SMART CAMPUS AS A CORE OF PROJECT-BASED BIM EDUCATION IN AECO, CASE STUDY IN SATBAYEV UNIVERSITY, KAZAKHSTAN

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Abstract

Concepts as Smart Campus, BIM and Project-Based Education have been widely studied in different aspects during the last 20 years; however, perspectives of their mutual integration are unsatisfactorily investigated. This paper examines Smart Campus as a core concept for Project-Based Education course “BIM technologies basics” for students in the AECO field, adopted in Satbayev University (Kazakhstan) for 4th-year students learning architecture in fall 2021. The advantages of Smart Campus development in the educational framework are described and discussed. Achievements and difficulties that students have reported are analyzed to specify the effectiveness of PBE and the barriers to implementing BIM accordingly.

Introduction

The new century faces humanity new challenges; on the one hand, we have a lack of natural resources, political and informational wars, pandemics, overpopulation; on the other hand, there are new technologies that keep us moving forward and create a promising future. In the AECO sector, one of the main revolutions is the adoption of the Building Information Modeling (BIM) methodology. This paradigm shift helps to avoid overuse of resources during all lifecycle of any building or infrastructure, effectively design in a virtual collaboration environment, overcome borders and optimize the design processes, and integrate cutting edge IT technologies in AECO with multiple benefits. The consistent implementation of such a method is a strategical target for the AECO sector worldwide, and the spreading is reaching most countries' authorities, scientists and practitioners. In turn, implementing new methods and related technologies is crucially dependent on education, which is paramount to producing adequate specialists and increasing broad knowledge. BIM as a methodology especially requires to be adopted massively to permeate the processes and change the traditional approach gaining effectiveness.

In the literature review of the published research, we can find many successful implementations of BIM in higher school curriculum introduced as specialized master programs, single courses, part of project-oriented workshops, special events like lectures or conferences. All these education methods generate a great experience of implementing and developing BIM. Among others, project-based education methods show the best results and fit education features of the AECO sector. One of this method's main challenges is finding an appropriate project for the project-based education finest standards.

Searching for the aim for a project-based education course, we turned to the opportunity to introduce the Smart Campus concept. This up-to-date direction of University environment development may effectively be strongly BIM-based as retrieved in existing studies. While some of such studies involved students of different levels for the integrated tasks of the project, it has never been considered as a core concept that can orchestrate the BIM education process; nevertheless, it opens to an evolving concept related to BIM-based Digital Twins.

The present paper shares the experience of the BIM course at Satbayev University in 2021, combining project-based education with the Smart Campus concept as a global purpose for BIM education activities. The plan of Satbayev University Smart Campus, Content of the current course and future developments and features of project-based education are described and discussed.

An additional goal has been to find methods to sidestep the barriers that prevent the intuitive use of BIM and create an image of BIM as an overcomplicated design method that represses creativity. Students' problems and failures during the course were underlined and analyzed for this aim. The goal of the course has been to open the methodology to the students, promote and boost the adoption for projects of different scales and purposes, making more accessible the wide adoption of the method.

State of the art

Since BIM became one of the forwards in AECO development, training of BIM prepared specialists became one of the widespread challenges in AECO education. Overviewing recent studies, we can find the following proposals to implement BIM training in the existing educational system:

- Organization of special BIM dedicated events such as lectures, conferences, summer schools and others;
- Creating new separate obligate or elective course in existed curriculum (Sacks and Barak, 2010; Pikas, Sacks and Hazzan, 2013);
- Integrating BIM methods and principles in existing courses of curriculum (Mcgough, Ahmed and

Austin, 2013; Ahn, Cho and Lee, 2013; Lee, Kim and Yonghan, 2018)

- Implementing of special BIM undergraduate master or PhD curriculum (Wu and Issa, 2013; Mcgough, Ahmed and Austin, 2013; BIM A+, 2021)

Comparing these approaches, table 1 summarizes the results identified as the main advantages and disadvantages of each analyzed method.

Table 1: Advantages and disadvantages of different types of BIM implementation in the school education for the AECO sector.

	Advantages	Disadvantages
Organization of special events	Indication of interest and demand for BIM in academical, practical and educational fields. Broad sharing of basic BIM knowledge	Impossible to provide fundamental knowledge and any skills
Creating separate course	Complex approach to BIM training, including theory and practice. Comparingly easy to organize	Requires a substitution of another course in the curriculum. Basic level of knowledge. May be "abstract" and isolated from the professional context of other disciplines
Integrating into existing courses	Understanding of BIM principles in the context of other disciplines	Required time and resources reserved for other aims of the course. May reflect separate parts of the BIM concept, hiding the big picture. Required involved professors to have special BIM knowledge and skills
Implementing master or PhD curriculum	Possible to include an advanced volume of skills and knowledge	Required involved professors to have advanced BIM knowledge and skills

It is possible to find similar results in more advanced research like Mlinkauskienė et al.. (2020). Likewise, very illustrative studies share stage-by-stage implementation using most of the described methods (Leite and Brooks, 2020). Furthermore, it is evident from the analyzed studies that any BIM training implementation has to be based on research and propose the most effective educational practices. While progressing in creating postgraduate programs and multidisciplinary integration is still essential, currently in Kazakhstan, developing a high-quality course is an optimal approach necessary for further developments.

Such course is implemented and developed, in Satbayev University (SU), for bachelor programs in Architecture, Civil Engineering and MEP systems. We aim to prepare specialists who will shift the BIM maturity level in Kazakhstan from the bottom of 1-st to the 2-nd level. In order to achieve this, best-described cases of BIM courses have been studied. Overview showed that compared to traditional (Lee, Kim and Yonghan, 2018) or problem-oriented (Rahman, Ayer and London, 2019), there are Project-Based Education (PBE) courses (Tsai, Chen and Chang, 2019; Zhang, Xie and Li, 2018; Leite, 2016;), which are prevalent and effective. Crucial for BIM is that PBE stimulates the development of multidisciplinary approaches (crucial for BIM) and shifts to the subsequent implementation stages (Zhang, Xie and Li, 2017).

Course preparation

The "Basics of BIM technologies" course in Satbayev University was started in 2017 as a reaction of the Architecture and Civil Engineering faculty to the increased level of BIM implementation in Kazakhstan and the extraordinary perspectives it promised in developing the AECO field. Naturally, for an initial period of implementation, the main focus was to study 3d information modelling tools and less attention was paid to the concept and methodic of BIM. The requirements of the field for the BIM knowledge of graduates were also primary the same –the knowledge of BIM software.

Accordingly, the content of the course was formed to give students theoretical knowledge of BIM principles and basic software use skills required to approach a project with BIM methodology. At the end of the course, the students had to be able to join BIM processes in design companies in Kazakhstan or develop further as a BIM specialist in particular directions. Such course was held for three years.

The Autodesk Revit authoring tool was chosen to demonstrate and applicate BIM as the most spread in Kazakhstan (Tatygulov et al., 2020) and worldwide (Big data construction, no date). Besides, free educational licenses available for the universities increase the attractiveness of this software. The "Building Information Modeling" course from "BIM Academy", available on the "Stepik" educational platform (Stepik, no date), was used as an example of containing and structuring.

In 2020 three circumstances forced pedagogues to review the course. First was an introduction of BIM national regulations that contain mandatory use of BIM, including the whole lifecycle period, for complex constructions that attracts state funds (SP RK, 2017). The second was the development of new professional standards with particular attention to BIM knowledge for specialists in the AECO field (Atameken, 2020). The third was a challenge of the Covid-19 pandemic that reshaped all existing educational formats and influenced the work processes in the AECO field worldwide.

To develop the course writers used the Tyler Model of curriculum development (Tyler and Hlebowitsh 2013), that is one of the most applicable for the scientific approach disciplines and was successfully implemented in comparable curriculum design studies (Ahn, Cho and Lee, 2013) According to Tyler Model course design consist of four steps:

1. Determination of course aims
2. Identification of processes that will lead students to the determined aims
3. Organization of the process
4. Evaluation of the determined aims achievement

The general objectives of the course are derived from the circumstances that prompt the process of creation:

- preparing students for the shift to the Level 2 of BIM maturity, with particular attention to BIM not as an only design tool but more as the design method
- considering new requirements of the AECO market pointed in professional standards
- searching for new pedagogical methods, effective both in online and offline formats

Shift to Level 2 of BIM maturity requires studying not only BIM tools but also BIM methods, including identifying BIM Goals and Uses, designing BIM execution plans, and developing Information Exchange. This approach meant the course needed a single core process imitating the information modelling on practice.

Requirements of professional standards on the bachelor level of education in addition state the demand for the Common Data Environment collaboration and automated calculations skills. Because the discipline volume did not change, these additions meant that the pedagogical paradigm should be switched from an individual universal approach (Keller, 1967) to working in groups with differentiated tasks (ERIC, 1987).

Increase of course's effectiveness in the conditions of on-line education as well as in the traditional conditions, according to the multiply research (Fu and Yu, 2006; Uhlig et al., 2007; Kim, Glassman, and Williams, 2015; Klimova, 2021;), may be achieved by the adoption of different educational methods: gamification, social collaboration, Project-Based Education. Project-based education was chosen as the best way to fit new purposes of the course described previously.

Intending to have an objective material to compare the results of new course, the PBE component was elective, and students from the same group had an opportunity to choose between PBE and the regular work. The regular task for course work was to create (individually) an information model of a building (house, for example) from 2d drawings (usually got from the Internet, previous or ongoing design studios). For PBE a group of students had to develop BIM model of existing building to improve the maintenance processes (details are described further in "Smart Campus Satbayev University" section).

While originally Tyler Model involved basically Assessment of students' academic performance as a course evaluation method, later research showed that such method may have some limitations. In the case of new experimental course with new conditions, methods of training and contain objective assessment of academic performance is hampered.

Instead, process oriented responsive evaluation (Stake, 1967) was implemented. Initial evaluation was made using PBE Gold Standard. For results interpretation it was hypothesized that students who arise and solve more problematic questions in the practical tasks, after adoption of the same theoretical material – will finally have accordingly higher level of knowledge and skills. To analyze also the student's vision and feedback, questionnaire study after the end of the course was planned.

Content of the course

The vital part of the PBE course was to find an aim for the project. We decided to start from the known experience of Smart Campus (SC) at the University of Brescia (De Angelis et al., 2015) as a strategy to organize the long last project as a core for the course.

SC concept was first mentioned in the latest 90th (Kaneko, Sugino and Suzuki, 2000) and became one of the educational trends from the beginning of the 21st century. Initially, it was based on the set of IT technologies helping to solve problems of new educational realities as distance learning. However, later SC was naturally integrated with concepts of Smart house, Smart city, Sustainable development and much more, that made it much more expansive and added connections to the organization of the material environment (Kar and Gupta, 2015; Jiang, 2017; Min-Allah and Alrashed, 2020; Yuxia, 2020).

The University of Brescia team was the first in Italy to expose and realize the potential of BIM in implementing SC (De Angelis et al., 2015). Building as an environment integrates all processes in University, i.e. education, administration, science, maintenance, consumption and building model may collect all the information about these issues. Moreover, it gives a visual frame to information, making it more structured, communicable, convenient and sharable.

In Kazakhstan, SC is currently introduced in three universities (Zhamanov, 2018; Tengri Lab, 2020; Al-Farabi Kazakh National University, no date), covering mainly the IT part of the concept. Satbayev University, as a leading technical university in Kazakhstan, may become a perfect platform to develop a more complex approach.

Smart Campus (SC) is an industry 4.0 era concept that concerns the sustainable redevelopment of universities facilities and processes using different approaches. Furthermore, SC may be BIM-based and developing a Smart Campus has several advantages when adopted as a purpose for PBE in BIM education:

- BIM allows operating and visualizing facilities, processes and information for Smart Campus;

- Smart Campus have infinite perspectives of development that mean infinite targets for PBE;
- Smart Campus development can help to underline the importance of BIM during the O&M phase of the building’s lifecycle;
- Smart Campus involves high-end technologies;
- Smart Campus definition requires to combine numerous efforts in different fields as IT, management, economics, AEC, robotics and others that stimulate the adoption of a multidisciplinary approach.

Therefore, we decided to implement SC as a project-based component to BIM-related courses at Satbayev University. We listed the following challenges occurring in Satbayev University on the date of research that a BIM-based SC could solve:

- Lack of a unified system of data storage, processing and updating;
- Loads of lost or outdated data;
- Inadequate data storage format;
- Limited range of collected data;
- Lack of transparency of operations;
- Lack of convenient navigation;
- Outdated mechanisms of interaction of the environment with users;
- Lack of mechanisms to minimize resource consumption and environmental impact.

Based on the latest research, we formulate an aimed SC model for SU, as shown in Figure 1.

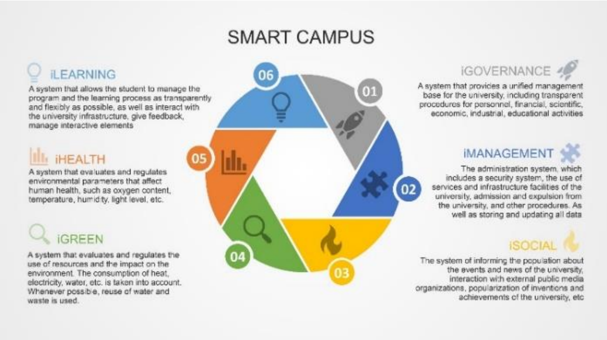

Figure 1: Satbayev University Smart Campus aims

The conceptual framework for SC development at the University of Satbayev was presented to the administration office and the university leadership and management team and approved with the roadmap depicted in Figure 2.

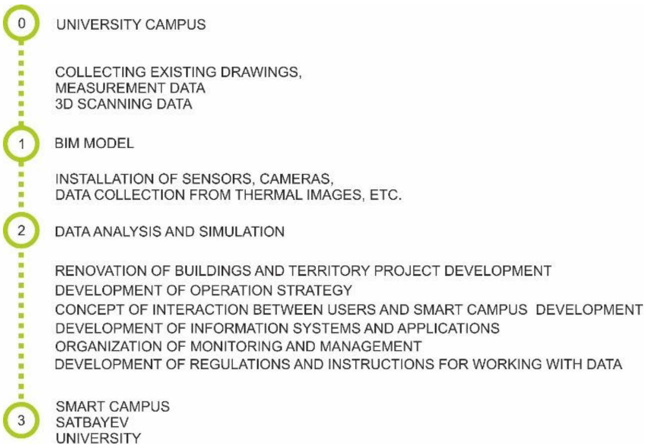

Figure 2: Satbayev University Smart Campus primary stages

It was decided to use the architecture department building as a pilot project for the first step. The following plan was thus approved for the future development. Nevertheless, before extending the application on the whole Campus, a pilot project for architecture department building was organized according to the following plan:

- Create a BIM model;
- Analyze current usage characteristics and patterns;
- Calculate possible benefits of reconstruction using sustainable principles and smart technologies;
- Create a BIM project for a renovation phase;
- Calculate the environmental and economic benefits of the proposed renovation project;
- Realize the renovation process and implement the smart technologies dissemination;
- Analyze the renovation effects and developments;
- Implementation of the strategy to the whole Campus.

The first phase from this list (Create a BIM model) became the first project task for the considered PBE oriented course. The collaboration between groups of Architects, Civil Engineers, and MEP engineers, studying BIM to create a complex model was planned. However, currently Architecture students had a course in the fall semester while their colleagues had it in the spring. Consequently, it was decided to create an architectural model in the fall of 2021 and then proceed with the construction specifications and networks in the second semester. For the future curricula, the purpose is to organize the joined work simultaneously.

Finally, the course that was conducted in fall 2021 had three main didactic sections:

- BIM Theory;
- BIM practice based on the Revit authoring tool;
- Course work: PBE component/ traditional course work (electively).

Practice and theory moved parallel according to Table2.

Table 2: Content of the “Basics of BIM technologies” course

№	Theoretical topic	Practical topic

1.	General BIM concept	Families: Parameters and information
2.	History of BIM	Families basic categories: windows, doors, interior equipment
3.	CDE	CDE – Common Data Environment
4.	Advantages and limitations of BIM	Main modeling tools: walls, roofs and ceilings
5.	BIM, state of art	Main modeling tools: constructional frame
6.	BIM case studies	Main modeling tools: curtain walls and rails
7.	BIM Software	Main modeling tools: rooms, spaces, areas
8.	BIM state standards	Main modeling tools: stairs and ramps
9.	BIM corporative standards and primary documents	Main modeling tools: topography and elements of landscaping
10.	BIM implementation process	Main modeling tools: 2D instruments
11.	Management in BIM	Schedules and specifications
12.	BIM and industry 4.0, perspectives of BIM	Graphical presentation and templates
13.	Smart Campus concept	Layout, import and export
14.	Smart Campus Satbayev University project and BIM	Adaptive families. Introduction to generative design.
15.	Course work presentation	PBE final work presentation

The course was basically off-line. Although some of the online methods that appeared to be effective were used. Microsoft Teams platform was used to:

- Store essential materials (e.g. books, articles, links and video lectures);
- Upload, receive, assess and return the tasks;
- Hold additional consultations (especially during the final stage);
- Organize a basic part of CDE with main project materials.

Initially, it was planned to create a CDE on the One-Drive platform that allows synchronizing files between multiple users. This approach was adopted in the theoretical part and realized in the practical classes. However, having experience with organization and exploitation of common storage file with simple template models, students found it very difficult, unstable and critically sensitive to software and hardware features, internet network stability and human factors. While the teaching staff still recommended trying the use of the CDE with «automagical» integration of different parts of the model and working in a single file, the students finally chose to integrate the model manually, arguing this could be a slower method, but more reliable for them to control the process strictly. It must be underlined that interviewing companies in Kazakhstan using BIM, during the preparation phase of the course to find a suitable CDE approach showed a similar result: companies in Kazakhstan are refusing to use online CDE solutions preferring local network solutions using the same arguments raised by the students/users. This shows that general insecurity about the online CDE is perceived, possibly due to the lack of widespread practice.

As mentioned above, students choose to attend PBE component or do traditional coursework. Of 18 students on the course, 12 (67%) joined the PBE component. Initially, the number was significantly lower, and the teaching staff stimulated the participants explaining the advantages of PBE and the possible influence of SC on their further learning experience. Both the group that chose the PBE and the team working on the traditional task had similar content of more motivated and weaker students, making it possible to compare their results in the final stage. In order to coordinate the modeling phase, a BIM execution plan was created. For that purpose, the Autodesk template was applied. BIM uses, roles in the team, schedule and additional features were described and utilized. This was particularly beneficial to specify the needed level of detail and level of information needed.

The course evaluation through Gold Standard of Project-based Learning

In order to verify that the chosen task was adequate according to the best practices of project-based education (PBE) it was analyzed using the Gold Standard of Project-based Learning (GSPBL) (Larmer, Mergendoller and Boss, 2015). In the following, the key criteria and checks are listed.

Student Learning Goals: assuming skills and knowledge to be ready for the industry 4.0 in AECO sector.

Key Knowledge: BIM.

Key Success Skills: “Collaboration” and “Technology skills and digital literacy”.

Essential Project Design Elements:

Challenging Problem or Question: Smart Campus development requires solving multiply problems vital to the modern world, such as effective data storage and operation, efficient energy management, multi-comfort environment.

Sustained Inquiry: While the basket of the materials was given to students, there were still some points requiring independent efforts, such as: measurements of the building’s portions and details that were not introduced in the existing documentation; organization of shared storage files using cloud services; interpretation of BIM tasks of the project to the list of necessary elements and data, organization of model integration.

Authenticity: Modelling the educational building or developing other parts of the smart campus project impacts the development of the University environment. Attending to the improvements in the everyday ambient is a perfect way to make a project equally authentic for all participating students.

Student Voice & Choice: For the first time, the project-based component of the course was elective, with possible further options to choose from. For the final practical work and some exercises, students could elect abstract tasks or tasks connected to their design project, or join modelling the university building for the Smart Campus pilot project. The students who joined the project-based component were also able to select their roles and tasks and determine which kind of tools and methods they would use. Such an approach enables them to characterize their perception in studying BIM concepts and demonstrate their willingness to use them.

Reflection: We consider two stages of reflection. Firstly, during the course, students were able to reflect on the theoretical knowledge about BIM and software skills, applying them to the Smart Campus project tasks. Furthermore, as resulted materials of the course are only one of the multiple steps of the whole SC project, the students will be able to follow how the product that they have created will be used and developed further, understanding possible mistakes and their consequences and increasing perception of belonging to the university campus development.

Critique & Revision: There were three stages of the revision process for PBE part of the course. The first was self-revision that students performed when they needed to combine their parts of the model or work with materials prepared by other students previously. Students responsible for integrating the parts of the model reviewed and critiqued others' work, observing all inconsistencies between the different parts. The second stage was a critique executed by the teaching staff on the weekly consultations and weekly tasks revision. The final revision was conducted after the final work was completed, and it was aimed to underline how the final result fits the initial aims.

Public Product: Results of Smart Campus development are highly demanded from the administration of the University. The students hence experienced accountability for their project. The preparation of the materials for the public presentation to the leading team of the Rector and Decan set high standards of the required quality.

As seen from this review, proposing an approach for the PBE course in BIM technologies based on the SC concept fits the PBE Gold Standards and promises highest results in education.

Results and discussion

During the course, the students completed all theoretical and practical modules. A questionnaire survey among the students showed the following average perception of the course (from maximum 10): overall quality: 9.25; complexity: 6.17; Relevance: 8.83. The average academic performance was 62/100. “CDE” was indicated as the hardest module, and “Graphical presentation and templates” as the easiest.

PBE team created a BIM model of University building (Figure 3) defining constructions, walls, slabs, roof, windows, doors, stairs, finishing, basic furniture, nearest landscape. Most of the information was created for rooms: number, function, capability, finishing of the main surfaces. It was considered that this information could be increased according to further developments. Finally, the model was ready to define the required management and maintenance data. 5th year students currently realize further integration of networks and constructions components as final thesis work.

Compared to the traditional team, the PBE team showed much more complex processes to face. The main problems are listed in the following:

1. The discrepancy of levels during the creation of the model sections;
2. Disconnection of the elements;
3. Mistakes in the location of the elements (e.g. columns, windows, doors and others)
4. Struggles in designing 3D topography from existing 2D drawings;
5. Incongruity in using specific types of elements;
6. Inconsistency of materials and other parameters in different sections of the model.

Figure 3: Model of Satbayev University campus building, realized in the framework of the course

Most of these mistakes (1-3) resulted from a manual mix of the general model. Experience of such mistakes and other challenges during manual combination and further corrections were much more convincing than theoretical explanations on the correct process for implementation.

Errors like 5 and 6 report a lack of pre-designed standards and descriptions, that have crucial role in BIM. Initially careless attitude pointed out that students did not significantly perceive the importance of the pre-designed stage, although it was clearly explained in theoretical lectures. Problems in creating 3D topography (4) were caused by students’ difficulties understanding 2D topographical drawings, unveiling the need to deeply analyze the environmental context. Reflection and correction of discovered problems underlined students’ omissions in BIM knowledge and skills and allowed to correct them and increase awareness of these crucial topics. The errors in the model were also amended.

At the same time, students who did the traditional course work did not experienced any of mentioned problems. According to the course results comparison hypothesis (described in “Methodology for the course preparation” section) such situation demonstrates that individual abstract tasks are less effective in strengthening knowledge and assessing the BIM methodology understanding and skills comparing to the PBE approach. The course experience showed that PBE helps students understand and assimilate vital BIM concepts. It also proves conformity of SC goals to purposes of PBE in BIM education. In the previous sections, a bunch of SC advantages as a subject for PBE in BIM were described to promote the idea; however, the course results show that we started with the beginning of the process, most of the perspectives and correspondingly challenges are not examined. The University hope is that our efforts will be continuous and will show interesting results in the future development of BIM education in Kazakhstan. The experience also aimed to attract the attention of colleagues and pedagogues to join the process and contribute in our implementation. It is worthy to note that, while the approach to the complex process of SC can show sensible positive changes in students education experience, separate segments may not have evident results. That may reduce the “authenticity” of the PBE application. In order to overcome this gap, lectures about SC and its implementation were added to the course. This lecture described the plan of SC implementation and the importance of the role that students would have in this process. There are also some significant difficulties revealed in the proposed method. Firstly, it is the long terms of SC implementation, in case it would be realized by students’ teams, as the teaching staff have to teach to a new team for each subsequent goal. Moreover, the goals have to be relatively simple to complete during a single course period. Therefore, it is clear that the most challenging sections have to be extracted and executed by the research team that is now under creation at Satbayev University. A second question is the diversity of the goals in the SC implementation plan that may require different skills and knowledge from each students’ group, depending on the stage of the process. This may prevent the unification of the course and achievement of the same positive results in each run of the curse. Nevertheless, at the same time, such a situation will require more flexibility both from students and educators. The need for a multidisciplinary collaboration that is also a consequence of diversity is nowadays paramount for successful work and career in the students' future.

Special attention is needed to point out some barriers to BIM implementation in Kazakhstan that were highlighted during the course. As it was mentioned previously, collaboration, especially in online CDE is still complicated. This has been detected in the perception of CDE among the students and professionals, at least in developing countries. As a significant part of BIM, it may delay the development of application in general. New intuitive and «error resistant» tools are highly demanded, and they could change the perception and speed up the diffusion of an advanced adoption of the BIM methodology.

Conclusion

The analysis of three modern concepts in AECO sector and education that are Building Information Modeling (BIM), Smart Campus (SC) and Project-Based Education (PBE) show the excellent potential for increasing the quality of BIM training and tutoring and developing university environment that can have a mutual integration in the educational process of the students. While some obstacles with organization, terms and unification are considered, they can be overcome by the efforts of developers or outweighed by strong positive effects.

Existing studies repeatedly prove the value of each concept, and this research is the first step to unveil the synergetic effect they may have together in a country such as Kazakhstan that is approaching BIM use while standards and education are not entirely mature. Based on the latest developments in each direction, we prepared and activated a BIM course with the project-based Education component, designed according to the PBE Gold Standard. The successful realization of the first step of Smart Campus for Satayev University during this course makes us believe in our proposal's successful attitude and the benefit of sharing it with other researchers working on implementing BIM in education through SC development and with the adoption of PBE.

While Kazakhstan is only at the beginning for implementing the BIM methodology, the same approach may be effective not only for this country or other developing countries: with expanding SC goals and education methods, it may be discussed and eventually adopted for education and practice also by countries where BIM adoption and AECO industry are mature. Moreover, developed countries have more resources to implement this approach with more advanced technologies and ambitious goals, and they can integrate the discovered advantages coming from the presented experience. The modern age creates new challenges for civil engineering, erasing familiar paths and borders. New versatile methods and technologies and their combinations have to be found to face the new future of the AECO sector and link the world in practice, science and education.

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