Organization of Training in Construction Technological Processes Based On Digital Resources

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Abstract. The purpose of research is to show the efficiency of the virtual construction site of a large-panel residential building as a digital resource of training on technological processes of construction. As the research methodology appeared the digital paradigm, providing the application of digital resources into construction education, the correlation between the best practice and quality changes based on smart technologies. The principal results of the research are maintenance of the virtual construction site of the residential building; criteria for efficiency of training construction operation processes on the basis of a virtual construction site; levels of student readiness for smart technology applications. The significance of the results is that the content of the virtual construction site allows to develop skills of planning and management of virtual projects. The criteria reflect the need of the digital economy for construction engineers who master modern digital technologies. The levels of students’ readiness to apply smart technologies reflect the current situation in construction education.

1. Introduction

The effective use of next digital technologies determines the competitiveness of construction companies [1, 2]. This leads to the introduction of digital technologies into construction education. Digital education resources make it possible to develop educational programs providing professional skills development of the 21st century [3-5] and create the ability to guide engineering processes and systems throughout the life cycle and be aware of the self-responsibility for the economic, environmental and technological consequences [6].

The target of research is a virtual construction site, as a digital education resource [7-9]. The main characteristics of the virtual construction site are cross-platform (compatibility of software with different operating systems); multimedia interactive content imitating professional activities at the each stage of the project. The purpose of research is to show the efficiency of the virtual construction site of a large-panel residential building as a digital resource of training on technological processes of construction [10, 11].
2. Research methodology
As the research methodology appeared the digital paradigm, providing the application of digital resources and enabling the correlation between traditions and innovations into construction education [12-14].

A complex of theoretical and empirical methods relevant to the purpose of research has been applied. Among theoretical methods were study, analysis and synthesis of national and international practice of application of digital resources in construction education. Empirical methods were observation, conversations, online survey, forum. Experimental work on testing the efficiency of the construction site as a digital training resource was done in three stages (reporting, forming, control). 400 people participated in the experimental work, among them 30 teachers and 370 bachelor's degree students of the Kazan State University of Architecture and Engineering (Kazan, Russia). Probabilistic sampling of teachers, students were drawn up. The sampling of teachers included professors (average age of 51 years old) and associate professors (average age of 37 years old) who gave training sessions in the disciplines "Technological processes in construction", "Basics of building production technology", "Organization, planning, management in construction", "Life safety" to the bachelor's degree students studying the training program of "Industrial and civil construction." The sampling of students included students of the 3-4 courses studying the training program of "Industrial and civil engineering." No one from the teachers, students objected to participate in the experimental work.

At the reporting stage via online survey the attitude of teachers and students to the organization of training on the basis of a virtual construction site was clarified, and criteria for the effectiveness of technological processes training on the basis of a virtual construction site were determined. The questionnaire included four closed questions with multiple choice. The questionnaire was circulated to respondents via Telegram. 81% of the respondents invited to the survey completed the questionnaire on the receipt day. The respondent feedback database was converted into files suitable for processing by SPSS and Statistica applications. The survey results were discussed in 3 online focus groups in forum mode. Each focus group included 19 people including 9 university teachers and 10 students. Teachers and students within one focus group were not acquainted with each other. Teachers were appointed as moderators of focus groups. The forum was held for 45 minutes within one day. At the forming stage a method statement for optimizing the duration of construction of a large-panel residential building was developed. At the control stage the levels of students readiness for smart technologies application was identified.

3. Results and discussions
In scientific literature, a virtual construction site is defined as a digital education resource allowing adaptation of virtual reality technologies to the educational process and providing simulation of production processes [15, 16]. The doubtless advantage of research is an integrative characteristic of a virtual construction site as a universal instrument for training in design, organization, management. The research boundaries are that no practical experience of introducing a virtual construction site into a building education is presented. Therefore, the principal results of the research are maintenance of the virtual construction site of the residential building; criteria for efficiency of training construction operation processes on the basis of a virtual construction site; levels of student readiness for smart technology application.

3.1. The maintenance of the virtual construction site of the residential building
The virtual construction site is based on 3ds Max [17-19] software and includes an interactive 3D model of construction with animation, additional text, graphic information, video, interactive presentations (Figure 1).
The content of the virtual construction site is a complex multilevel menu. Universal points are characteristic of all processes (construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection) [20]. Special items are specific to certain processes (table 1).

Table 1. The content of the virtual construction site of the residential building

| Fixed vertical line items | drop-down menu |
|---------------------------|----------------|
| Procurement processes     | construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection, construction materials and equipment |
| Transport processes       | construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection, installation of temporary roads, loading, unloading, storage |
| Preparatory processes     | construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection, construction site security, construction site fencing. |
| Site erection processes   | construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection, earthworks, foundation engineering, bearing and enclosing structures, erection of exterior walls, roof coating, erection of internal partitions, installation of windows, floor cement screed, utility services, installation of lift equipment |
| Special Processes         | construction documentation, health, safety and environmental protection, operational dispatching management, construction supervision, site inspection, finishing of public premises, finishing of apartments, finishing of facade, urban landscaping |
3.2. Criteria for the effectiveness of training in the technological process
The criteria reflect the need of the digital economy for construction engineers who master modern
digital technologies (table 2).

Table 2. Criteria and indexes for the effectiveness of training in the technological process of
construction operations on the basis of a virtual construction site

| criteria       | indexes                                                                 |
|----------------|-------------------------------------------------------------------------|
| digital        | knowledge: know the content of the concept of "intelligent construction site" | ability: able to characterize an intelligent construction site | skill: master construction applications |
| professional   | knowledge: know the international standard forms of contracts for investment and construction activities, national construction code | ability: able to apply international and industrial standards of health | skill: master methods of information modeling |
| personal       | knowledge: know applications on self-organization, self-education | ability: able to form an electronic portfolio | skill: master self-presentation methods |

3.3. Levels of student readiness for smart technology applications.
Student readiness levels have been identified during experimental work on testing the effectiveness of
a virtual construction site as a digital training resource. Experimental work contained
three stages (reporting, forming, control). At the reporting stage via online survey the attitude of teachers and
students to the organization of training on the basis of a virtual construction site was clarified (Table
3).

Table 3. The results of online survey of teachers (T) and students (S) reflecting the attitude to
organization of training on the basis of a virtual construction site at the reporting stage of the
experimental work (%)

| Question                                                                 | Possible answers                                                                 | T  | S  |
|-------------------------------------------------------------------------|---------------------------------------------------------------------------------|----|----|
| 1. What is a point of application of virtual reality technologies in training? | 1.1. professional skills of the 21st century development and readiness to smart technology adoption | 93 | 97 |
|                                                                        | 1.2. readiness formation for organization of design and construction activity based on modern software | 91 | 96 |
|                                                                        | 1.3. readiness formation for organization of intelligent construction sites      | 94 | 92 |
| 2. What is a point of visualization of construction production data?     | 2.1. formation of capability to accompany construction throughout the life cycle | 97 | 96 |
|                                                                        | 2.2. motivation of professional activity developing                              | 96 | 94 |
|                                                                        | 2.3. granting an opportunity to follow step by step the process of construction and to master professional knowledge, abilities, skills | 98 | 97 |
| 3. What are the main functions of the virtual construction site in the course of training? | 3.1. it provides personalization and security of training                         | 97 | 98 |
|                                                                        | 3.2. it increases educational motivation                                          | 96 | 93 |
|                                                                        | 3.3. it promotes 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 survey results were discussed by teachers and students in 3 online focus groups in forum mode. Each focus group included 19 people including 9 university teachers and 10 students. Teachers were appointed as moderators of focus groups. Focus groups clarified the criteria for the effectiveness of training in technological processes on the basis of a virtual construction site: digital, professional, personal. The criteria allowed to identify levels of student’s readiness for smart technologies application.

At the forming stage, students developed method statement to optimize the duration of construction of a large-panel residential building using a virtual construction site. On the results of the method statement development, students prepared interactive reports. The method statement has five sections; each one includes several items (Table 4).

Table 4. Content of method statement for optimization of construction duration of large-panel residential building

| sections                        | points                                                                 |
|---------------------------------|------------------------------------------------------------------------|
| 1. Application field            | 1.1. Environmental conditions of the construction area                 |
|                                 | 1.2. Technical and economic characteristics of the building           |
| 2. Organization and technology of construction process | 2.1. Requirements for completion of previous or preparatory processes |
|                                 | 2.2. List of the used machines, equipment and mechanisms with specification of their technical characteristics, types, model and quantity |
|                                 | 2.3. List and technological sequence of operations and basic processes, schemes of procedure to obtain the final product |
|                                 | 2.4. Layout of mechanisms, machines and devices                        |
|                                 | 2.5. Materials and structures storage schemes                         |
| 3. Site inspection              | 3.1. Incoming quality control of structures and used materials         |
|                                 | 3.2. In-process quality control of operations performed                |
|                                 | 3.3. Acceptance inspection of operations performed                    |
| 4. Calendar progress chart      | 4.1. Stages and periods of construction, indicating the number of working days for each scope of work, the staff content for each scope of work and in total for all construction |
|                                 | 4.2. Schedule of technological processes                              |
|                                 | 4.3. Material and technical resources                                 |
|                                 | 4.4. Technical and economic indicators (hourly and shift schedules, time of machines productivity (in hours), standard prices and expenses of materials per unit of scope, wages) |
| 5. Health, safety and environmental protection | 5.1. Safe work practice                                                |
|                                 | 5.2. Safe certain work practice                                       |

370 students participated in the development of the method statement. For method statement developing the students were divided into two flows. The first flow (206 students) developed a method statement with the help of a virtual construction site of a large-panel residential building. The second flow (164 students) developed a method statement without using a virtual construction site. Students of both flows were offered two different forms of work: to work individually or in groups of 4 people. Each item of method statement was rated within 5 points. Total number of items in the method statement is 16. In total each student could score 80 points for the method statement development. Students were divided into four groups, based on the number of points scored for the method
statement development. The maximum points scored (80 points) was got by the first-flow students who worked individually (144 students) (Table 5).

**Table 5.** Student results on method statement to optimize the construction duration of a large-panel residential building

| Flows   | work types of students | Student groups formed in accordance with points scored |
|---------|------------------------|------------------------------------------------------|
|         |                        | 1 group from 80 points | 2 group from 79 to 70 points | 3 group from 69 to 40 points | 4 group from 39 to 0 points |
| 1       | Participated in total 206 students | 172 students | 27 students | 4 students | 3 students |
|         | Worked individually 167 students | 144 students | 19 students | 3 students | 1 students |
|         | Worked in groups 39 students | 28 students | 8 students | 1 students | 2 students |
| 2       | Participated in total 164 students | 51 students | 82 students | 27 students | 4 students |
|         | Worked individually 115 students | 37 students | 66 students | 12 students | 0 students |
|         | Worked in groups 49 students | 14 students | 16 students | 15 students | 4 students |

At the control stage the levels of student’s readiness for smart technologies application was identified. The students were offered to answer questions and complete tasks which were estimated according to the 5-point grading scale (Table 6).

**Table 6.** Results of answering the questions and tasks performed by students at the control stage of the experimental work (average grade).

| Criteria and indexes                                                                 | average grade |
|-------------------------------------------------------------------------------------|---------------|
| Digital criteria (D)                                                                |               |
| 1. Know the content of the concept of “intelligent construction site”               | 4.7           |
| 2. Able to characterize an intelligent construction site                             | 4.6           |
| 3. Master construction applications                                                  | 4.6           |
| Professional criteria (V)                                                           |               |
| 4. Know the international standard forms of contracts for investment and construction activities, national construction code | 4.8           |
| 5. Able to apply international and industrial standards of health, safety and environmental protection | 4.6           |
| 6. Master methods of information modeling, creation and use of three-dimensional objects | 4.4           |
| Personal criteria (P)                                                               |               |
| 7. Know applications on self-organization, self-education                           | 4.5           |
| 8. Able to form an electronic portfolio                                             | 4.7           |
| 9. Master self-presentation methods                                                 | 4.5           |

In order to identify the levels of student’s readiness to apply smart technologies, the value (Q) was determined as the sum of values (S) for each criteria: \( Q = SD+SV+SP \)
Values by each criteria were calculated using the formula: $S=\sum \frac{q_i}{n}$, where $q_i$ is the average grade got for an index, $n$ is a quantity of indexes of criteria. Values (Q) from 0 to 5 are formally considered as a low level. Values from 6 to 10 are considered as an intermediate level. Values from 11 to 15 are high. Characteristic of levels are the following. Low level (2% of students). They partly master construction applications; self-presentation methods. Their knowledge of methods of information modeling, creation and use of three-dimensional objects is very limited. Intermediate level (38% of students). They master construction applications; self-presentation methods. But the knowledge of the methods of information modeling, creation and use of three-dimensional objects are partial. High level (60% of students). They master construction applications; methods of information modeling, creation and use of three-dimensional objects; self-presentation methods.

4. Conclusions
Practical recommendations for effective application of the virtual construction site of a large-panel residential building as a digital resource of training in technological processes of construction operations are as follows. The importance of the virtual construction site increases if students master information modeling, creation and use of three-dimensional objects. The performance of training in technological processes of construction operations increases if students are familiar with digital technologies in construction. The results provide prospects for further research into the problem, which is related to the identification of risks of introducing digital resources into construction education. The article can be useful for teachers of construction universities, staff of constructing engineer development centers.

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