Gamification and virtual reality immersion in the education of future engineers in the AEC sector

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The article deals with BIM education issues in the field of increasing the degree of user involvement in the learning process, using the example of the use of virtual reality and gaming tools.

Building Information Modeling (BIM) is one of the key digital technologies used in the architectural, engineering, and construction (AEC) sector and has recently taken lead role in the field of higher education for AEC [1]. Academics or educators have the responsibility to update the AEC curriculum to provide students with the most recent digital skills and to foster their capacity for developing broader skills in the rapidly evolving environment, which is undergoing a radical and dynamic change toward raising efficiency in design and construction [2]. However, it is not only the content of the curriculum that counts, but also the form in which the information is provided. Obviously, the more attractive the form of delivery is, the more the students' involvement increases [3]. The instructor should be also aware of how important a friendly learning environment is for stimulating students' deep learning [2]. Commitment is the key to growth no matter what benchmark is established. From the smallest scale of involvement in personal development to the involvement of humanity as a whole in such engaging topics as environmental protection. Controlling user involvement is the holy grail of all kinds of fields from entertainment [4] through school [5] to politics [6].

Immersion and gamification

Engagement is not only about active action, but also about dedicating one's attention. Capturing the user's interest is one of the goals of existence for different types of media, such as text, sound, graphics, animation and video. In the world around us, one can observe a constant evolution of multimedia content combining various of the above-mentioned media to increase the involvement of the audience of the content. The peak form of such engagement is immersion, which is related to a mental state that is very captivating and involves the focus of mental resources during a certain activity [7]. By involving the various senses and leaving little or no space for external inputs, it gives the impression of complete absorption in the content presented. This is why the concept of virtual reality is gaining more and more attention today.

A significant section of the world's population is now interested in the video game culture, and parents are also joining their children in their gaming activities. The rising interest in gamification, or the usage of video game components in situations other than games, runs parallel to that [8–10].

Fig. 1. Screenshot from BIMaHEAD Clash Detection Module in spatial.io; source: authors

Fig. 2. Screenshot from BIMaHEAD Clash Detection Module in spatial.io; source: authors

In writing about video games, "immersion" is one of the most often used concepts [11]. As the primary goal of both game designers and players, it has drawn a lot of devoted academic study in an effort to comprehend the psychological consequences of this impact. It is broad enough to take into account a wide range of activities in other media [12]. Researchers have tried to harness the potential advantages of game designs and virtual reality in boosting user incentives through gamification in an effort to raise users' pleasure with technology applications [13,14]. In recent years, gamification has been applied in various professional fields such as employment [15], commerce [16], health [17], and the field of education [18].

Gamification is the incorporation of game components, primarily those from video games, into contexts that are not games in order to increase motivation and engagement in learning. Many students who feel alienated by conventional teaching approaches might find some relief in the application of gamification in an educational environment [19]. The fall in student motivation and engagement that the educational system is now experiencing may partially be resolved by the application of gamification [20]. Particularly, gamifying college course material and curricula might have significant positive effects on the campus environment [21–23]. This could complement existing graduate recruiting tactics [8]. Identifying this promising potential for increasing student engagement through gamification was the starting point for exploring its implementation in teaching aspects of the engineering and technology field at the university level. The chosen topic as the basis for the research was practical application of gamification in the AEC sector.

Methodology

In line with the experiences described in the literature, an e-learning course was developed using gamification. The course was created as part of the European BIMaHEAD project (Building dIgital coMpetencies of students and teacHers in construction related degrees & incrEasing digitAl reaDiness of EU universities) under the Erasmus Plus programme [24].

The BIMaHEAD Project, carried out by five institutions from France, Germany, Sweden, North Macedonia, and Poland has been designed to all those interested in gaining practical training and raising their specialist competences, mainly to architects, designers and engineers engaged in the construction industry, as well as students majoring in these fields. The BIMaHEAD Project Partners have developed five e-learning Modules addressing the following topics:

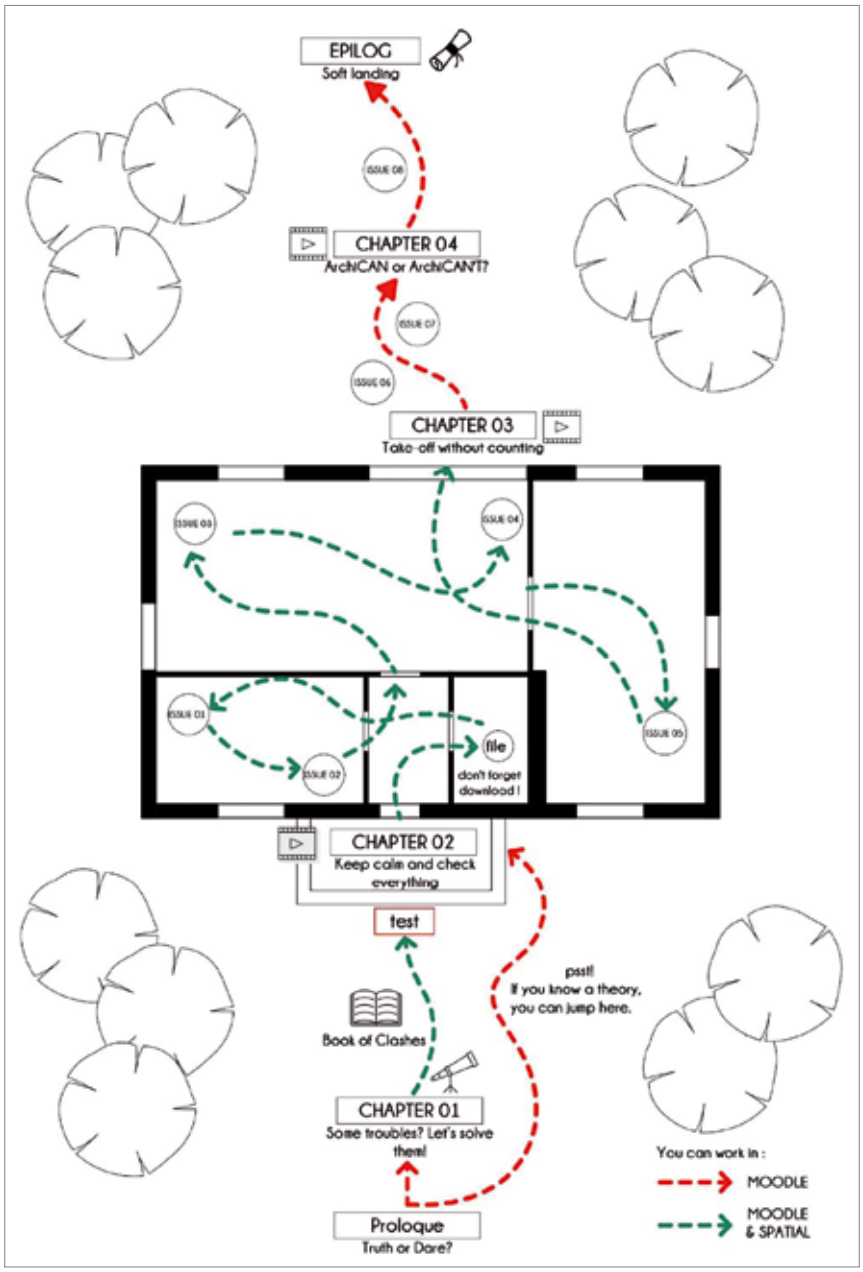

Fig. 3. A map showing the paths through the game learning experience in BIMaHEAD Clash Detection Module; source: authors

Fig. 4. A screenshot from CHAPTER 02 of the BIMaHEAD Clash Detection Module; source: authors

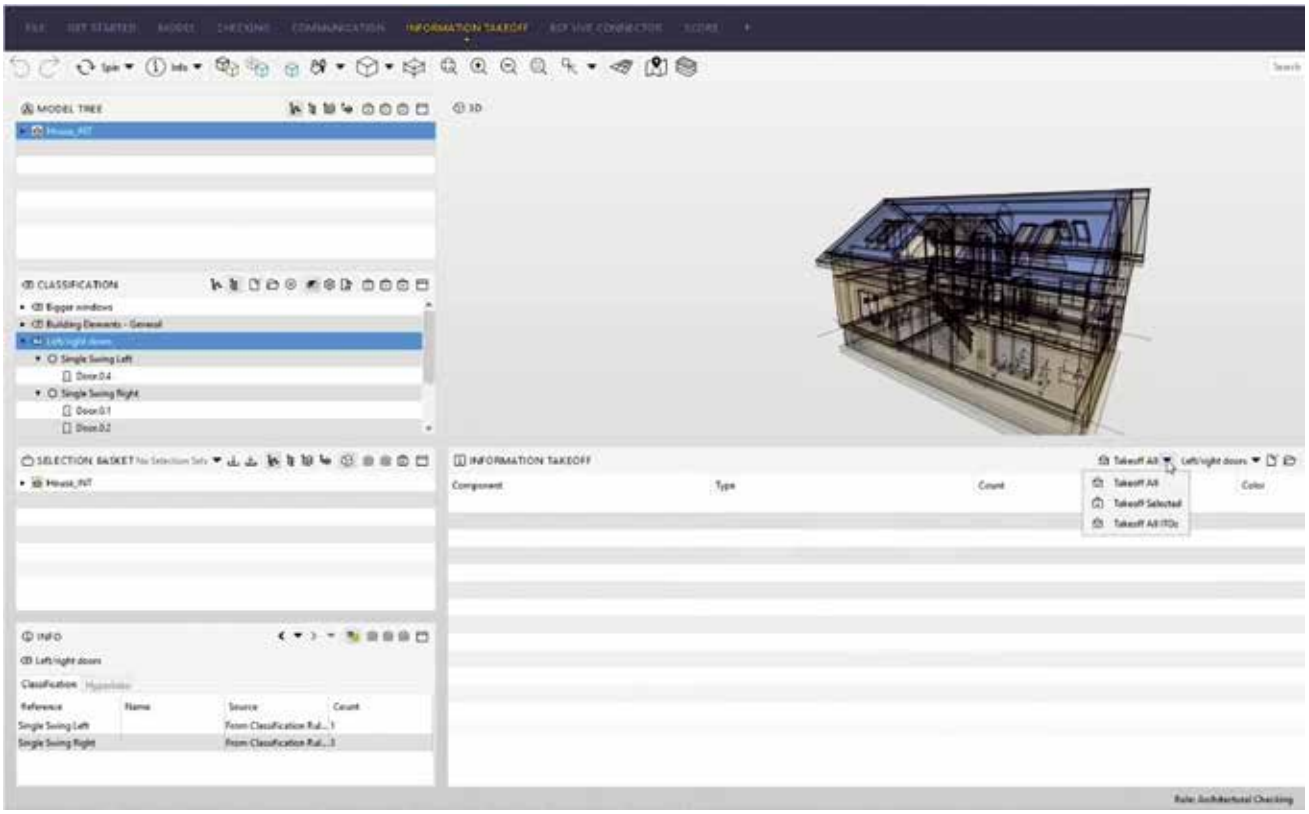

Fig. 5. A screenshot from an exercise in CHAPTER 03 of the BIMaHEAD Clash Detection Module; source: authors

BIM Form Finding from Environmental Constraints (developed by ENSA Nantes, France)

BIM Modelling (developed by HCU Hamburg, Germany)

Clash Detection (developed by TUL Lodz, Poland)

Digital Calculation (developed by HH Halmstad, Sweden)

BIM Energy Calculation and Evaluation (developed by IECE Skopje, North Macedonia)

All modules were designed in readiness to e-learning, but special emphasis on gamification was specifically addressed in The Clash Detection Module. Experiments and observations described in this article were made on its basis. This module provides students with advanced knowledge and skills in Building Information Modelling (BIM) that is focused on detecting clashes and collisions in AEC projects [25]. By detecting errors in projects at the early stage of design, engineers save resources, materials, costs, and time and by that, they contribute to a more sustainable built environment. The Module introduces theory and practices through sequences of tasks to gain skills needed for future architects and engineers in the AEC sector [26].

Fig. 6. Photo of students exploring the virtual world during the testing phase; source: authors

The main inventive element in this Module is the innovative user interface in the form of a virtual world explored by a student-directed character (fig. 1., fig. 2.). There is a three-dimensional model that is used in which users observe a world depicted from the back of a guided character and by moving around the theory of clash detection is explored in the form of a computer game. There are also instructive interactive videos that support the learning process.

The uniqueness of the Module is based on three main features:

1. The pedagogical method: it is designed to lead a learner through a game with levels to be achieved and scores to be collected. Successful completion of the Module may be rewarded with a certificate. Such method is not common in higher education learning environment, and what is more, it addresses the needs, and the way young generation acquires knowledge and skills most efficiently.
2. The independence of the Module from the physically assisting teacher. Besides, learning by doing and self-assessment are the key elements of the Module.
3. The uniqueness is visible also in the content which offers only useful real-based knowledge and carefully designed practical exercises.

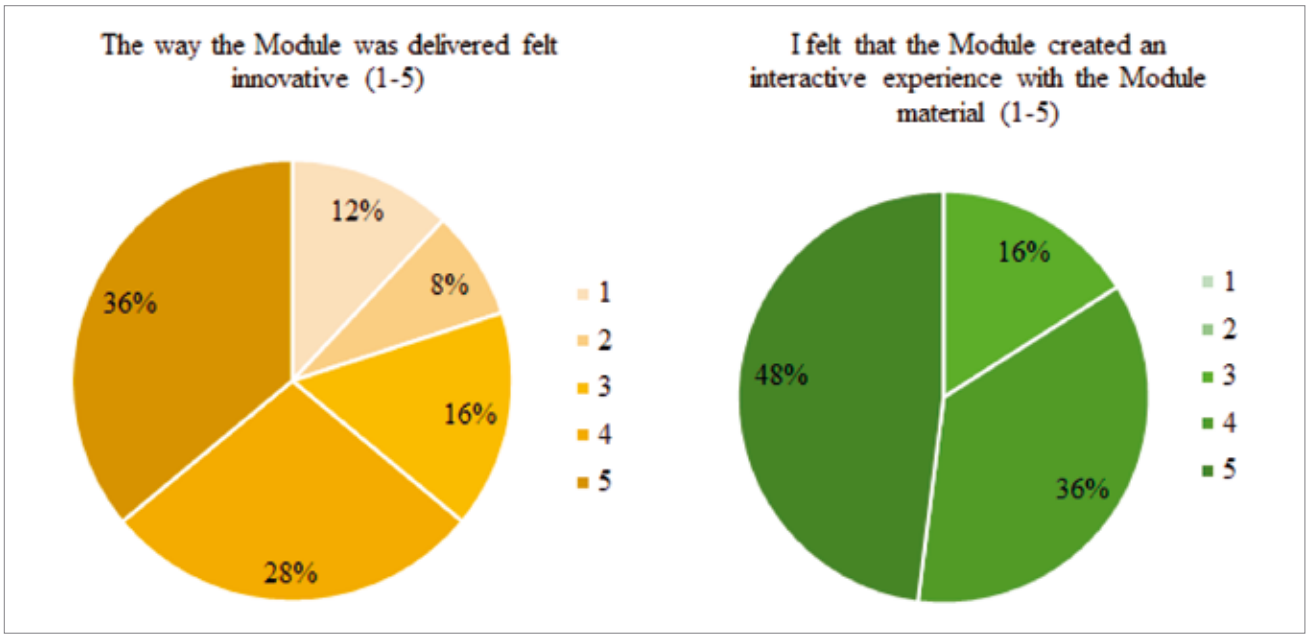

Fig. 7. Graphs showing the percentage share of survey responses to the course innovativeness and interactivity questions; source: authors

Structure of the Module

The Module starts with a brief introduction to the content and prerequisites required to take the Module.

Then, the following parts go as follows:

Prologue: Truth or Dare?

CHAPTER 01: Some troubles? Let's solve them!

CHAPTER 02: Keep calm and check everything

CHAPTER 03: Take-off without counting

CHAPTER 04: ArchiCAN or ArchiCAN'T?

Epilogue: Soft landing

At the end, the Continuative BIMaHEAD Modules are proposed to link all BIMaHEAD Modules. The course, like computer games, has a certain predetermined pattern of task performance presented to the participant in the form of a diagram-map. However, the way of exploring the world leaves the participant a certain degree of freedom, it is pre-divided into two levels grounded in a pedagogical approach. The first one is based on theory of clash detection and the second one considers practical parts (fig. 3.). Students, based on the model, had to indicate, for example: which beam intersect with roof or how many collisions were found between building elements. In addition to finding geometric collisions based on built-in and custom rules, an inspection of the model's structure was also performed, and material lists and presentations of the collisions found were prepared. The questions were e.g. choose the correct answer, indicate true/false statements or complete the sentence.

Results

The testing phase was one of the major milestones of the whole Project. The BIMaHEAD team at TUL, Poland, called it beta-testing of the product. Testing the product by users who had never seen it before was crucial for collecting genuine and accurate observations and reliable feedback from participants (fig. 6.). What is more, none of them had a prior knowledge in clash detection domain or software skills. All students were given the same time for the experiment. Additionally, at the end of the testing time they were asked to fill an anonymous questionnaire that allowed for grading the user experience and writing opinions.

From the product design and e-learning experience development perspectives, the questionnaire had a prominent value. Participants delivered significant feedback that allowed authors to reflect upon user experience and to develop the product.

What was the most appreciated was the idea of using the spatial.io virtual space, presenting 3D examples of collisions and tasks to be performed. With the help of the platform spatial.io, one may design your own virtual avatar using popular 3D formats, manage events in real time, and engage in social interaction in a metaverse. The platform created for BIMaHEAD, although somehow distracting, made learning more attractive, introduced an element of fun and encouraged further exploration of the Module (fig. 4.). Students compared learning in the Module to a video game. They pointed out that thanks to the Module they discovered, apart from dedicated clash detection software, new possibilities of the well-known BIM program (ArchiCAD). They appreciated the theoretical part, which contained explanations of concepts. They liked interactive, replayable videos, enriched with comments and questions because it kept learners focused (fig. 5.). Students also found it sensible to start learning in the Module with a knowledge test. It is desirable for students to receive a certificate for completing the course.

Discussion

The survey, which users were asked to complete at the end of the testing phase, was divided into closed and open questions. Among 19 the closed questions, the innovation of the modules had to be rated on a scale of 1 to 5 (fig. 7.). Collected results show that 36% of the respondents rated the innovativeness as 5 and 28% as 4. Then, 48% of the respondents rated the degree of interactivity of the course as 5 and 36% as 4 (fig. 7.). The aforementioned questions were most concerned with impressions of interactivity, and other questions included e.g. impressions regarding the potential of clash detection in practical applications. Among the answers to the open questions, there were comments on the distraction caused by the interface, but most of the answers rated the possibility of using avatars as interesting. The ability to explore content independently was appreciated. There was a strong preference for a character-based learning space, making it engaging enough to hold attention and pay attention to the examples presented. The subsequent tour of the building also made the experience much more enjoyable.

From the observations made by the event organisers, the world accessible from the avatar level was at first a major distraction, especially as the students sat together in the course, in the same activity room (although one computer per one student) so virtual experiences were exchanged live. In addition, students were able to see each other's characters in the virtual world, so they mutually explored each other's abilities, which, in addition to walking and jumping, also included various kinds of gestures and dancing. On the other hand, the possibility to socialise in the virtual world attracted the students' attention and was a good starting point for

discovering the substantive issues hidden in the house model and its surroundings. The observations made confirmed the position [19] that motivating people is one of the advantages of gamification. The operation of the virtual world posed no problem for the students.

Observing users' interaction with each other, it would be worthwhile to conduct a broader study for courses that constitute a series of recurring meetings, e.g., on a semester scale, when the impact of novelty would be diluted in favor of an increase in the user experience. Providing the user with the opportunity to take an entire course related to the subject involves the challenge of providing dozens of hours of " game-playing," that is, converting a large amount of educational material into a gamification-friendly character. It is also worth verifying the ability to practically apply the knowledge gained through this method.

Conclusions

In light of contemporary research and observations of the world around us, gamification is one way of increasing user engagement and capturing user attention. Additionally, it is a good tool to increase the user's immersion in the content presented, and given that this content can have educational value, the use of gamification in teaching becomes a natural choice. Although the preparation of such material and virtual environment is time-consuming and requires additional skills from the teacher, the material created can be used repeatedly. Giving the user a certain degree of freedom to explore knowledge makes it feel less forced and more fun. If a student's right to learn is correctly identified and interpreted, and in addition is not confused with an obligation, knowledge is better absorbed by the brain [27]. The experience of teaching engineers in the AEC sector can also be transferred to the commercial aspect of the architect's work. Presenting projects in this way can be an innovative distinctive feature of an architect's work. By being able to visit a custom-designed building themselves, the client can get to know it better, experience it and provide more complete feedback.

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PRAWIDŁOWY SPOSÓB CYTOWANIA
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Abstract: The article deals with issues in the field of increasing the degree of user involvement in the learning process, using the example of the use of virtual reality and gaming tools. The research was conducted on the example of a course for future engineers in the building sector on clash detection in Building Information Modelling. In the course, the educational content was presented through a virtual world, and it was possible to explore by an avatar controlled by students from a third-person perspective, as in computer games. This was met with an exuberant response from the students and consequently led to an increase in their involvement in performing the prepared educational tasks. The collected experience can also be used in commercial presentations of designed buildings.

Keywords: Building Information Modelling, clash detection, AEC sector, gamification, virtual reality

Streszczenie: GRYWALIZACJA I IMMERSJA W RZECZYWISTOŚCI WIRTUALNEJ W KSZTAŁCENIU PRZYSZŁYCH INŻYNIERÓW SEKTORA AEC. Artykuł podejmuje zagadnienia z zakresu podnoszenia stopnia zaangażowania użytkowników w proces nauczania na przykładzie wykorzystywania wirtualnej rzeczywistości oraz środków stosowanych w grach komputerowych. Badania zostały przeprowadzone podczas przygotowywania oraz przeprowadzania kursu dla przyszłych inżynierów sektora budowlanego z zakresu wykrywania kolizji w modelowaniu informacji o budynku. W trakcie kursu treści edukacyjne prezentowane były za pomocą wirtualnego świata, a ich odkrywanie możliwe było za pomocą awatara sterowanego przez studentów z perspektywy trzeciej osoby, jak w grach komputerowych. Spotkało się to z żywiołowym odbiorem studentów i w konsekwencji doprowadziło do wzrostu ich zaangażowania w wykonywanie przygotowanych zadań edukacyjnych.

Słowa kluczowe: BIM, modelowanie informacji o budynku, wykrywanie kolizji, sektor AEC, grywalizacja, wirtualna rzeczywistość