A REVIEW OF VR AND GAMIFICATED EDUCATIONAL METHODOLOGY IN VIRTUAL CONSTRUCTION FROM NON TO FULL IMMERSION

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Abstract
VR has a significant role as a tool of educational models in digital learning. Particularly, a sub-group concerns the use of Virtual Learning Environments, depicting building construction sites remotely for the Construction Courses. This concept is seen in the earliest VR editions, where a construction site is projected via basic means (screen, mouse) in Non-Immersion (the user maintains the feeling of his presence in the real space). The necessity of more realistic simulation and the advancement of technology led to an expanded body of cutting-edge research related to Full-Immersion in these sites with more sophisticated techniques, devices (Head-mounted Display devices), where learning becomes isolated from the real environment and is transferred into a sensory level to a 3D and 360° graphic or video, representing a building in the construction phase.

A smaller group of these tours involves Gamification simultaneously to enrich the educational procedure with benefits like user engagement and involvement. During the Gamification of these immersions, traits of the Game Design, (e.g. badges, scores) are incorporated. More analytically, the virtual construction site is projected either in a Non-Immersive or Full-Immersive simulation, as a grounds for the addition of traits of Gamification.

This research addresses the historical perspective of the use of gamified virtual tours in constructions from Non to Full Immersion. Methodologically, the authors used a review in relative applications and proposals, emphasizing on the historical continuity of their development. In conclusion, it occurs that the gamified Full-Immersions in constructions in education should not be regarded as an independent method, but as an evolution of simpler applications, with which specific traits and guidelines are aligned, and have been modified accordingly to notable gaps of the past. Finally, supplemental research is proposed regarding the comparisons between the early and modern ways of the learning process in question.

Key words: *virtual construction site, gamified construction site, non-immersion, full-immersion*

Introduction

Extended Reality technologies have long been integrated into educational scenarios in the context of the digitalization of the conventional learning processes. In this direction over the years Virtual Reality (VR) tools have provided innovative ways of approaching an educational subject, case etc. To better understand its concept, it should be mentioned that Steuer (1992) considered VR to be “a real or simulated environment in which a perceiver experiences telepresence” (p. 76-77). Its provided capacities are dependent on its different categories associated with the level of immersion, which as Agrawal et al. (2020) proposed is a mental engagement in a deep way in which the individual is led to a cognitive attention shift that has to do with their disassociation, in terms of their awareness of the real world. Supplementary, they correlated it with immersive potential and tendency. The first refers to the systems or contents liable to provoke it and the second to the predisposition of the person to become immersed. More specifically the above-mentioned categorization leads to the Non-Immersive VR (NIVR), Semi-Immersive VR (SIVR) and Immersive VR (IVR) (Badomu & Ye, 2013). The former, known also as Desktop VR, describes the case when a user views and interacts with a virtual environment displayed on one conventional monitor (e.g. computer screen) or more (Mandal, 2013). Moreover, it can even be more sub-categorized into the 2DNI and the 3DNI, with a difference being in the monocular view or a view mediated by anaglyphic glasses for stereo presentation (Kozhevnikov & Dhond, 2012). The second one, also called Hybrid or Augmented provides immersion, with the simplicity of a desktop VR system or the use of real models. Examples of such systems are the CAVE (Cave Automatic Virtual Environment) and the driving simulator (Badomu & Ye, 2013). The CAVEs are basically cubic rooms with projections on the walls, floors and ceilings which encompass the user and were widely utilized in previous years in a lot of different educational sectors. Finally, the latter refers to a surrounding experience in a way that is perceptually similar to the one of actually being inside its space (Hodgson et al., 2019). This can be accomplished by several types of software and hardware, such as 3D modelling programs, game-engines, Head-mounted Display, joysticks, data gloves, omni-directional walking/running platforms etc. Their successful use can potentially lead to visual isolation, sound independence, tactile, haptic relationships with virtual objects and the re-creation of the user’s real moves virtual equivalents.

Each of the above types provide a different way of being, interacting etc. with a Virtual Environment, which can be regarded as an environment generated by a computer where its integrated objects are displayed on a device, offered for real-time interactions via a technological interface, rather than existing in a genuine way (Flavián et al., 2019). When used in an educational frame and purpose it can be regarded as a Virtual Learning Environment (VLE). When the user approaches such an environment according to the principles of the more sophisticated and complex IVR, they can highly acquire the basic concepts of VR, which according to Walsh and Pawloski (2002) are telepresence, interaction and immersion. First, telepresence can be thought of as a kind of sense of feeling present in an environment that is distant in physical terms (Schloerb, 1995). Secondly, according to the concept of interaction, the user of a mediated environment can modify it in real time, in terms of its form and content (Steuer, 1992) and as Mihelj et al. (2014) noted that it can be generally distinguished in manipulation, navigation and communication. Lastly, in an IVR Learning Environment, the user can obtain not a partial but a full sense of immersion which was described earlier. Such features in the case of a VLE, can provide the user with a sufficiently realistic simulation of an educational practical approach as a supplemental extension to the theoretical part of a course.

The resulting potential cognitive gain led researchers and educators of the pedagogy for the Engineering Studies to investigate how to implement these practices in academia. Specifically, throughout the past years there has been an increasing interest in the implementation of such methods into Construction Education in a plethora of related schools and departments. The relevant proposals and applications either as pilots or as fixed methodologies, can facilitate students with additional means for getting in touch with virtual structures, construction sites and other related settings.

Their successful use led to the synergy of these practices with the additional use of Game Design traits, techniques etc. for the enhancement of the whole innovative educational concept, to improve it further. In fact, these elements in collaboration with VR can lead to learning outcomes in accordance with different Learning Theories and their sub-theories. More specifically, as Kanellopoulos and Antoniou explained (2025), the unification of VR and Gamification methodologies in educational settings can result in the co-existence of different learning theories and consequently to a mix of beneficial learning outcomes that derive from each one.

The above methodological collaboration is progressively becoming an object of research, as nowadays it appears to be a transition to the more subtle educational use of Game Design elements, in contrast to other game-related strategies like Serious Games and Game-based Learning. These three game-related practices share similarities as Krath et al. (2021) underlined because they use gameful experiences in a positive way and rather than entertainment they have a serious aim.

The previously mentioned subtle dimension of use was described easier by Kapp (2013) who sees Gamification related to Games like a piece to a puzzle. In other words, a collection of conceptual and structural parts that guide the gaming experience but can also be borrowed to be used elsewhere. Alvarez (2008) defined Serious Games as “IT applications that combine aspects of tutoring, teaching, training, communications and information, with an entertainment element derived from videogames” (p. 11) and provided a scheme that briefs his definition: Utilitarian scenario + videogame scenario = serious game, that according to their objectives can be split into the: message-based that deliver a specific message, training ones that have to do with the improvement of cognitive and motor skills and the simulation or serious play ones with various uses. Game-based Learning is related to environments where game content and play boost knowledge, skills obtaining, and the integrating problem-solving cases are accomplished by game activities, providing a feeling of achievement (Qian & Clark, 2016). Gamification according to a widely accepted definition coined by Deterding et al. (2011) is the “use of game design elements in non-game contexts” (p. 10). According to another more education-related definition, it is about “using game-based mechanics, aesthetics, and game-thinking to engage people, motivate action, promote learning, and solve problems” (Kapp, 2012 as cited in Kapp, 2013). Its basic concept can be described by the consecutive use of the elements of Mechanics, Dynamics and Aesthetics. Mechanics (e.g. betting in a card game) are elements for the representation of data and algorithms, like actions, behaviors and controls that are available to the player. Dynamics (e.g. time constraint) describe how Mechanics affect the inputs of the players and each other’s outputs. Lastly, Aesthetics (e.g. challenge) have to do with the wanted feelings aroused in the player, while interacting with the game system (Hunicke et al., 2004).

Today, there has been an increasing interest in implementing Gamification in full Immersive Environments for educational purposes and indeed in Engineering Studies. Thus, this research addresses the clarification of the historical background of its evolution in the specified topic of gamified IVR visits in construction sites. This perspective covers its maturation both in terms of the VR typology used and the game practices as well. The authors reviewed the matter through different examples from early to modern relative methods, regarding the differentiated evolutions of the two tactics under examination, which are in a synergistically collaboration in the gamified IVR educational experiences of virtual construction sites.

Early attempts at implementing VR in learning for building constructions

The educational field of pedagogy for the Construction Education has over the last decades adopted different VR tools for the creation of realistic simulations concerning building structures, construction sites etc. representations and their internal procedures, ambience etc. The different VR types cover a spectrum from low immersion, presence and telepresence from desktop to their high form using Head-mounted VR (Kim & Leathem, 2018). The same range of uses appears historically regarding the above-mentioned educational implementations, as being dependent on each VR era's technological capabilities offered, in the matter of available software, hardware and experience. So, the earliest attempts of such methods were mainly developed and applied to NIVR, but also simple SIVR and IVR systems were used. Indeed, according to a review from Wang et al. (2018) between 1997 and 2001 the most common used form of VR in construction education of engineers was the Desktop-based one. Related to that, one of such NIVR approaches concerns the utilization of the modeling systems of Computer Aided Design (CAD) (Isdale, n.n., as cited in Badomu & Ye, 2013). Using CAD teaching practices appear to be a sub-class of the wider CAL (Computer-aided Learning), such a program -as Shelbourn et al. (2001) noted- was first developed in 1954 and led to the broad acknowledgment of its target of bringing settings as simulating concepts in which learners can be navigated by using an abundance of learning resources and tools. CAD modelling is used even in today's educational settings in the process of creating construction plans and 3D models in Engineering Studies for self-evaluation and external evaluation. So, the use of software like AutoCAD, ArchiCAD etc. has replaced partially or in total the traditional drawing procedure made by hand and analog geometric tools in the related studios. Consequently, students can plan and model precise, exhaustive detailed and rendered 3D representations to visualize their construction designs, along with the added materials, textures, such as concrete, wood grain. As a result, they get better spatial and aesthetic understanding, due to their projections in software interface in conjunction with simple hardware, such as an electronic computer, rather than paper.

Furthermore, as NIVR indicates they can manipulate the -given or created by them- building structure under examination, using their mouse and keyboard, so as to obtain ample degrees of freedom, like multiple perspectives by using specific commands (movement, scaling etc.). The flexibility provided of experiencing models rapidly proved more effective and timelier in comparison with the more established conventional axonometric or perspective depictions of the past. CAD as today's conventional practice of building design studios may have enhanced them but not without drawbacks. As Kostopoulos (2022) pointed out, these are dissociated from the real-world practical application of the building process. An argument that led him to a scenario of a Practice-based Learning methodology for the Building Technology Education, towards a collaborative teaching strategy upon a tangible design-build project in real time and data-based. Based on the earlier, the turning point of CAD breakthrough appears as an early educational inclusion of experiencing building structures in NIVR, that pioneered the way for the implementation of further developed VR systems, particularly in terms of more realistic simulations.

In this direction, one of the earliest attempts at using VR in the academic context was presented by Messner et al. (2003) in Penn State University in the undergraduate Architectural Engineering Program. Students developed and tested a 4D CAD model (3D design plus time) via two experiments. The first was about reviewing and identifying construction schedule conflicts (e.g. sequencing rules) in an office building project. The second was a CAVE-like display system visualizing a 3D nuclear power plant project, where the students developed a sequence of construction by interacting with graphical elements like air handling units.

These kind of early simple editions of 4D Desktop-based VR seem like a precursor which set the foundations for the shape of the latter 4D BIM-based IVR. Such a model like the 4D BIM-based Digital one can integrate an abundance of data like structural data, MEP (Mechanical, Electrical and Plumbing) data, but also data about the schedule, the cost estimation of the construction among other factors (Alizadehsalehi et al., 2019). In the next year, Sampaio et al. (2004) used a virtual 3D model of a double-brick external wall as a case didactic tool for Civil Engineering Education for the simulation of the sequencing of the construction processes. Initially the 3D model was developed using AutoCAD which was then transposed to the VR system for a visualization which emphasized the dynamic evolution during the gradual additions of the components (e.g. bricks). In its space, manipulation of such elements was available, while they could be seen in animations, for instance with exploding exhibitions of doors or windows for didactic purposes (e.g. examination of the connections).

Later, in the same context Setareh et al. (2005) presented the system VSAPD, in the Virginia Polytechnic Institute and State University. It included desktop, semi-immersive and total immersive interfaces for interacting with building structures. The desktop one was based on simple hardware (computer, mouse, keyboard). Their CAVE was based in a cubic room with surrounding projections and user's interactions based on joystick's pointing and buttons. In the immersive edition an HMD, a tracked tablet and pen were used for actions like object manipulation or even to "fly" around the structure. The portable edition of the latter used only HMD orientation and a chord keyboard device for selection.

After the years the virtual visualizations became even more advanced, indeed Sampaio et al. (2010) in the beginning of the previous decade presented relevant work in the context of Civil Engineering Education. Their scenario was far more detailed and realistic in terms of the representation of the 3D models (rendered views of a bridge under construction) and believable animations that allowed the step-by-step inspection of the several sequential stages, able to be projected on PC VR display. Rather than bridge elements the visualization was associated with the use of the necessary equipment, like the temporary supporting systems.

Modern utilizations of Immersive VR in learning for building constructions

In the modern phase of the universal attempts on digitalizing sections of academic education, Construction Education relative stakeholders implement way more improved types of full immersions in construction sites, with a more advanced level of realism. The desirable progressed realistic approach has to do with how the model is displayed, but also with the user's simulation of the feeling of "being" inside it and interacting with it. As NIVR means served as the technological precursors of high IVR in teaching contexts in general, it seems reasonable that the same relation appears in the educational experiences of construction structures and sites.

In the pioneering educational scenarios of becoming immersed into construction-based virtual environments, these spaces were mainly developed in connection to a 3D graphical representation of a building model. Consequently, engineering students wearing special equipment could feel themselves present in such an environment in which they could test previously acquired knowledge from the theoretical parts of the Construction Courses in lectures. Moreover, they could obtain valuable pieces of practical insight that was not able to be sufficiently delivered in the conventional way -even in the case where a video of a real constructional operation is used as tutorial material- which is a far cry from offering actual familiarity with constructional phases, due to an abundance of objective drawbacks and constraints.

After the years, advancements in VR research made it possible to overcome limitations of previous versions via highly competent software capabilities and realistic simulating devices. These realistic simulations supported by means of IVR equipment benefited engineering education serving as a medium that can bridge the previous theory-practise gap to a certain degree and are inseparable in full immersive constructional experiences. For instance, the currently well-established VR headsets provide visual and auditory isolation to the under-examination space and independence from the physical one. Also, the hand control devices (e.g. joysticks) can replicate the real-world movements to their equivalent to virtual-environment movements, necessary for manipulating building elements (e.g. columns, bricks) or others. In total, the various devices which are used as extensions of the human body's sensory organs have led to a new dimension of the available tech-centred subject material for students and educators alike.

The current technological advancements are aligned with the increasing need of getting immersed into construction sites, rather than in more simple graphical representations of building structures of the past. Meaning the full workplace environment of a building under development taking place in a plot of land, including safety signage, heavy machinery, temporary structures etc. and most importantly construction crew members, in a more dynamic manner. That different practise has become more popular since it not only provides construction knowledge as it used to happen with its simpler precursors, but furthermore a cognitive background for students of engineering about the work-environment in a more authentic way. The offered authenticity provided by IVR in construction sites rather than: 1) NIVR and SIVR in construction sites, but even 2) IVR only in building structures, assists them way more in terms of bridging the perceptual gap between their present academic and their future professional development by providing a prior exposure to the construction work environment and thus familiarity with their upcoming work challenges. Let alone the virtual workplace equivalent can lead to their smooth transition to their eventual occupation in their future careers.

A modern example presented by Bashabsheh et al. (2019) in the context of the architectural pedagogy for building constructions, tested the use of a VR software, via a sample of students of Architecture. Its immersive display (by a headset) allowed them to view a 4D graphical model of a house in construction through several phases like the placement of the formwork for the necessary foundations. In relation to the wide use of graphical representation of models, it is worth mentioning that in modern immersive types of VR in learning for building constructions BIM models are commonly used as spatial basis. Their employment in this context is familiar from the early NIVR visualizations and at present BIM-based IVR aided construction education represents one of the state-of-the-art of fully immersive VR experiential simulations of tours in construction-related environments in a dynamic manner. As Huang argues (2021) Extended reality (XR) -including VR- offers solutions to the BIM weakness of unrealistic presentation of information in terms of scale, as the user may have the possibility of walking into a project but not on a human scale manner. So, the collaborative use of BIM and IVR technology can lead to data-rich (total) surrounding environments that also involve the progress of work reflecting to the model’s morphology under examination. This cutting-edge type of IVR has its roots in the early 4D CAD based NIVR, as it similarly provides a 3D model enhanced by constructional project data which is valuable for the better comprehension of the students. As the specific review started with the initial example of the NIVR approach of CAD software in construction studies, it should be mentioned that they can also contribute to the modern more complex immersions. Indeed, most of these types of software that are based on BIM, such as Autodesk Revit or Autodesk Civil 3D provide the opportunity - by VR plugins- to extract the model in a suitable format to be displayed with a headset (Huang, 2021).

In the case of these more complex IVR scenarios, a virtual space is offered for full immersion -completely sensory isolated from the real environment- rather than projection, where the user maintains a strong feeling of being present inside it. One such example is the one presented by Han et al. (2022) about testing a VR-driven learning system using headset and other devices to get into a graphical model of a construction site in comparison with the traditional teaching based in textbooks, with the assistance of university students -without efficient site experience- as experimental participants. Their implemented construction site model was able to provide a realistic approach of virtual scenes where the students could - with first person views- navigate, interact with the overall setup (using a control) regarding the accomplishment of the site’s safety-related tasks.

On the other hand, because of the specific educational field being based on an essential need for optimum realistic simulations, there has been a growing need for life-like IVR environments which are aimed to provide an authentic experience as a treat to the lack of real construction-site experiences in the traditional educational settings on an academic level. That need is being addressed by using virtual spaces that derive from actual captured construction sites, that can be in every part of the world. Therefore, in a lot of modern studies correlated to this topic, it appears that there is an increasing interest in using 360-degree photos or videos of a building construction site (that currently exist or existed in the past) of the actual world. Rather than the graphical representations of the past, today’s advanced capturing equipment have led to high-resolution VR depictions and therefore immersions in the source constructions sites, as well as in their work-ambience. Of course, there is a significant number of graphical approaches of construction site models that incorporate virtual human figures of workers dressed in uniforms (helmets etc.), much like the gaming Non-Playable Characters which are placed for enhancing the content narrative and bringing the virtual environment to life. Sometimes in the cases of Serious Games and Game-based Learning the students are actively engaged in them, as they provide instructions, guidance, serve as hint and quest-givers and therefore facilitating their game-driven experience.

Yet, even in these cases, the virtual construction sites do not offer a full realistic approach, whereas they provide a game-looking space, in which there is a possibility that the aspect of entertainment overlaps to some extent the overall didactic aim. Since the target of this research is the evolution of the described educational methodology to the full-immersive editions, it is worth mentioning that realistic immersive experiences are now easier and more upgraded than ever, due to the progress of the 360-degree capturing mechanisms. This is closely related to the subjective basis of an individual's immersion to such an environment because the user recognizes the realistic spatial reference. So, many of the modern widely implemented true-to-life IVR environments depict the authentic immaterial objects that are necessary (e.g. structure), but in addition to that they integrate the recorded crew member human factors (visually and auditory) operating tasks, using heavy machinery etc. or even communicating with each other (e.g. task information sharing). In these cases, immersion is optimized, because as mentioned earlier it depends on the subjective perceptual state of an individual being already predisposed to become disassociated from the real and become immersed into the virtual. Therefore, the most possible realistic depiction of construction workspaces can trick their perceptual limits leading to the ultimate version of their immersion, so to fully obtain the sense of being present while they are only actually viewing and interacting across mediums.

Today's advanced capturing technologies can provide realistic portrayals of any space given, with cutting-edge capabilities such as higher resolution rather than the ones of the past, addressing the above-mentioned need for authenticity towards real-world spaces. The resulting displays in suitable formats can be imported into virtual engines (even in the most affordable and user-friendly ones) that enable their role as a basis for the creation of an IVR environment. Huang (2021) presents two of the many ways, the low-cost method of joining photos to a panoramic one with mobile apps and the capture technique with a 360-degree or omnidirectional camera in which users can be immersed. According to this method Feng et al. (2022) added that it is the fastest way of creating a virtual environment, that needs less computational demands. But the most significant constraints are the lack of manipulation of the photo-captured objects and walk-through is based on predefined routes through point of teleportation. Modern representative examples of the use of photo captured mechanisms are the ones presented by Eiris (2021), Shojaei (2021) and Kim & Leathem (2018) who all used 360 panoramic displays based on captures from construction sites of the real world.

The authentic 360-degree depictions of the construction sites in question can be imported in game-engines like Unity and serve as backgrounds for the development of scenes in which graphical objects (e.g. start buttons, progress bars, point system, timers) related to game mechanics that in sequence enable dynamics and so aesthetics which can be layered to the scenes. The produced mixed environments can lead to a gamified and full immersive educational scenario to engage engineering students and facilitate academic educators, who for a long time could not address mainly the: 1) lack of ready-for-use full construction sites and indeed in lifelike editions and also 2) lack of motivation-boosting strategies that rather than the fun aspect offer additional learning outcomes and indeed in an indirect game-full manner.

The basis of Serious Games and Game-based Learning in learning for building constructions

Having outlined the gradual evolution of VR practices in experiencing construction-related spaces, the authors proceeded to an overview pertaining to the evolution from earlier common commercial games and game-oriented educational approaches to Gamification, which stands as the most cutting-edge part of this game-driven methodological ecosystem. As the center of this ecosystem is gameplay it is worth beginning with representative examples of actual games which provide knowledge about constructions -but not as their main aim-, differentiated by any related method with a targeted use in typical educational settings.

Quite an old example found at the end of the previous century in 1996 which was related to the game Tonka Construction, released by Hasbro Interactive and created by Vortex Media Arts. It could be supported on the Macintosh platform in CD-ROM form, with the supplemental use of a keyboard and mouse, as singleplayer. This game for children aimed at introducing different construction projects within five environments, uses of necessary vehicles for the completion of seven projects, leading to the claim of the title of Master Builder (Moby Games[1]). Another construction-themed game is the Construction-Deconstruction one, which was released in 2003 by ValuSoft Inc. in the United States of America, developed by Gabriel Interactive Inc a. This single-player CD-ROM PC game was created for the Windows platform, with keyboard and mouse as main input devices. This construction simulation game focused on the utilization of seven different types of vehicles in nine different construction site environments for the completion of distinct projects (Moby Games[2]). A later example from the previous decade is Professional Construction-The Simulation, released by United Independent Entertainment in 2012 and created by VIS-Games. In this game heavy equipment and vehicles were utilized for the construction of road networks, offering a number of different challenges such as road repairs, excavations etc. (Steam[3]).

Rather than games that primarily developed for entertainment, there are a lot of Serious Games that by definition have as a main goal a specific serious purpose. Various studies of Serious Games implementations in construction health, safety training and skills development in comparison with traditional education and evidence from empirical research showed the former as more effective (Feng et al., 2022).

A related popular Serious Game is the VCS4 simulation game which involved learning about the design and management process of a construction project. This game was targeted at engineering students emphasizing on building elements and methods as well. Game tactics such as challenges, time limitations among others structured and drove the overall experience of the user (Castronovo, 2018). Initially, it was based on a 4D CAD system dependent on a 3D building model (in 3D game engine interface) about a construction project. Another example in the beginning of the last decade presented by Lin (2011) was about a 3D video game called Safety Inspector which provided a safety training environment for checking for

[1] https://www.mobygames.com/game/14902/tonka-construction/
[2] https://www.mobygames.com/game/13164/construction-destruction/
[3] https://store.steampowered.com/app/502450/Professional_Construction__The_Simulation/

hazards which was tested in the Department of Construction Management at the University of Washington.

On the other hand, Game-based learning approaches are also widely used like the one introduced by Zhang (2017) which was basically a construction site investigation game for civil engineering students in a 3D highly game-looking graphical environment that involved questions and tasks among other gaming features. An additional very modern game-based approach was presented by Lawani et al. (2022) and was about a game-based construction site inspection by providing simulation of the use of drones flying around a relative 3D graphical environment able to be displayed in web browsers. Furthermore, a game-based learning for building constructions approaches can be applied using a pre-existing common game (e.g. studying building projects in Minecraft) when integrated correctly into an educational context, as its key-factor is how this game is being utilized.

Modern Gamification's practices in learning for building constructions

Nowadays, researchers and stakeholders of education are more focused on integrating elements and practices that derive from Game-design in the innovative framework of Gamification. So, there has been a transfer of the research interest of the modern pedagogical approaches mainly from Serious Games and Game-based Learning to Gamification. In other words, over the last years there has been a shift in the way educators lend and use Game Design traits mostly in terms of their proportion and their incorporation. So, it appears that the former game-oriented learning means have been reshaped to more subtle inputs in educational scenarios, which emphasize more on the additional learning outcomes, rather than the playful character of the user's experience.

In that direction Serious Games and Game-based Learning in construction education paved the way gradually for the gamified approaches or even the remote visits in building structures and construction sites. Particularly, as it pertains to the pre-existed independent employment of VR in construction education, Gamification can stand as a collaborative tool in the context of their methodological synergy. The synergy in question alters significantly in relation to the different types of VR, mostly concerning the level of the students' immersion in each construction-related space. Indeed, in relevant studies and applications the incorporation of Game Mechanics, Dynamics and Aesthetics in Virtual Learning Environments, occurs at a non-immersive, semi-immersive and full-immersive level. Yet, these factors are not necessarily dependent on virtual reality, for instance Reyes et al. (2021) formed a contest-based gamification activity of a test with photos and filling the gaps, about building material damage.

Such an example in IVR was showcased by Wolf et al. (2019) using mobile VR for construction training in a graphical construction site with the ads of Gamification's elements as score, time limit etc. related to the safety awareness training. Another gamified form in a graphical representation of a construction site was shown by Mora-Serrano et al. (2021) who used an IVR system with adds of gamification elements like a scoring system and a health level counter. One very modern application of IVR combined with Gamification practices presented by Kraus et al. (2022) using a prototype model of basement wall construction details, was experienced by students on immersion with HMD devices. Moreover, in this environment gamification tools were placed like tables, hints, quiz modes. This example is very interesting as it provides immersion to a plain environment which is used as a scene for a focused view of a detailed case. Another example of being present in a realistic construction site was presented by Szóstak et al. (2024) and had to do with the usage of Unmanned Aerial Vehicles for the construction in scenarios that also implemented Gamification techniques. For example, there were questions and immediate feedback about the win and loss. Finally, as the current historical perspective initiated from the NIVR CAD, it should be mentioned that this early type nowadays can also contribute to the synergy under examination. In fact, with the spread of the software of 3D modelling editions of Autodesk like Autodesk 3ds Max or Autodesk Maya, it is possible to use virtual environment with the supplemental use of game scenarios (Feng et al., 2022).

Yet examples like the above do not offer a full authentic sense of being in a real construction site, a concern that as was said paved the way for the use of environments made by captures which can also be gamified. One Gamification application in a platform-based VR was examined by Eiris et al. (2020a) and was about gamifying the construction safety training in both a graphical and a 360-degree panorama training space, overlaid with game elements like informative tables, questions etc. regarding safe-related matters. Another example combining the photorealistic presentations and the graphical game traits was presented by Eiris et al. (2020b) who subtly gamified a virtual construction site created by 360-degre panoramas served for the placement of tables and icons, animated virtual guides, narration etc. which could be experienced via a VR headset.

Alignments and modifications throughout time

The historical view towards the educational implementation of gamified IVR tours in construction sites was outlined by the presented scenarios and pointed out distinct similarities and alterations. These have to do with technical or conceptual factors that either remained unchanged or were modified for the overall optimization of the IVR experiences in question. The following points cover the fundamental traits that gradually structure the latter as most importantly the representation tactics, the immersion mode and the incorporation of game-linked elements, ideas, appearance etc.

Firstly, to date such methods are aligned with the use of the tested principles of their precursors concerning the model's representation techniques. Even in the era of the progressed immersion with available software and hardware that are capable of providing the needed realism, researchers still do not only utilize authentic life-looking environments but also graphical and rendered ones. Today's researchers and educators in the construction pedagogy employ both graphical and photographic models to establish their learning environments and execute different didactic approaches. Yet, both of these different display approaches are currently established in the idea of the modification of the past use of simple structures to full and dynamic constructions sites. The evolving interest in using complete constructional workplaces is based on the former concepts which served as foundations in experiments with the aim of integrating the on-site ambience, rather than just the building elements, operational tools or constructional sequencing.

Alternatively, as far as the modifications are concerned, it appears that there has been also an effort in borrowing tested and successful techniques from the most familiar forms of the Serious Games and Game-based Learning, but with alterations. That shift regards the redefinition of the way game-design elements, thinking, strategy etc. and conventional factors, course material coexist in the learning context and let alone the immersive one. That gradual reconstruction of the above led to a similar change to the general game-looking environment to a more realistic one, with the subtle overlaid placement of Gamification's traits.

Regarding the immersion level it seems that a plethora of NIVR approaches of construction sites -which are still in use- set a lot of valuable foundations for the IVR as they were the basis of how game-elements can be integrated in several virtual environments. In addition, in these simple desktop-based strategies another innovative shift took place which was the alternative way of using construction sites, even the photo-captured ones that bring their overall ambience, instead of simpler building structures. Two practices that are increasingly found in the modern IVR approaches, but in a more technically advanced manner.

Finally, as the basis of these applications is strongly dependent on the technical background it is worth mentioning the increasing use of advanced devices of spatial and auditory isolation, aligned with the aim of achieving the high form of immersion. But regarding the hardware involved it seems that today's developing BIM models to be used as a basis for IVR environments has it roots in the early CAD development progresses for the NIVR applications.

Conclusions

The aim of this research was to explore the historical background towards the evolution of today's gamified immersive visits and experiences in virtual construction sites. Having reviewed representative educational scenarios of its game-related and VR-related precursors, the historical continuity of the method under examination was drawn. It was thus clarified that it is technically and conceptually based in accordance with established methods of the past with similarities but also alterations for optimizations where it was deemed necessary or more practical.

It is now clear that the full immersive level of this gamified learning tactic stands not just as an independent method, but as a product of historical evolution of simpler applications in terms of distinct factors. That gradual multidisciplinary evolution was set on the grounds of providing more authentic experiences for the students that imitate the real construction sites. Indeed, in the best possible manner using more sophisticated types of software and hardware, emphasizing on the wearable devices like HMD.

Rather than the case of immersion and in the same direction of providing the needed authenticity, virtual environments used in modern scenarios depict dynamic construction sites in contrast to the most common use of simple structures. Indeed, using even real-world construction sites captured (360-degree), in contrast to the earlier graphical displays.

Concerning the integration of game-design elements, it seems that such modern applications are more and more attached to the more subtle Gamification, which have been gradually disassociated from the rich game-look and gameplay-oriented uses in Serious Games and Game-based Learning, so as to now seem more targeted at the educational rather than the gaming-related experience.

Yet rather than the above modifications, similar practices now used in modern education still cover the whole spectrum of VR and game-linked tactics and for instance run in NIVR or in the context of Serious Games. So, it seems that their modified nature to altered practices did not lead to their non-use. On the contrary, there is still justified educational reasoning for their utilization where necessary.

Finally, the specific research provided valuable points, which should be examined in supplementary stand-alone research of a comparative analysis between the uses of Serious Games, Game-based Learning and Gamification for learning in IVR construction sites, via primary level research on a sample of engineering students.

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