have too little knowledge about the advantages and application of the BIM method in their field and accordingly do not (or cannot) clearly formulate their requirements for a BIM model in the early project phase of new construction and renovation projects. The acquisition of BIM-related knowledge, particularly the procedural aspects, proves to be a challenge when relying solely on traditional frontal teaching methods. In addition, the BIM use cases itself can be different for each FM sector and therefore processes and requirements can be very individual. There is a lack of appropriate formats available for the effective dissemination and transfer of this specialized knowledge. This paper undertakes a literature review, focusing on existing BIM Serious Games. Among other things, the different building phases, the game methods and the learning success achieved are analyzed. Building upon the findings from the literature review, this paper introduces a general framework for a BIM Serious Game, specifically tailored to address the challenges faced within the field of FM. By leveraging the strengths of game-based learning, it seeks to effectively overcome the aforementioned obstacles and bridge the existing gap in the realm of game-based BIM education.

Keywords: Building information modeling, Facility management, Serious game, Game-based learning

INTRODUCTION

The benefits of BIM for FM are often still underestimated. It offers valuable benefits as it supports FM by integrating various disciplines that aim to optimize functionality through the seamless integration of people, places, processes, and technologies. While the initial focus for building owners and project stakeholders tends to be on design and construction costs, it is important to recognize that the long-term maintenance and operational expenses exceed the initial capital investment in construction (Edirisinghe et al., 2017).

The limited adoption of BIM in FM is caused by various obstacles. One significant obstacle that hinders the widespread adoption of BIM is the limited knowledge and awareness among building operators about the numerous advantages and practical applications of the BIM method in their specific field. As a result, these operators often find themselves unable to clearly articulate and express their specific requirements and needs for a comprehensive BIM model during the initial phases of new construction or renovation projects (Durdyev et al., 2022; Pärn et al., 2017; Toyin and Mewomo, 2022; Tsay et al., 2022)

Given the inherent complexity of the subject matter, the acquisition of BIM-related knowledge, particularly the procedural aspects, proves to be a formidable challenge when relying solely on traditional frontal teaching methods. In addition, the BIM use cases itself can be different for each FM sector and thus processes and requirements can be very individual. There is a lack of appropriate formats and methodologies available for the effective dissemination and transfer of this specialized knowledge.

Game-based approaches can be an appropriate way to teach BIM. They provide an interactive learning experience that makes complex concepts more accessible. Through gameplay, learners actively participate, make decisions, and experience the direct impact of their actions, which promotes understanding and application of BIM principles. There are also opportunities to apply the BIM method in virtual simulations and gain hands-on experience in creating, editing and analyzing BIM models. This allows skills and knowledge to be developed and refined in a risk-free environment before entering the real world. In addition, game-based approaches often have a high motivational factor, as they include rewards, challenges, and competition to encourage continuous improvement. Finally, Serious Games can foster teamwork and collaboration by facilitating knowledge sharing, communication, and problem solving among participants - important skills for BIM collaboration (Meier and Seufert, 2003).

This paper will focus solely on Game-Based Learning (GBL) formats for teaching BIM. According to the definition of Breuer and Bente (2010), these are complete games with a specific goal and fixed rules that are developed solely for the teaching and learning context. This differentiates them from Serious Games in that these are also complete games with a specific goal and fixed rules, but can be used for any non-game context (Breuer and Bente, 2010; Deterding et al., 2011). This makes GBL a subcategory of Serious Games. The term Gamification is again differentiated from Serious Games in that it is not a complete game, but merely game elements developed for a non-game context (Deterding et al., 2011; Kapp, 2012).

LITERATURE REVIEW

A systematic literature review is conducted with the aim of locating existing GBL approaches for teaching BIM and then analyzing them based on criteria. The literature review thus complements previous studies that have examined gamification approaches in the Architecture, Engineering and Construction (AEC) industry. The work of Cunha Leite et al. (2016) proves that,

up to the time of publication, no studies could be identified that relate to the topic of gamification in the AEC industry. Building on this, Pütz 2021 published a literature review where 12 studies relating this topic were found. Likewise, it complements previous studies on current BIM trainings. Pütz and Helmus (2021) examined 78 different studies on BIM training, of which only one was identified as a Serious Game. Furthermore the study of (Olowa et al., 2019) investigates the use of BIM for construction education, aiming to gain an understanding of existing examples, their characteristics, challenges faced in implementation, and trends. A systematic search of peer-reviewed BIM education literature was conducted, identifying 51 specific cases of BIM education.

Since specific information is sought and criteria for classifying study results are established, a Systematic Literature Review is conducted following the approach of vom Brocke et al. (2009). The literature databases Scopus, Web of Science and various specialized databases were selected after an initial search for studies to ensure comprehensive coverage of the available literature. The search term TITLE-ABS-KEY ((“Game Based Learning” OR “Game-based Learning” OR GBL OR DGBL OR Gamification OR Serious AND Gam* OR Business AND Gam* OR Simulation AND Gam*) AND (“Building Information Modeling” OR BIM)) was used in those databases to match in title, abstracts or keywords. Although the literature review searches for GBL and Serious Games with a teaching-learning context, it also searches for terms related to the topic due to possible differing definitions of the terms.

The database search revealed 464 results. Of these, 460 were excluded from the analysis. The exclusion affected works that presented teaching formats that fall into Underwood et al. (2013) categories of “BIM-aware”, where participants only are ensured to be aware of BIM and the changes coming along with it, as well as “BIM-enabled”, where learning is embedded in a virtual BIM environment. The studies included in the analysis had to be appropriately “BIM-focused”, i.e., have the primary learning objective of teaching the BIM method. Also excluded were works that are not GBL or Serious Games.

The criteria chosen to evaluate the included studies were

1. the target group (A - professionals, B - students),
2. the game mechanics (A – Simulation, B - Role play, C – Points, D – Competition, E – Feedback and Assessment, F – Collaboration and Teamwork, G – Knowledge Testing, H – Guidance and Support)
3. the game duration and
4. the phase in which BIM is considered (A - planning, B - execution, C - operation),
5. the format (A - presence, B - online).

All studies show that the approach of using a GBL for teaching BIM is effective, regardless of whether they are designed for students or professionals or both. However, it is emphasized that the inclusion of professionals through experience and practical knowledge give further added value especially to the students. According to the participants, all simulation games succeeded in simulating practical scenarios for teaching the BIM processes.

Table 1. Results literature review.

Author (Year)	Game name	1	2	3	4	5
Ben Rajeb and Leclercq (2019)	BIM'ShareLab	A	A, B, F, G	One day	A, B	A
Heins et al. (2021)	BIM Game (PING PONG)	B	A, B, D, F, G, H	Three days + tutorials	A	A
Heins et al. (2021)	BIM Game (JADE Work)	A, B	A, B, D, F, G, H	Three days + tutorials	A	A
Aibinu et al. (2022)	BIM Immersion and Competition	A, B	A, C, D, F, H	Two days + training	A, B	A
Özener (2023)	BIM adoption game	A, B	A, B, C, F			A
Özener (2023)	BIM execution game	A, B	A, B, C, F	Four weeks	A	A

The chosen gaming mechanics also achieve consistently positive results in the studies considered. Simulation as a game method allows learners to practice creating, editing, and analyzing BIM models, exposing them to the complexity and challenges they would encounter in real construction projects. In this way, they develop practical skills to understand the impact of BIM on project outcomes and gain valuable experience in a risk-free and controlled environment (Özener 2023). BIM requires collaboration and coordination among various stakeholders. Role-playing in a Serious Game allows learners to assume different roles and experience the perspectives of architects, engineers, contractors and others. This method promotes empathy, teamwork, and a holistic understanding of BIM workflows. By incorporating collaboration elements into the game, such as shared tasks, joint problem-solving, or communication channels, the learners of each game were able to experience the benefits and challenges of working together in a BIM environment. Including knowledge testing within the Serious Game allows learners to evaluate their comprehension, identify areas for improvement, and reinforce their understanding of BIM principles and processes (Heins et al., 2021). The inclusion of support mechanisms, such as in-game coaches or guidance, can assist learners in navigating complex BIM concepts, providing assistance, explanations, and tips when needed. This support feature ensures that learners receive guidance and help to overcome challenges and reinforce their learning effectively. By providing feedback on learners' actions, decisions, and BIM models within the game, they can understand the implications of their choices and make improvements (Heins et al., 2021; Aibinu et al., 2022). The inclusion of points and competitions adds a gamification element, motivating learners to actively participate, perform well, and strive for higher scores. This competitive aspect encourages engagement, reinforces learning, and fosters a sense of achievement (Aibinu et al., 2022). A distinction between online and presence games was not possible, as all games analyzed were held in presence.

It is mentioned, that it is difficult to adapt the games to different knowledge and experience levels of the participants. For this reason, different game scenarios were developed in part to address the different starting situations and needs of the participants. In some cases, tutorials and trainings were

also developed that were made available to the participants before the game so that they could assume a certain level of basic knowledge for the game (Aibinu et al., 2022; Heins et al., 2021).

The periods in which the respective games are played are rather different. Ben Rajeb and Leclercq (2019) emphasize that one day is too short to teach the content. According to them, one-day training raises awareness in the participants, but it does not leave them enough time to go beyond the hypothetical scenario and use the blended experiences of all the participants in an applied setting. Aibinu et al. (2022) noted that the game duration of two days was too short and the majority of participants would have liked more training before the actual game as well.

All simulation games focus almost exclusively on the planning phase. This is not surprising, since the planning phase is where the capabilities of BIM are prominently leveraged to optimize design, coordination, quantification, cost estimation, simulation, and stakeholder engagement. The studies found are spread over the years 2019 to 2023 and are thus all very young. Accordingly, the focus on BIM use cases beyond planning has not yet been set.

DISCUSSION

Since previous studies have generally found little gamification in the AEC industry, it is not surprising that is only a small number of studies on game-based BIM education. But those already showed positive results and underlined the potential for being successfully used in trainings on. Compared to previous literature reviews a trend towards game-based BIM education can be seen.

Although the results of BIM GBL approaches have been consistently positive, it should be noted here that some of the main challenges in BIM teaching as analyzed in Olowa et al. (2019) literature review still remain through game-based formats. Developing GBL for BIM is complex and time-consuming, requiring expertise in both BIM principles and game development. To this end, BIM practices are constantly evolving, requiring continuous adaptation.

The literature review did not identify any BIM games designed specifically for FM purposes. However, it is important to recognize that the benefits of BIM can be realized throughout the entire project lifecycle, including construction execution, operation, and maintenance. The absence of FM-focused BIM games highlights a potential research and development opportunity in the field to further enhance BIM education and support FM practitioners in their roles. Further work should investigate whether and to what extent GBL for BIM in FM leads to learning successes.

FRAMEWORK FOR FM-FOCUSED GBL FOR BIM EDUCATION

Building on the findings of the literature review, a framework for GBL is presented. The format should not be limited to one target group, but should appeal to both students and professionals. The analysis has shown that the cooperation brings added value for both groups.

The need among students is the integration of BIM into university education in FM. While the importance of BIM in the FM industry has been recognized, its incorporation into academic curricula is relatively slow. Challenges such as the need for faculty training, access to BIM software, and curriculum adaptation have contributed to the gradual implementation (Sampaio 2021).

The needs that can be addressed with the help of GBL for professionals is, that there is a general lack of BIM knowledge and understanding among FM professionals, which inhibits the adoption of BIM. Accordingly, there is a need to teach BIM fundamentals (Kassem et al., 2015; Toyin and Mewomo, 2022). In addition, the FM industry is relatively rigid, making the adoption of new processes and technologies a key challenge. Accordingly, it is important that the benefits of BIM for FM are clearly highlighted to gain acceptance among professionals (Kassem et al., 2015; Love et al., 2014). Furthermore, the BIM requirements for data interoperability with the company's own systems is a complex issue, as the facilities information systems are very different. A fundamental treatment of this topic is also conceivable, as this is a key issue in the introduction of BIM in FM (Love et al., 2014; Patacas et al., 2020).

This leads to three learning objectives for students and professionals that should be covered:

Identify BIM use cases in FM: The primary objective is to empower students and professionals in the FM sector to identify the various use cases where BIM can be effectively applied in FM. Through engaging scenarios, participants should gain a comprehensive understanding of how BIM can be utilized to optimize FM processes. They should learn to recognize the areas where BIM can bring value, such as maintenance planning, asset management, space utilization, energy efficiency, and lifecycle cost analysis. By developing this skill, learners will be equipped to identify and capitalize on opportunities to implement BIM in their FM practices, ultimately enhancing operational efficiency and effectiveness.

Perform BIM use cases in FM: In addition to identifying BIM use cases, the aim is to provide participants with hands-on experience in performing these use cases within the FM context. Through simulated scenarios and interactive tasks, learners could have the opportunity to actively engage with BIM-enabled processes and workflows commonly encountered in FM. They will navigate through tasks such as managing digital models, extracting relevant data, generating reports, and analyzing performance metrics. By immersing themselves in these activities, participants could develop the necessary skills and confidence to effectively utilize BIM in their FM roles, leading to improved decision-making, and enhanced collaboration with stakeholders.

Define requirements for BIM use cases in AIR: An essential aspect of leveraging BIM in FM is the ability to define clear and comprehensive requirements within the framework of Asset Information Requirements (AIR). Participants should be guided through exercises that involve creating and customizing AIR templates, identifying essential data elements and parameters, establishing data exchange protocols, and ensuring compliance with standards and regulations. By mastering the process of defining requirements for BIM use cases in AIR, learners will be able to effectively communicate their expectations in the early project phase.

The GBL format should consist of a training phase and a game phase. The training phase consists of modules that the participants can select as needed and independently in order to acquire the necessary basic knowledge for the start of the game. In this way, the difference between the various levels of knowledge of the participants should be alleviated.

The game phase can also be divided into modules to be selected, each covering different BIM use cases in FM. This would be a possibility to adapt the game to the individual needs and interests of the participants. In order to internalize the contents of the game, a playing period of at least three days exclusive of training time has proven to be effective.

The game methods considered in the literature review all had their justification in the BIM Education context, so that at least from these presented methods can be selected.

CONCLUSION

The literature review conducted in this study reveals a growing trend towards game-based BIM education, demonstrating the positive impact of Serious Games on learners' understanding and application of BIM principles. Simulation, role-playing and collaboration among others emerge as effective game methods in teaching BIM. The integration of professionals alongside students in the game-based learning environment further enhances the educational experience, drawing on their practical knowledge and expertise.

Notably, a significant gap is identified in the lack of BIM games specifically designed for FM purposes. This observation prompts the proposal of a general framework for an FM-focused GBL for BIM education. The framework aims to address the unique needs of both students and professionals in the FM sector, empowering them to identify BIM use cases, perform BIM processes, and define BIM requirements in the context of AIR.

The effort to promote BIM education through Serious Games is still in its early stages, and this paper serves as a stepping stone towards unlocking its vast potential. As the BIM landscape evolves, the continuous exploration and application of innovative teaching methodologies will be vital to advancing the integration of BIM into FM and providing professionals with the knowledge and skills necessary to do so.

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