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DIGITAL LITERACY TO DEVELOP LONG-TERM IMPLEMENTATION OF DIGITAL TWINS

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Abstract

This article explores how the challenges and opportunities are manifested in educating with and about the Digital Twin in the construction industry. The exploration is conducted with focus group interviews of students from two Danish educations seen from the theoretical perspective of challenging the students within their zone of proximal development while utilizing the digital twin as a semantic learning material and investigating their digital literacy regarding the digital twin. The findings indicate several opportunities to improve the learning sessions for the students to improve how they learn to understand and apply it to their contexts.

Introduction

Building Information Modeling (BIM) has provided construction education with a robust set of digital tools, which enable students to work with data to create qualified and well-founded decisions, apply information, make calculations, simulate solutions, etc., based on the BIM model. However, the work with BIM needs to develop to reach the next level of implementation. This long-term implementation transitions into what is conceptualized as working with the Digital Twin.

Deng et al. (2021) suggest looking at the construction industry's digitalization process as it has been focusing on BIM but is now progressing into talking about the Digital Twin emphasizing new skills needs. For example, working with a Digital Twin in the construction industry entails working with information provided by external sources, such as sensors from existing buildings, that can provide a more efficient feedback loop to inform, e.g., better design decisions (Deng *et al.*, 2021).

The interest in digitalization and the Digital Twin as an extension of digitalization in the construction industry has increased the later years (Molio, 2020; National BIM Standards, 2020). As a result, there is an increasing need for digitally literate students (Anderson et al., 2019) Suwal et al., 2014). The students must therefore be competent in understanding and using today's (and tomorrow's) digital tools. Also, digital education allows them to work innovatively with the Digital Twin and develop new working methods, ensuring a uniform data exchange, minimizing errors, achieving intelligent quality assurance, and increasing buildability, thus creating the digital construction of the future.

To meet the new digital needs of the industry, digital skill sets need to be integrated into educational institutions. The technical competencies deal with modeling skills, whereas the conceptual competencies deal with the Digital Twin skills in the process, method, interdisciplinary collaboration, and forms of collaboration. For the students, it is typically the technical competencies that are given the highest priority, whereas, for the industry's further development, it is the conceptual competencies that are most important.

Due to digital tools' constant and rapid development, more technical competencies are needed concerning long-term implementation and development (Abdirad and Dossick, 2016). To facilitate the long-term implementation, two parts are required – standardization and experimentation with new solutions and tools, as it is a keyway to learning and developing new methods (Miettinen and Paavola, 2014).

To ensure the continued and long-term development of learning about and with the Digital Twin in the education sector, there is a need for conceptual competencies, digital literacy, and exploratory learning style to become the cornerstone through value-creating experiments. This paper investigates how students from interdisciplinary educational backgrounds approach the work with Digital Twins.

A focus group interview was conducted to explore this work, making the students mirror their answers and reflections to find a joint construction of meaning. The study shows the necessity of digital literacy, including creativity, critical thinking, and practical knowledge, as a part of the learning design. The paper presents the potential for further developing the learning design for including the Digital Twin in the construction industry education. The importance of combining training in digital tools and processes to understand how the data works and develop, visualize, and evaluate data. The future learning design must embrace continuously evolving BIM technologies, making students aware of the needed processes.

The Digital Twin in the Construction Industry

One of the most talked about "future" technologies to be implemented in the construction industry is the Digital Twin. The interest in Digital Twins has increased greatly since 2019. Still, its practical implementation has been challenged by a lack of cooperative approaches to working together, limitations of data sharing, and project inefficiencies (Hosamo *et al.*, 2022).

Using Digital Twins embeds many different sub-technologies, such as internet-of-things, machine learning, and simulation models, to provide a near-real digital representation of a building that can be used for many other purposes. The concept of Digital Twins dates to 2002 at the University of Michigan, where the Product Lifecycle Management center was created. Here the first courses of PLM were established that conceptually laid the foundations for the Digital Twin, however, calling it mirrored spaces model.

The term Digital Twin was mentioned for the first time in 2011 when the concept was expanded (Grieves and Vickers, 2016). There is some confusion about what Digital Twin technology is, and some even need clarification about what constitutes a Digital Twin (Hosamo *et al.*, 2022). Nikolaev et al. (2018) argue that one of the main challenges of educating students in Digital Twins is the interdisciplinary nature of the technology that contrasts the typical monodisciplinary nature of many engineering disciplines.

There are many interpretations of the Digital Twin Concept in the industry and the research literature. Sacks et al. (2020) state that many authors use the term Digital Twin simply as a synonym for BIM models, while other authors, e.g., Tao et al. (2019), state that digital twins have three main elements: a physical artifact, a digital counterpart, and the connection that binds the two together.

Digital Twin technology is an essential concept in the construction industry, as it provides a near-real digital representation of a building that can be used for various purposes. However, its implementation has been challenged by a need for cooperative approaches, limitations of data sharing, and project inefficiencies (Feng *et al.*, 2021).

Educating students through Digital Twins is challenging due to the mediated and interdisciplinary nature of the technology. With the increasing interest in the technology and its practical implementation, it is becoming increasingly important to understand and develop digital literacy in relation to Digital Twins to implement and utilize the technology in the industry effectively. The following section will focus on framing the Digital Twin into what it means to educate about digital literacy.

Digital Literacy

Scaffolding learning through Digital Twins

This section describes the theoretical notion of a proverbial 'scaffold' for the learners to stand on while reaching for complex topics. The scaffold is either built by the teacher through the teachers' pedagogies, activities and rigor or nested in learning material. However, in everyday teaching, the scaffold is often a combination of scaffolding pedagogies and scaffolding learning materials.

The traditional 'textbook' is an example of scaffolding learning material. The textbook is designed to support learners. It often has an inbuild progression and a variety of learner aids, such as a glossary of terms, examples, imagery, and reflection questions.

The Digital Twin and the material learning categories

The learning process almost always centers around some materiality, object, or phenomenon relevant to what is being learned. In the theories of learning materials, the following tripartition is often utilized (Hansen, 2010, p.: 47):

- **Didactical learning material**
  - Designed for teaching and learning.
  - Contains adaptations of texts for specific strong demographics.
  - Intended for education.
- **Semantic learning material**
  - Content for teaching
  - Holds content for no specific key demographic.
  - Not intended for education
- **Functional learning**
  - Has a function that may be of pedagogical value.
  - Placeholder for the content provided by teachers and students.
  - Not intended for education

The textbook is a 'didactical learning material' is different from the Digital Twin in that the Digital Twin may be used for educational purposes. Conversely, it was not intended nor designed to support learning processes. Thus, it falls under the category of 'semantic learning material.' Therefore, the Digital Twin is defined as a 'semantic learning material' that may provide a scaffold for the learners to learn something in an authentic simulation that they would have only been able to read about.

The Digital Twin as a Scaffold

The notion of scaffolding learners through learning materials goes back to Johann Comenius (1592-1670) and maybe even further. Comenius wrote the seminal work ‘Didactica Magma’ (The Great Didactics) in 1638. ‘Didactica Magma’ constitutes a new direction in pedagogy that focuses more on how to learn than the scholastic school’s focus on what is being learned. Comenius theorizes ten ‘Footsteps’ toward good education (Comenius, 1986 p.: 137). In this context ’footsteps’ 8 and 9 are relevant:

- [education is good] If everything is taught in the medium of the senses.
- [education is good] If the use of everything taught is continually kept in view.

This leads to two principles that may support the definition of the Digital Twin as a semantic learning material:

- The Digital Twin lets the learner experience the building through more senses than other alternative learning materials (books, blueprints, videos, etc.) The Digital Twin is readily available in the learners’ context.

- The optimal learning material might be the building itself; however, the learner probably only has limited access to the actual building; thus, the building simulation becomes a powerful alternative to being there.

Vygotsky introduces two significant notions to understanding the scaffolding metaphor: The Zone of Proximal Development (ZPD) and the More Knowledgeable Other (MKO). The ZPD refers to the appropriate challenge a learner can manage with the help of an MKO.

The more recent theories of scaffolding (Bruner, 2009; Bruner & Haste, 2010; Gibbons, 2002; Vygotsky, LS., 2012; Vygotsky, L. & Cole, 1978) suggest that the more we understand the learners’ ZPD and the more we delineate and frame the content for learning, the more likely we are to support the learning processes.

“The term scaffolding was first used by Wood, Bruner, and Ross (1976): […] The scaffolding is temporary but essential for the successful construction of the building. Bruner (1978) describes scaffolding in the metaphorical sense in which we are using it here, as “the steps taken to reduce the degrees of freedom in carrying out some tasks so that the child can concentrate on the difficult skill she is in the process of acquiring” (Gibbons, 2002 p.: 16)

The Digital Twin, this way, becomes a rigor that delineates what the learner should learn. In all its richness of impressions, the building is difficult to limit to a few specific learning objectives. Furthermore, the students rarely have continuous access to the building. The Digital Twin as a scaffolding learning material is a convenient means to focus and support the learning process, have continuous access to the simulated building, and open for a more multimodal approach to learning.

These notions of using the Digital Twin as a Scaffold constitute the theoretical foundation of our study, which will be elaborated upon in the methodology section.

Methodology

In this article, an investigation of the student’s current understanding of Digital Twins and how it is facilitated in their education will be conducted. Making such an investigation in a Danish setting, two construction industry educations at two universities have been chosen: University College of Northern Denmark and Aalborg University.

With students from both educations, two focus group interviews were conducted. Using the focus group interview method will enable the students in each group to reflect on their understanding of the Digital Twin across disciplines and individuals. This will give a more nuanced response, which can be used to better understand and identify the facilitated learning with and about the Digital Twin in the construction industry.

The Case

The construction industry in Denmark has a long tradition of working closely between professions. In this article, the educational case of primarily the University College of Northern Denmark for Bachelor education in Architectural Technology and Construction Management (ATCM) and secondarily Aalborg University´s Master education in Construction Management and Building Informatics (CMBI). The ATCM education at UCN. Each education works with the Digital Twin in different approaches.

Following Deng et al.´s (2021) taxonomy of the Evolution from BIM to Digital Twin, each education is at different levels. However, both are on the evolutional scale, ultimately moving towards what is defined as Level 5, the ideal Digital Twins Concept. Level 5 is briefly summarized as a Visualization of real-time built environment data—predictions based on the data and Automatic control feedback (Deng *et al.*, 2021).

The ATCM education focuses on the practical use of the technologies for concrete goals, e.g., making specific analyses for decisions. We defined this education as being on level 2 or what Deng et al. (2021) define as BIM-supported Simulation. Here the curriculum is focused on making BIM models and simulating using the models.

The CMBI education is more focused on a theoretical perspective on information systems in the construction industry and managing the implementation of the technologies. This education as being on level 3, or what Deng et al. (2021) define as BIM integrated with Sensor. The curricula of CMBI are aimed at using the BIM models rather than creating them for, e.g., simulation and use of sensor data. The students are educated in creating BIM-models and using the models for drafting, quality assurance, cost-estimation, planning and analysis of sustainability aspects such as life-cycle assessments. They are trained in using visual programming software to create their own automation using the BIM-models and using photogrammetry software to create point cloud models. Lastly, they are educated in managing BIM-processes using standards, manuals etc. The use of BIM-models for their projects starts at first semester and is continued throughout the entirety of the 7 semesters.

A limitation of the current curriculum regarding Digital Twins is the lack of integrating sensor data into the BIM-models. The students do not get any training in either sensors, databases or API´s and are therefore not facilitated to explore the possibility of gathering data into their BIM environment. Moreover, their data processing proficiencies are also somewhat limited to simple Boolean logic. However, it is important to acknowledacknowledge that the digital aspect of education is only of the many other topics that this rather broad and multidisciplinary education contains. On average, it accounts for 7,7 % of the lectures at the education.

The finished candidates from both educations typically work together in the Danish construction industry, and they constitute the digital backbone of the industry.

Focus group interviews

The Focus group interview is used as a technique that emphasizes an in-depth interview with selected participants to highlight responses subject to group dynamics. Such reactions are often more profound and prosperous than typical one-by-one interviews (Rabiee, 2004). The recommended number of participants in a focus group interview is between six and eight (Krueger and Casey, 2000). Each group interview usually lasts approximately one to two hours, depending on the questions' complexity.

Participants

The participants from each education were selected to represent an intermediate representation. From the ATCM education, the students were chosen at the end of the fifth semester because they, at this point, have experience working with the Digital Twins. From the CMBI degree education, the students were from the fourth semester.

A similarity between the two groups of students was that they had participated in a digital workshop called the Digital Days ("De Digitale Dage", n.d.) that emphasized working collaboratively with the digital twin recently and, therefore, their recollections of how that part of the education played out.

Table 1: Overview of participants in each focus group interview.

	ATCM students	CMBI students
Group 1	4	1
Group 2	5	2

Interview guide

The interview guide is based on theories of Digital Literacy and the Digital Twin. The first questions regarded the students' personal experiences with these concepts and how they are used in their profession and education. After the students respond to these questions, they are presented with two pictures representing the Digital Twin in different ways to help them continue the interview and focus on specific aspects of the Digital Twin, such as simulation and model representation.

The questions explore how the Digital Twin helps or hinders their professional work and education. Specifically, the students are asked how parts of digital construction are constituted in their work with the Digital Twin and how they should be constituted for professional use.

Data analysis

The transcripts of the interviews were reviewed to identify common themes and patterns in the data. A thematic analysis approach was used, which involved coding the data to identify key themes and organizing the data around those themes. Qualitative data analysis software was utilized to assist with the coding and organization of the data. This allowed for the identification of patterns and trends in the data. Through the analysis, several key themes emerged from the focus group interviews.

Results

Here we present the results of the focus group interviews with students from the CMBI and the ATCM educations. The results of these interviews provide valuable information that can be used to improve the curriculum and education regarding Digital Twins. Furthermore, the results support a deeper understanding of how a Digital Twin may be exploited as a semantic learning material.

Understanding the concept of the Digital Twin

The students needed help understanding and formulating the concept of the Digital Twin and how to utilize it as a semantic learning material scaffolding them to understand the academic subjects. Especially the students from ATCM needed help with the definition of DT; only one AAU student had quite good insight. For example, one group saw the digital twin as a digital copy of the building. Throughout both interviews, the students highlighted aspects that they found meaningful, including collecting data for the digital twin use of augmented reality and use in facility management.

In general, they highlighted that the digital twin provided a great scaffold for experiencing learning through the models. These experiences can serve as reflection starters for future projects. Due to the lack of available data from, e.g., users of the building, the students were only working on what would be considered very superficial elements of the digital twin.

Group 2 suggested using Digital Twins; instead of designing buildings based on personal experience, the group sees it as an opportunity to use data from other projects to create a good foundation for the new building.

The Digital Twin in the education

One group argued that they needed a more in-depth introduction to the technology and that it needed to be better framed with the theory about the technology. Moreover, it is essential that technology teaching is aligned with the general flow of the other lectures.

In this way, the technology is presented in the context where it is needed for the students to produce the output. The students also highlight that they need to structure the learning processes regarding the technology around good examples, which help them remember the learning better and contextualize it – for example, workshops where they can test the digital tools in specific cases.

Among the students, it is discussed that one unconsciously works with data: "You don't necessarily know why you do what you do. Only in the later semesters we have awareness about the processes achieved", Group 1. One group argued that the collection of data and the transfer of parameters were not that structured. The other group expressed that the routine of working and adding data to the models has not been developed in the curriculum.

The data was only seen in relation to the specific project; therefore, no data was used across semesters. The students from the CMBI education argued that working with laser scanning and point clouds was part of their work. Group 1 argued that it is all about data, after all. Working with a digital twin makes good sense because data collection is essential to improve the workflow.

Group 2 was somewhat divided regarding the software tools introduced to them for working with the Digital Twin. Some would like to have knowledge of more tools, and others would like to focus on a few fewer tools than many. However, Group 1 argued that to be able to work with the Digital Twin, the necessary systems were sensors regarding every functional aspect of the building (ventilation, lights, doors, windows).

However, they agreed that thoroughly familiarizing yourself with a tool means that you have much knowledge to familiarize yourself with a new tool in practice. So, it serves well as a reflection point. However, you still need to experience the buildings physically. Group 2 believes they have been given some tools to optimize, e.g., the design, but the projects they are working on are very small. They want to test their skills in a larger project to reflect on practice.

Digital literacy and the Digital Twin

One group argued that for it to make sense, it was essential for them to that the learning processes with the technology were put into a concrete and relevant context of their practice. Furthermore, they explain that in some cases, it would require much work at the beginning of the process but later allows for more efficient work by, e.g., automatically retrieving information from the twin.

One group argued that they need to spend more time on the technologies to explore their capabilities better. Especially with complicated topics, such as augmented reality: *"Exciting topic, but it is so in-depth knowledge, and we haven't had it in our hands"* Group 2.

Group 1 discussed the differences in achieving deeper learning with the Digital Twin. In one educational session, they had time to define their goals and use the Digital Twin to write a report about its use. In another, they were presented with a "simulated" real-life building project they had to complete as a part of the curriculum. In this session, they felt there was a lack of time to fully explore the use of the Digital Twin in the simulated project that allowed them to specialize.

The other group corroborated that they need to align the technological skills in relation to their contexts by taking the technology to the actual practice context, e.g., at a building site or in close collaboration with companies. Group 2 argued that real-life examples are essential to building their experience of using the tools by testing and making mistakes and successes.

Group 1 believes more feedback could be very good in the learning process, and preferably someone from an architectural or engineering company to gain immediate feedback on the construction of the models: "Someone with the latest knowledge," Group 1. In daily teaching, continuous feedback from the teacher in the guidance. Group 1 points out that it helps to get some good habits for maintaining your twin. "But it is difficult to create good habits if you do not know how to do it. It can be facilitated by lecturers or several", Group 1. They continued that it was difficult to understand what is good to include in a twin and why.

Some individual pieces of information are incorporated into the models, but not structured working process: "It is because you have not had this knowledge binding experience in what the information/data can be used for." They argued that "you don't get that at school. It is only in practice". And claims that it is essential to have input and output data to be worked with actively to facilitate their learning. They suggested that it could be good to have a checklist. This was corroborated by Group 2, which said that it would help with video guides etc.

However, the groups can see if the data needs to be fixed. Group 1 argued that they could assess a simple model to determine whether an analysis is misreported. Group 2 debated that they could evaluate good and bad data.

Discussion & conclusions

In this chapter, the results from the two focus group interviews are discussed from the theoretical perspectives formulated at the beginning of the article, with relevant literature also focusing on education with and about the digital twin.

A vague conceptualization of the Digital Twin

The interviewed students, in general, need help to comprehend the Digital Twin concept better. This aligns with the somewhat "confusion" of the topic, as discussed in our theoretical section attempting to frame the Digital Twin. A potential issue with the many efforts to conceptualize Digital Twins gives a vague notion of the role of the technology and its many sub-technologies.

The students generally conceptualized the Digital Twin based on the recently used processes and technologies. So, the CMBI students of Group 2 focused on point cloud representation and argued that this was the most important aspect of the Digital Twin. Thus, it is a powerful, semantic learning material for scaffolding a complex learning process. However, it requires a layer of interaction with a teacher (MKO).

Moreover, when the groups discussed the Digital Twin, it often was conceptualized very close to BIM. One of the reasons for this could be related to also vague definitions of BIM (Sůra, 2018), where the direct use of BIM de facto is currently aimed at the design, simulation, and planning of a building, whether the Digital Twin is often representing something that is mainly used for operating and is considered a dynamic real-time representation of a building. However, most of the conceptualization of BIM does not exclude similar features (Deng *et al.*, 2021; Sacks *et al.*, 2018).

Focusing more on fewer technologies

An issue for the interviewees was reported to be the amount of software they encountered. While a modern BIM-modelling process in its full could require much software for authoring BIM models, quality checking, planning, cost estimating, rendering, and collaborating, the amount introduced in a school situation was reported to be, in some cases, too much.

To gain digital literacy BIM processes and concepts are considered more important than software skills (Dossick et al., 2014). By starting with a smaller number of platforms and approaches, researchers and practitioners can gain a deeper understanding of the technology and build a strong community of practice.

They can expand their focus to include other technologies as they become more proficient. This finding is essential to the future utilization of Digital Twin as semantic learning materials scaffolding the students' learning process since it represents concrete learning design advice. Thus, the Digital Twin should define a clear, exemplary case of what the students are learning for the Digital Twin to be a good learning material.

In the case of Digital Twins, scaffolding can be provided through training, tutorials, and documentation specific to the chosen technology. This will help researchers and practitioners quickly gain the skills and knowledge they need to work with the technology effectively. Additionally, focusing on a smaller number of technologies also allows for better development of the technology and its implementation in the industry and Develop digital competency – a breadth of understanding across the industry and a depth understanding in a particular area (t-model).

Better usage of Blended Learning

The students mentioned the need to continue learning asynchronously with the tools presented to them. They wished for the opportunity to follow video learning material where they could catch up on learning about the technologies. They specifically said that the ability to catch up on the learning sessions and, e.g., see what buttons to press could greatly help them continue learning when not in class.

In general, it is highlighted by Sepasgozar (2020) states that including blended learning aspects in mere physical classes is critical for enhancing the learning outputs regarding DT. In his study, he showcased increased learning outcomes for the set of complex technologies used for DT and was appreciated by the new generation of digitally savvy students.

The Digital Twin, in connection with video learning materials in a clear and exemplary learning design, could be a powerful learning design for future Blended Learning designs.

The theory is further needed.

Another aspect that the students promote is the need for theory to frame the technology they work with. This signals that, in some cases, they maybe understand what is in front of them but need help understanding its full context and use. Costa et al. (2019) argue that the need for theorizing about a technological phenomenon assists in developing a language that can illuminate and amplify the phenomenon to be explored.

The language of DT is essential not only for communicating with researchers and academic literature but necessary for the public discourse on the technology. Here the students are expected to contribute to the continued development of DT in their practices as the phenomenon develops and accommodates tomorrow's practice.

Costa et al. (2019) suggest that in theorizing about technology in education, it is important to position the relationship between the technology, person, and environment, which will best position the opportunities for using technology like DT without being too optimistic or pessimistic. An approach to balance this can be done by crossing different disciplines, including sociological texts, with positivist statistics. Moreover, looking to the pasts conceptual categories like BIM and adapting to the new context of DT.

However, the field of DT in construction is still somewhat young, and the theoretical conceptualizations are still in its mere infancy, which means that its pivotal for educators to continue to support research in the phenomenon that enables a clearer idea of what DT in construction is and how it can provide value for the industries practices. Future work will investigate incorporating these findings into learning sessions, evaluate its impact on learning outcomes, and identify if the student's digital literacy regarding the DT can be improved.

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References

Abdirad, H. and Dossick, C.S. (2016), "BIM curriculum design in architecture, engineering, and construction education: A systematic review", *Journal of Information Technology in Construction*, Vol. 21 No. September, pp. 250–271.

Costa, C., Hammond, M. and Younie, S. (2019), "Theorising technology in education: an introduction", *Technology, Pedagogy and Education*, Routledge, Vol. 28 No. 4, pp. 395–399, doi: 10.1080/1475939X.2019.1660089.

"De Digitale Dage". (n.d.). , available at: https://dedigitaledage.dk/ (accessed 9 December 2022).

Deng, M., Menassa, C.C. and Kamat, V.R. (2021), "From BIM to digital twins: A systematic review of the evolution of intelligent building representations in the AEC-FM industry", *Journal of Information Technology in Construction*, Vol. 26 No. November 2020, pp. 58–83, doi: 10.36680/J.ITCON.2021.005.

Feng, H., Chen, Q. and de Soto, B.G. (2021), "Application of digital twin technologies in construction: an overview of opportunities and challenges", *Proceedings of the International Symposium on Automation and Robotics in Construction*, Vol. 2021-November, International Association for Automation and Robotics in Construction (IAARC), pp. 979–986, doi: 10.22260/isarc2021/0132.

Grieves, M. and Vickers, J. (2016), "Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems", *Transdisciplinary Perspectives on Complex Systems: New Findings and Approaches*, No. August, pp. 85–113, doi: 10.1007/978-3-319-38756-7_4.

Hosamo, H.H., Imran, A., Cardenas-cartagena, J., Svennevig, P.R., Svidt, K. and Nielsen, H.K. (2022), "A Review of the Digital Twin Technology in the AEC-FM Industry", Vol. 2022.

Krueger, R. and Casey, M.A. (2000), *Focus Groups: A Practical Guide for Applied Research*.

Miettinen, R. and Paavola, S. (2014), "Beyond the BIM utopia: Approaches to the development and implementation of building information modeling", *Automation in Construction*, Vol. 43, pp. 84–91, doi: 10.1016/j.autcon.2014.03.009.

Molio. (2020), "Byggeriets Digitale Barometer", No. September.

National BIM Standards. (2020), "10th Annual UK's National Building Specification Report 2020", *NBS Enterprises Ltd.*, pp. 1–39.

Nikolaev, S., Gusev, M., Padalitsa, D., Mozhenkov, E., Mishin, S. and Uzhinsky, I. (2018), "Concept for Modern Project-Based Engineering Education", pp. 193–203, doi: 10.1007/978-3-030.

Rabiee, F. (2004), "Focus-group interview and data analysis", *Proceedings of the Nutrition Society*, Vol. 63 No. 4, pp. 655–660, doi: 10.1079/pns2004399.

Sacks, R., Eastman, C., Lee, G. and Teicholz, P. (2018), *BIM Handbook*, *BIM Handbook*, doi: 10.1002/9781119287568.

Sepasgozar, S.M.E. (2020), “Digital twin and web-based virtual gaming technologies for online education: A case of construction management and engineering”, Applied Sciences (Switzerland), Vol. 10 No. 13, doi: 10.3390/app10134678.

Sůra, M. (2018), “Detecting, modeling and quantifying differences in terms meaning, in BIM environment”, MATEC Web of Conferences, Vol. 146, pp. 1–6, doi: 10.1051/matecconf/201814601004.

Suwal, S., Jäväjä, P. and Salin, J. (2014), “BIM education: Implementing and reviewing ‘opeBIM’ - BIM for teachers”, Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering, No. June 2014, pp. 2151–2158, doi: 10.1061/9780784413616.267.