

The Virtual Construction Site: Knowledge Management in Virtual Environments

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Abstract—The purpose of this study is to examine the potential of the virtual construction site as a tool of knowledge management on technological processes of construction production at the university. A digital paradigm that ensures the unity of innovative and smart technologies in construction education and improves knowledge management tools has become the methodological basis. The authors present the criteria for the effectiveness of teaching technological processes with the help of virtual construction site (digital, professional, personal). The guidelines for teaching students to make a technological map in construction are proposed. The levels of knowledge of modern digital technologies are presented. The practical significance of the study is to present the experience of teaching technological processes using digital content. The social significance lies in the formation of a sustainable orientation of students towards the digitalization of construction production. Originality of research consists in substantiation of virtual construction site as the effective tool of knowledge management.

Keywords—Construction education; digital paradigm; knowledge management; virtual construction site; Virtual Reality and Visualisation.

1 Introduction

The effective use of digital technologies affects the competitiveness of construction companies [1,2]. The labor market requires highly qualified specialists with digital skills capable of developing and implementing smart technologies [3,4]. The need for such specialists has updated the creation and implementation of digital resources in construction education and the application of knowledge management practices in universities [5].

Digital educational resources allow: 1) to develop educational programs to develop professional skills for the 21st century [6]; 2) to create training platforms to adapt virtual reality technologies to the training process and to form the readiness of future engineers for the organization of intelligent construction sites [7]; and 3) to build personalized training trajectories to improve the readiness of future engineers for the introduction of smart technologies in the organization and management of construction [8].

The application of knowledge management practices in universities allows: 1) to include practical tasks in the content of the education to share knowledge and develop the ability of students to accompany complex engineering products and processes throughout the life cycle and to understand responsibility for the economic, environmental and technological consequences of their actions [9]; and 2) to introduce an electronic portfolio to validate students' individual achievements in engineering product development and to organize monitoring of the development of knowledge, skills, competencies [10,11].

The topic of this research is a virtual construction site as a knowledge management tool at the university. Virtual construction sites are interactive 3D models of construction processes with animation, additional text, graphic information, video, and interactive presentations. The virtual construction site is created using the software packaged 3ds Max and Autodesk Revit [12]. The main features of a virtual construction site include: cross-platform and multimedia interactive content [13,14].

The purpose of this study is to examine the potential of a virtual construction site as a tool of knowledge management on technological processes of construction production at the university.

2 Materials and Methods

2.1 Research design

A digital paradigm providing introduction of digital resources into construction education and improvement of knowledge management tools was chosen as the methodological basis for the research. Paradigms, as recognized scientific achievements, have for some time provided the scientific community with a model of problem statement and their solutions [15]. Paradigms are characterized two-fold through: 1) consolidation, providing for unification of supporters from competing scientific directions on the basis of recognition of legitimacy of certain rules and standards of scientific practice; 2) openness, providing for possibility for new generations of scientists to find

innovative ways of problem solving. The digital paradigm ensures the unity of innovative and smart technologies, which is recognized by the scientific community as the basis for further practice.

There are several stages in the development of the digital paradigm of construction education, including: 1) creation of digital technologies to prepare students for successful professional activities in the knowledge economy and career growth [16]; 2) introduction of digital textbooks to develop professional skills for the 21st century [17]; and 3) development of digital educational resources to train engineers who have modern digital technologies in the transition to a digital economy [18]. The organization of construction education based on a digital paradigm creates a professional community that actively introduces virtual reality technologies into the learning process, adapted to the requirements of construction production [19].

2.2 Sample

Experimental work on verifying the efficiency of a virtual construction site included some stages (stating, forming, control). The experimental work involved 400 respondents: 30 teachers and 370 Bachelor's-level students of the State University of Architecture and Civil Engineering. Probabilistic (convenient) samples of teachers and students were compiled. The sample of teachers included doctors of science, professors (average age 51) and associate professors (average age 37). Professors and associate professors underwent training sessions on disciplines "Technological processes in construction", "Basics of technology of erection of tasks", "Organization, planning, management in construction", "Computer technologies of designing of buildings", with undergraduate students studying in the direction of training "Industrial and civil construction". The sample of students includes students of 3-4 years studying at the bachelor's programs in the field of "Industrial and civil construction" training. None of the respondents refused to participate in the experimental work.

2.3 Survey

At the ascertaining stage in May 2019 the survey was conducted and the attitude of teachers and students to the virtual construction site as a tool of knowledge management about technological processes of construction production was elicited, and the criteria of efficiency of teaching technological processes were defined. The questionnaire includes four closed questions with multiple choice answers (Table 1).

Table 1. Results of online survey of teachers (T) and students (S) about the attitude to the organization of training on the basis of virtual construction site at the ascertaining stage of experimental work (%)

Content of the question	Options for answers	T	S
1. Why use virtual reality technologies in the learning process?	1.1. To develop professional skills of the 21st century and be smart-ready	93	97
	1.2. To form readiness to organize design and construction activities based on modern software	91	96
	1.3 To form readiness to organize intellectual construction sites	94	92
2. Why visualize data for construction production?	2.1 To develop the ability to accompany the construction industry throughout the life cycle (Conceive-Design-Implement-Operate).	97	96
	2.2. To develop professional activity motivation	96	94
	2.3. To provide an opportunity to observe the construction process step by step and improve professional knowledge, skills and abilities	98	97
3. What are the main functions performed by a virtual construction site during training?	3.1. Facilitates personalization and safety of training	97	98
	3.2. Increases learning motivation.	96	93
	3.3. Facilitates personal and professional development	94	96
4. What components can a virtual construction site include?	4.1. 3D models	97	99
	4.2. Animation, video.	99	97
	4.3. Interactive presentations	98	95

The questionnaire was sent to the respondents via Telegram. Of the respondents invited to the survey, 81% completed the questionnaire on the first day. Over the course of the survey, the entered values were automatically checked, and the mandatory completion of questions was monitored. To protect against repeated responses, respondents could be identified by their IP address and using an individual account (Cookie). Respondents' answers were converted into files for processing by Statistica. The survey results were discussed in 3 focus groups in an online forum. Each focus group included 19 people: 9 teachers and 10 students. Teachers and students who do not know each other personally were invited to focus groups. Focus group moderators were appointed as teachers. The Forum was held for 45 minutes over a single day. The focus groups identified digital, professional, and personal training efficiency criteria for the technological processes on the basis of virtual construction site.

At the formative stage, students developed technological maps to optimize the construction duration of a large-panel residential building using a virtual construction site. The content of a virtual construction site is a complex multi-level menu, consisting of a permanent vertical line, each element of which has a drop-down menu. The points of the constant vertical line correspond to the technological processes of construction production. The technological processes are separated for the following purposes: blank, transport, preparatory, assembly and laying, and miscellaneous. Each item in the permanent vertical row has a drop-down menu (Table 2).

Table 2. Content of virtual construction site of a large-panel residential building

Elements of constant vertical line	Drop-down menu
Metal preparation processes	Construction documentation, occupational health and safety, operational dispatch, construction control and supervision, quality control, construction materials and equipment, construction structures and products
Transport processes	Construction documentation, occupational health and safety, operational dispatch department, construction control and supervision, quality control, temporary road construction, loading, unloading, warehousing, moving materials and structures to the work area, moving to the workplace on site
Preparation processes	Construction documentation, occupational health and safety, operational dispatch department, construction control and supervision, quality control, construction site security, construction site fencing, debris removal, access roads, utility rooms, temporary communications, trenches for communications
Installation processes	Construction documentation, occupational health and safety, operational dispatch department, construction control and supervision, quality control, excavation works, foundation, supporting and enclosing structures, installation of exterior walls, roofing, arrangement of interior partitions, installation of windows, floor screed, engineering networks, connection to communications, installation of elevator equipment
Specials processes	Construction documentation, industrial safety and health, operational dispatch department, construction control and supervision, quality control, decoration of public premises, apartment decoration, facade decoration, landscaping

In the maintenance of a virtual construction site there are universal and special points of the dropping down menu. Universal points are characteristic of all processes (construction documentation, industrial safety and labor protection, operational dispatching department, construction control and supervision, quality control of work). Special items are specific to specific processes [20]. Based on the results of the technological map development, the students prepared interactive reports. At the control stage, the students' levels of knowledge of modern digital technologies were identified.

3 Results

The main results of the research address the following issues: criteria of efficiency of teaching technological processes with the help of virtual construction site; guidelines for teaching students to make a technological map in construction; levels of knowledge of modern digital technologies.

3.1 Criteria for the effectiveness of teaching technological processes

Criteria (digital, professional, personal) reflect the need of the digital economy for specialists who are knowledgeable in modern digital technologies, ready for successful professional activity and competitiveness in the labor market, and capable of self-organization and self-education. The indicators include knowledge, skills and competencies (Table 3).

Table 3. Criteria and indicators of technological processes training efficiency

Criteria	Data		
	<i>Knowledge</i>	<i>Skills</i>	<i>Skills</i>
Digital	Know the meaning of "intellectual construction site".	Know how to characterize an intellectual construction site.	Own construction applications
Professional	Know the international standard forms of contracts for investment and construction activities, the national code of rules for the organization of construction	Are able to apply international and industry standards of industrial and occupational health and safety	Possess methods of information modeling, creation and use of three-dimensional objects
Personal	Know the self-organization, self-education applications	Can create an electronic portfolio	Have a way with self-representation

Criteria and indicators facilitate identifying the level of mastery of modern digital technologies.

3.2 Guidance on teaching students to draw up a technological map in construction

The manual includes setting the goal of the technological map, content formation, organization of students' work.

Setting the purpose of the flow chart: Setting a goal affects the content of the workflow chart and the organization of students' work. Students prepared a technological map for optimizing the duration of construction of a large-panel residential building. There are three aspects to the choice of the purpose of the flow chart. The first requirement is to modernize the construction technology for a large-panel residential building with a reduction in labor, material and technical and fuel and energy resources. Shortening the construction period contributes to the development of investment projects, which differ from each other by design and volume planning solutions, general organization of production, and technologies of construction processes. Secondly, there is a discrepancy between the normative and actual duration of construction of large-panel residential buildings in Russia. The reasons for this discrepancy include the lack of regional norms for construction duration. In Russia there are 4 main construction-

climatic zones, which in their turn are subdivided into 16 climatic subareas, and a special northern construction-climatic zone, which includes areas of severe, least severe and most severe. The construction of large panel residential buildings are based on standard standards. The natural and climatic conditions of the construction area, which are essential for making constructive decisions, are not taken into account. Thirdly, by successive implementation of construction stages (preparatory, underground, above-ground, finishing), the construction time is significantly increased. It is known that if the house has several sections, it is possible to combine the stages and reduce construction time by applying the flow method.

Generation of the content of the technological map: The content of the flow chart depends on the target. The technological map for optimizing the construction duration of a large-panel residential building has five sections, each of which includes several points (Table 4).

Table 4. Contents of the flow chart to optimize the duration of a large-panel apartment building

Sections	Paragraphs
1. Scope of application	1.1. Natural and climatic conditions of the construction area
	1.2. Technical and economic characteristics of the house: total building area (m ²), construction area (m ²), construction volume (m ³), including the basement (m ³), the number of floors (pieces), height of the floor (floor to ceiling) (m), technical floor (m)
2. Organization and technology of the construction process	2.1 Requirements for the completion of prior or preparatory processes
	2.2 Composition of machinery, equipment and mechanisms in use, specifying their technical characteristics, types, brands and quantity
	2.3 List and technological sequence of operations and simple processes, their execution schemes for the final product
	2.4 Layouts of mechanisms, machines and fixtures
	2.5 Storage diagrams of materials and structures
3. Quality Control	3.1 Input quality control of structures and used materials
	3.2 Operational quality control of work performed
	3.3 Acceptance inspection of work performed
4. Calendar work plan	4.1 Stages and periods of construction, specifying the number of working days for each scope of work, the composition of the team for each scope of work and in the aggregate for the entire construction project
	4.2. Schedule of technological processes
	4.3. Material and technical resources (data on the need for tools, materials, structures for the envisaged scope of work)
	4.4 Technical and economic indicators (hourly and shift work schedules, time of operation of machines (in hours), normative rates and expenses of materials per unit of volume, salary)
5. Occupational Health and Safety	6.1. Regulations for safe execution of processes (personal protective equipment, acts on safe use of machinery, machines)
	6.2 Rules for safe execution of specific types of work

The content of the technological map is tied to the object under construction and the natural and climatic conditions of construction, and is also aimed at teaching students the technological processes of construction production.

Students' work organization: The development of the technological map involved 370 students. To develop a student workflow map, the students were divided into two groups. The first group (206 students) developed the technological map with the help of a virtual construction site of a large-panel residential building. The second group (164 students) developed the technological map without using a virtual construction site. Students of both groups were offered two forms of work: work individually or in small groups of 2 people. Each point on the flow chart was rated at 5 points. There were 16 total points in the technological map. In total, each student could gain 80 points for developing a technology card. As a result, students were divided into four groups, based on the number of points earned for the development of the technological map (Table 5).

Table 5. Results of students' work on technological mapping to optimize the duration of construction of a large-panel residential building (number of students)

Groups	Student work forms	Groups of students allocated on the basis of points earned			
		Group 1 (80 points)	Group 2 (79 to 70 points)	Group 3 (69 to 40 points)	Group 4 (39 to 0 points)
1	In total, there was 206 students	172	27	4	3
	167 students worked individually	144	19	3	1
	39 students worked in groups	28	8	1	2
2	In total, there was 164 students	51	82	27	4
	115 students worked individually	37	66	12	0
	49 students worked in groups	14	16	15	4

The maximum number of points (80) was highest among the first stream students who worked individually (144 students). In the process of developing the technological map, students presented the scope of their work at each stage of construction in percentage terms and received a coefficient of combining different types of work (Table 6).

Table 6. Scope of work and coefficient of combination of different types of work when constructing a large paneled dwelling house

Stages of construction	Work scope	Coefficient of matching
Preparatory	100%	1
Underground	60%	.73
Overground	30%	.86
Finishing	30%	.92

3.3 Ownership levels of modern digital technologies

In order to identify the levels of knowledge of modern digital technologies, students were asked to answer questions and complete the tasks, which were evaluated on a 5-point system (Table 7).

Table 7. Results of answering questions and completing tasks by students in the control stage of experimental work (average score)

Criteria and indicators	Grade point average
<i>Digital criterion (D)</i>	
1. Know the content of the term "intellectual construction site".	4.7
2. Know how to characterize an intellectual construction site	4.6
3. Own construction applications	4.6
<i>Professional criterion (V)</i>	
4. Know the international standard forms of contracts for investment and construction activities, the national code of rules for the organization of construction	4.8
5. Able to apply international and industry standards of industrial and occupational health and safety	4.6
6. Own methods of information modeling, creation and use of three-dimensional objects.	4.4
<i>Personal criterion (P)</i>	
7. They know applications for self-organization, self-education.	4.5
8. Know how to create an electronic portfolio	4.7
9. Possess methods of self-representation	4.5

In order to identify the levels of ownership of modern digital technology, we defined the value (Q) as the sum of values (S) for each criterion: $Q = SD + SV + SP$

The values for each criterion were calculated by formula: $S = q_i n \Sigma /$, where q_i is the average score obtained for an indicator, n is the number of indicators of the criterion.

Values (Q) from 0 to 5 are conventionally considered a low level. Scores from 6 to 10 are average. Scores between 11 and 15 are high. Characteristics of the levels are as follows:

Low level (2% of students). Students are familiar with international standard forms of contracts for investment and construction activities, the national code of construction organization. They experience difficulties in disclosing that concept of "an intellectual construction site". They cannot name applications for self-organization or self-education. They are able to apply international and industry standards of industrial safety and health. They can build an electronic portfolio, but experience difficulties in characterizing an intellectual construction site. Partially own construction applications and various methods of self-presentation. Very limited amount own apps for information modeling, nor those for the creation and use of three-dimensional objects.

The average level (38% of students). Students know the content of the concept of "intellectual construction site"; international standard forms of contracts for investment and construction activities, the national code of rules for the organization of construction; applications for self-organization, self-education. They are able to characterize an intellectual construction site; apply international and industry standards of industrial

safety and health; form an electronic portfolio. They own construction applications; methods of self-presentation. But methods of information modelling, creation and use of 3D objects are owned partially.

High level (60% of students). Students know the content of the concept of "intellectual construction site"; international standard forms of contracts for investment and construction activities, the national code of rules for the organization of construction; applications for self-organization, self-education. They are able to characterize an intellectual construction site; apply international and industry standards of industrial safety and health; form an electronic portfolio. Own construction applications; methods of information modeling, creation and use of three-dimensional objects; methods of self-representation.

4 Discussions

The problem of implementing virtual reality in construction education has garnered much attention of late in the academic community. There are several approaches to its solution.

The first step is to emphasize the virtual construction environment. In this approach, the object of research forms an environment that is created digitally, simulates reality and provides the user with a presence effect, through total or partial sensory immersion. Within this approach, the subject of research is:

- Immersive reality as the system integrity of virtual and augmented reality, panoramic photo/video. The immersive reality reflects the actual reality, provides a new vision of the construction site, fosters a willingness to organize intellectual construction sites, and to design and implement intelligent construction sites [14,21];
- Virtual reality as a component of immersive reality, providing visualization of data on design, organization, management in construction, to form readiness for integrated project implementation, application of virtual methods of human resources and knowledge management [22];
- Augmented reality as part of an immersive reality that increases knowledge of innovative construction site management techniques to form project management readiness using versatile and specialized software [1,23].

The obvious advantage of the research is the scientific justification of the strategy and practice of organizing the innovative educational environment and the formation of professional skills of the 21st century. Research limitations include the lack of a link to open learning that ensures fair access to education [24]. This study allows for greater access to training. The virtual construction site includes 3D models, animation, video, interactive presentations. In the course of training the virtual construction site carries out functions of personalization of training and maintenance of its safety; increase of educational motivation; improvement of professional knowledge and skills of students, along with personal and professional development. Students used a virtual construction site to visualize construction production. Students moved around the construction site

in first person, managing three-dimensional models of construction processes with animation, additional text, graphics, video, interactive presentations.

The second step is to emphasizing virtual reality as an important innovative resource. Within this approach, the object of research is digital educational resources that provide the development of 21st century skills and the ability to respond quickly to changes in the external environment and to achieve results effectively [18,25]. Within this approach, the subject of research is:

- Methods of application of construction applications, applications of universal information and communication technologies, Internet resources for personal and professional development [8,26–29];
- Design and implementation of multimedia textbooks to personalize learning based on the individual characteristics of each student [26,30];
- Opportunities of BIM technology (Construction Information Modeling) to develop students' ability to interactively model buildings and increase competitiveness in the labour market [31];
- Methods of applying cloud services to develop students' ability to search, store, analyze and integrate different types of information obtained from web services [32];
- Interactive learning methods based on computer classrooms to develop the ability to self-organize, self-education, self-presentation, self-control, communication [6];
- Pedagogical tools for interacting with objects in virtual 3D environments on desktops and mobile devices in 3D games that promote digital literacy [33].

The scientific rationale for the role of digital resources in improving the quality of vocational education and in promoting digital literacy is an advantage of research. The research limitations are that open digital educational resources available in different languages have not been identified; the risk of implementation for students' health has not been identified; and the pedagogical potential of digital educational resources has not been revealed [24]. In this study, the pedagogical potential of a virtual construction site allows: 1) ensure the safety of the educational process and develop interdisciplinary links; 2) simulate production processes at each stage of a construction project, develop digital literacy and professional skills of the 21st century; 3) integrate explicit and implicit knowledge in the process of design and construction activities and form the professional identity of future civil engineers.

The third approach is analytical. Within the limits of this approach a subject of researches make: the critical review of articles on integration of a virtual reality with new educational paradigms and technologies of visualization in construction education. The advantage of research is: identification of best educational practices; drawing attention to original scientific articles; development of educational potential of digital technologies. Research limitations are that no paradigm shift in research has been established. This study substantiates the digital paradigm of construction education as part of the digital economy [34].

The fourth approach is integrative. Within the limits of this approach the subject of researches makes virtual construction site, as a digital educational resource which allows to adapt technologies of a virtual reality to educational process and to provide simulation of industrial processes [13,14]. Undoubted advantage of researches makes

integrative characteristic of a virtual construction site, as the universal tool on training to designing, the organisation, management. Research restrictions consist that practical experience of introduction of a virtual construction site in construction education is not presented. This study shows practical experience in teaching technological processes using digital content. The content of the virtual construction site allowed to form a stable attitude to the construction production of a large-panel residential building as a single object with architectural and design, technological, installation and adjustment, maintenance, technical and economic parameters and characteristics.

The findings of the listed authors formed the basis for this study. Management of knowledge of technological processes of construction production by means of a virtual construction site provides formation of professional skills of 21 century and readiness for introduction of smart technologies, the organization of intellectual construction sites, design-construction activity on the basis of the modern software. Visualisation of data on construction production is directed on granting of possibility to supervise step by step construction process and formation of readiness to accompany construction projects throughout all life cycle (Conceive-Design-Implement-Operate).

5 Conclusion

The aim of the study was to substantiate the viability of virtual construction site as a tool for knowledge management on technological processes of construction production at the university. It was found out that a virtual construction site allows: 1) to build a digital model of the house based on technical and economic characteristics; 2) learn the technical characteristics and models of the used machines, mechanisms, tools, study the layout of their location; 3) understand the meaning of the requirements for technological processes; learn how to draw up a network work schedule that reflects the relationships between the construction participants and sets the deadlines for issuing documentation, installation and commissioning; 4) to master the procedure for drawing up a calendar plan for building a house based on a feasibility study with the maximum possible combination of work by year, month, day with the distribution of capital investments; 5) identify the possibilities of maximum combination of the types of work carried out by the in-line method in two and three shifts, and determine the duration of each stage of construction; to study the methodology for the maximum allowable combination of types of work in the flow organization of construction; 6) determine the duration of construction by interpolation and extrapolation methods, taking into account the level of organization of construction production, the use of modern technologies, the use of the latest construction materials, parts, structures, as well as the number of shifts of a tower crane; 7) to consolidate knowledge of norms and standards on industrial safety and labor protection.

Practical recommendations for effective knowledge management of the technological processes of construction production at the university by means of a virtual construction site are as follows: 1) the value of a virtual construction site as a knowledge management tool increases, provided that students have information about digital technologies in construction; 2) efficiency of knowledge management about technological

processes by means of a virtual construction site increases provided that students own methods of information modelling, construction applications.

The received results ensure the planning of promising further researches of the given problem which are connected with revealing the risks of implementation of digital resources in construction education. The research conducted herein should be useful for university professors and staff working at centers for advanced training of civil engineers.

6 References

- [1] Edirisinghe, R. (2019). Digital skin of the construction site. *Engineering, Construction and Architectural Management*, 26(2): 184-223. <https://doi.org/10.1108/ecam-04-2017-0066>
- [2] Lou, M. (2017). A Virtual Reality Teaching System for Graphic Design Course. *International Journal of Emerging Technologies in Learning*, 12(09): 117-129. <https://doi.org/10.3991/ijet.v12i09.7492>
- [3] Digital Research LLC (2017). [Online]. Available: <http://digitalresearch.ru/index.html> [Accessed October 19, 2019].
- [4] The World Bank (2016). World Development Report 2016: Digital Dividends. [Online]. Available: <https://www.worldbank.org/en/publication/wdr2016> [Accessed October 19, 2019].
- [5] Peng, C. (2013). Designing Innovative Learning Spaces in Higher Education at a Turning Point: Institutional Identities, Pervasive Smart Technologies and Organizational Learning. In *Designing Organizational Systems* (pp. 217-244). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-33371-2_12
- [6] Mihailidis, P. (2018). Civic media literacies: re-Imagining engagement for civic intentionality. *Learning, Media and Technology*, 43(2): 152-164. <https://doi.org/10.1080/17439884.2018.1428623>
- [7] Akeem, P., Quang, T. L., Chan, S. P. (2016). Framework for Integrating Safety into Construction Methods Education through Interactive Virtual Reality. *Journal of Professional Issues in Engineering Education and Practice*, 142(2): 713-725
- [8] Willett, R. (2018). Learning through making in public libraries: theories, practices, and tensions. *Learning, Media and Technology*, 43(3): 250-262. <https://doi.org/10.1080/17439884.2017.1369107>
- [9] CDIO (2019). [Online]. Available: <http://www.cdio.org/> [Accessed December 19, 2019].
- [10] Gachino, G., Worku, G. (2019). Learning in higher education: towards knowledge, skills and competency acquisition. *International Journal of Educational Management*, 33(7): 1746-1770. <https://doi.org/10.1108/ijem-10-2018-0303>
- [11] Houda, S., Naila, A., Samir, B. (2019). Knowledge Management and Reuse in Virtual Learning Communities. *International Journal of Emerging Technologies in Learning*, 14(16): 23-39.
- [12] Autodesk (2019). [Online]. Available: <https://www.autodesk.ru/> [Accessed October 19, 2019].
- [13] Ji, Y., Obergrießer, M., Dori, G., Borrmann, A. (2009). Digital Tools for Planning and Execution of Construction Projects. ForBAU The virtual construction site. Technische Universität München. [Online]. Available: <https://www.cie.bgu.tum.de/en/education/bachelor-masterthesis-offers/60-forbau-virtual-construction-site> [Accessed December 19, 2019].

- [14] Virtual Construction Site – Gaia Studio (2019). [Online]. Available: <https://studio.gaia-tech.com/product/virtual-construction-site/> [Accessed October 19, 2019].
- [15] Kuhn, T. S. (1977). *The Structure of Scientific Revolutions*. Moscow, Russia: Progress.
- [16] Miller, H., Arnold, J. (2003). Self in web home pages: Gender, identity and power in cyberspace. *Towards Cyberpsychology: Mind, Cognitions and Society in the Internet Age*, 1: 73-94.
- [17] Rosman, P. (2008). M-learning - As a paradigm of new forms in education. *Ekonomie a Management*, 11(1): 119-125.
- [18] Kivunja, C. (2014). Teaching Students to Learn and to Work Well with 21st Century Skills: Unpacking the Career and Life Skills Domain of the New Learning Paradigm. *International Journal of Higher Education*, 4(1): 1-11. <https://doi.org/10.5430/ijhe.v4n1p1>
- [19] Setareh, M., Bowman, D. A., Kalita, A. (2005). Development of a virtual reality structural analysis system. *Journal of Architectural Engineering*, 11(4): 156-164. [https://doi.org/10.1061/\(asce\)1076-0431\(2005\)11:4\(156\)](https://doi.org/10.1061/(asce)1076-0431(2005)11:4(156))
- [20] Ministry of Development of the Russian Federation (2011). Organization of construction. [Online]. Available: <http://docs.cntd.ru/document/1200084098> [Accessed December 19, 2019].
- [21] Pedro, A., Le, Q. T., Park, C. S. (2016). Framework for integrating safety into construction methods education through interactive virtual reality. *Journal of Professional Issues in Engineering Education and Practice*, 142(2): 04015011. [https://doi.org/10.1061/\(asce\)ei.1943-5541.0000261](https://doi.org/10.1061/(asce)ei.1943-5541.0000261)
- [22] Young, B., Ellobody, E., Hu, T. W. (2012). 3D Visualization of Structures Using Finite-Element Analysis in Teaching. *Journal of Professional Issues in Engineering Education and Practice*, 138(2): 131-138. [https://doi.org/10.1061/\(asce\)ei.1943-5541.0000093](https://doi.org/10.1061/(asce)ei.1943-5541.0000093)
- [23] Kumar, V., Nanda, P. (2019). Social media in higher education: A framework for continuous engagement. *International Journal of Information and Communication Technology Education*, 15(1): 109-120. <https://doi.org/10.4018/ijicte.2019010107>
- [24] Ministerial Forum (2018). Global Dialogue on ICT and Education Innovation – Towards Sustainable Development Goal for Education. UNESCO. [Online]. Available: <https://iite.unesco.org/publications/ministerial-forum-global-dialogue-on-ict-and-education-innovation-towards-sustainable-development-goal-for-education-sdg-4-proceedings/> [Accessed December 19, 2019]. <https://doi.org/10.1787/888933801430>
- [25] Suwal, S., Singh, V. (2018). Assessing students' sentiments towards the use of a Building Information Modelling (BIM) learning platform in a construction project management course. *European Journal of Engineering Education*, 43(4): 492-506. <https://doi.org/10.1080/03043797.2017.1287667>
- [26] Brilingaitė, A., Bukauskas, L., Juskeviciene, A. (2018). Competency Assessment in Problem-Based Learning Projects of Information Technologies Students. *Informatics in Education*, 17(1): 21-44. <https://doi.org/10.15388/infedu.2018.02>
- [27] De Amicis, R., Riggio, M., Shahbaz Badr, A., Fick, J., Sanchez, C. A., Prather, E. A. (2019). Cross-reality environments in smart buildings to advance STEM cyberlearning. *International Journal on Interactive Design and Manufacturing*, 13(1): 331-348. <https://doi.org/10.1007/s12008-019-00546-x>
- [28] Kalelioglu, F. (2017). Using Facebook as a Learning Management System: Experiences of Pre-service Teachers. *Informatics in Education*, 16(1): 83-101. <https://doi.org/10.15388/infedu.2017.05>
- [29] Yi, T., & Yun, S. (2018). BIM (Building Information Modeling) Education Program in KSA: A Case Study of BIM program at Prince Sultan University. In *E3S Web of Conferences*

- (Vol. 65, p. 04004). EDP Sciences. <https://doi.org/10.1051/e3sconf/20186504004>
- [30] Canedo, E. D., Santos, G. A., Leite, L. L. (2018). An Assessment of the Teaching-Learning Methodologies Used in the Introductory Programming Courses at a Brazilian University. *Informatics in Education*, 17(1): 45-59. <https://doi.org/10.15388/infedu.2018.03>
- [31] Rodríguez-Rodríguez, K. Y., & Dávila-Perez, J. L. (2016, May). Framework Development to Introduce BIM into the Civil Engineering Undergraduate Curriculum at University of Puerto Rico, Mayagüez Campus. In *Construction Research Congress 2016* (pp. 68-77). <https://doi.org/10.1061/9780784479827.008>
- [32] Despotović-Zrakić, M., Simić, K., Bogdanović, Z., Milić, A., Vujin, V. (2012). An application for integrated resource management in educational cloud. In *6th International Technology, Education and Development Conference*, Valencia, Spain (pp. 1089-1097). IATED.[Online].Available:<https://library.iated.org/view/DESPOTOVICZRAKIC2012ANA>[Accessed October 19, 2019].
- [33] Shirazi, A., Behzadan, A. H. (2015). Design and assessment of a mobile augmented reality-based information delivery tool for construction and civil engineering curriculum. *Journal of Professional Issues in Engineering Education and Practice*, 141(3), 04014012. [https://doi.org/10.1061/\(asce\)ei.1943-5541.0000229](https://doi.org/10.1061/(asce)ei.1943-5541.0000229)
- [34] Deloitte (2019). What is Digital Economy? [Online]. Available: <https://www2.deloitte.com/mt/en/pages/technology/articles/mt-what-is-digital-economy.html> [Accessed October 19, 2019].

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