Л.Н. Гумилев атындағы Еуразия ұлттық университетінің ХАБАРШЫСЫ.
ISSN: 2616-7263. eISSN: 2663-1261
ТЕХНИКАЛЫҚ ҒЫЛЫМДАР ЖӘНЕ ТЕХНОЛОГИЯЛАР СЕРИЯСЫ / TECHNICAL SCIENCES AND TECHNOLOGY SERIES/ СЕРИЯ ТЕХНИЧЕСКИЕ НАУКИ И ТЕХНОЛОГИИ

IRSTI 67.07.01
Scientific article

https://doi.org/10.32523/2616-7263-2024-149-4-326-350

Designing a master degree program in building information modeling (BIM) using national professional standards: a case study in Kazakhstan

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Abstract. This article presents the design of a master degree program focused on "Building Information Modeling (BIM) Technologies in Architecture, Engineering & Construction (AEC)" in Kazakhstan. The demand for such a program arises from the scarcity of qualified professionals proficient in BIM implementation, both in Kazakhstan and worldwide. The proposed method utilizes national professional standards as a reliable source of essential competencies. These professional standards aim to foster collaboration between higher education institutions, the government, and AEC companies. The design process incorporates various methods, including an indexation system to track each requirement from the standards throughout the program, multicriteria analysis for selecting appropriate competencies, and the implementation of a cognitive levels taxonomy to structure the program effectively.

Keywords: BIM-technologies; curriculum design; professional standards; multicriteria analysis; indexation system; Bloom's taxonomy.

Received 12.12.2024. Revised 18.11.2024. Accepted 20.11.2024. Available online 31.12.2024

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Introduction

All professionals in the Architecture, Engineering & Construction (AEC) field wish for the ability to effortlessly manage routine processes, such as generating construction documentation. Over the past two decades, this dream has become a reality with the advent and advancement of Building Information Modeling (BIM) technology. BIM is a computer-aided design technology based on parametric modeling, shared data environments, 3D (and more) design, and other features. Not only does it facilitate the creation of affordable, energy-efficient, intelligent, and sustainable buildings, but it also propels forward the entire AEC process.

However, companies worldwide continue to face a shortage of BIM specialists. Many lack the necessary expertise or are unable to invest in staff training due to lengthy time requirements and high costs, particularly in countries that are in the early stages of BIM implementation, where the return on investment may not be immediately apparent. This shortage is even more pronounced among independent professionals seeking to acquire BIM skills on their own [1,2,3]

Becoming proficient in BIM requires a diverse range of skills and knowledge. As a result, educational institutions face a new challenge of preparing skilled BIM specialists. Existing literature suggests various approaches to train BIM specialists in the AEC field. These include work-based education [4] or specialized training services [5] offered by AEC companies, integrating BIM training as part of higher education courses [6,7] or separate online courses [8-11], capstone modules [12], or a systematic implementation of these approaches [13].

Despite these efforts, there remains a gap between the skills acquired through education and those in demand by industry practitioners. The complexity of BIM necessitates a vast amount of knowledge for its comprehensive understanding and implementation. While isolated success stories of individual courses or corporate training practices can be found in the literature [14], such approaches may soon prove insufficient as BIM technology continues to advance, and requirements evolve rapidly.

Therefore, universities play a critical role in addressing the need for BIM experts equipped to tackle the modern challenges of the AEC industry. Some universities in developed countries have already introduced postgraduate programs in this field (BIM A+, n.d.; Building Information Modelling (BIM) in Design Construction and Operations - MSc - UWE Bristol: Courses, n.d.) [15]. We hypothesize that universities in developing countries, such as Kazakhstan, also need to develop curricula that cater to local characteristics and institutional requirements, thereby accelerating BIM integration within the local sector. Recent research has demonstrated such cases in Kazakhstan and other countries [17,18,19].

Existing studies on BIM curriculum design propose several main methods [20]: (1) product model curricula, which analyze practical requirements of the field to allocate, classify, and prioritize competencies systematically; (2) technology model curricula, which leverage the latest advancements in the field [21, 22, 23]; and (3) process model curricula, which are based on real projects requiring flexible implementation of best practices to achieve their goals.

The first method involves complex mathematical analysis and extensive social surveys, as seen in Zhang et al., (2016) study [21]. This method is not always efficient due to the constant evolution of BIM technology, resulting in changing requirements year after year.

The second method may be suitable for international universities in developed countries that aim to prepare specialists capable of working in high-end global companies, adapting and advancing the best knowledge and skills. However, professionals often require a stronger focus on local characteristics and requirements than on cutting-edge technologies.

The third method eliminates the need for additional surveys and offers a practical orientation, but it is most effective when BIM technology is widely and regularly utilized, allowing students to actively participate in real-time BIM design processes.

The current state of BIM implementation in Kazakhstan presents certain challenges that render existing methods unsuitable. These challenges include the lack of governmental or private funding for extensive surveys aimed at creating new BIM curricula, the presence of a specific construction field with complex regulations and a conservative market, as well as the limited demand for BIM [24] and consequently, the scarcity of projects that could serve as a foundation for project-based courses [25]. Therefore, alternative methods needed to be explored.

Among the various publications on curriculum design across different disciplines, an approach based on professional standards has emerged [26]. Many countries develop professional standards through trusted public, political, and social instruments, which encompass up-to-date requirements for specific fields [27]. By utilizing these standards, the need for social surveys can be circumvented while maintaining a strong connection with local industry practices.

In this research, we examined Kazakhstan's professional standards and devised a method to interpret the listed BIM requirements into a multidisciplinary postgraduate program. This method incorporates multi-criteria analysis to extract the necessary competencies and leverages Bloom's taxonomy, applied to AEC workflow levels, to structure the program effectively. It is a relatively straightforward method that can be regularly employed to update and align the program with the evolving phases of BIM development. Furthermore, with minor modifications, this method can be adapted for use in other disciplines within Kazakhstan and in countries that utilize professional standards to develop market-oriented programs, thereby producing highly qualified professionals.

The methodology

Standard analysis and indexation system

The methodology employed in this study is based on the analysis of Kazakhstan's professional standards and the development of an indexation system. To provide a brief overview, the current professional standards in Kazakhstan were established by "Atameken," the National Chamber of Entrepreneurs of the Republic of Kazakhstan, in 2020 [28]. These standards cover approximately 30 fields, including "education," "services," "medicine," and more. Each field consists of various directions that represent specific types of professional activities. For instance, within the "Construction" field, which is the focus of this research, there are directions such as "Work on flooring and wall covering," "Earthwork," and "Insulation work." Each direction is associated with a professional standard, which may encompass several professions of different qualification levels. These professions are described in "Profession Cards," and they are identified by unique identification numbers.

For this study, only the directions related to BIM at the first level of maturity were considered [29], namely "Architecture and urban planning" and "Development of construction projects." The master's program aims to train specialists at the 6th and 7th levels of qualification, according to the Kazakhstan national qualification framework. Consequently, only the relevant professions were analyzed. In the aforementioned standards, these professions include Architect, AEC Design Engineer (which is essentially an urban planning specialist), Landscape Architect, Automated Systems Specialist, Cost Engineer, Fire Alarm Engineer, Structural Engineer, and Senior Engineer. The requirements for these professions, as outlined in the professional standards, will be further reviewed in this article.

Combining multiple professions into a single curriculum presents challenges for both curriculum developers and prospective students. As Kazakhstan has embraced the Bologna Declaration [30], we believe it is crucial not only to provide a high-quality educational program but also to make it student-centered. Therefore, a method was devised to establish connections between the content of the standards and the educational program, enabling a clear understanding of the background of each discipline. To achieve this, we developed a reference tool that links each item of the standards throughout the curriculum design process. This tool serves as a reference for enrollees and students, illustrating the competencies they can acquire and which professions require specific competencies.

To create the reference tool, we analyzed the structure of the "Profession Cards" and assigned indications for each level. Figure 1 depicts the structure of the "Profession Cards," the principles of indicating specific items at each level, and examples of merging them into a comprehensive reference index (see Figure 1).

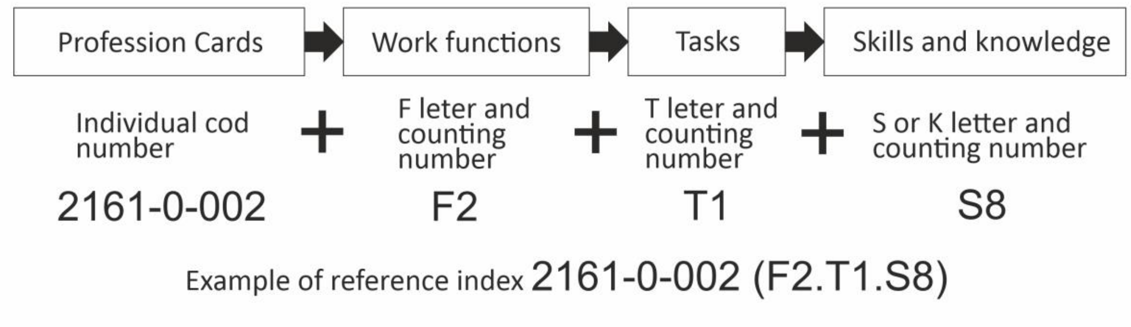

Figure 1. Structure of professional standard and reference index

The inclusion of such links can greatly enhance the transparency of the program creation method and provide several benefits for curriculum methodologists, pedagogues involved in program implementation, and students considering participation in the program.

By utilizing the indexation system, methodologists can easily update the program to accommodate changes in the original professional standards. Given the rapid development in various knowledge areas, including BIM technologies, it is likely that the professional standards will undergo regular revisions. In such cases, methodologists can simply trace the skills from the program components to the content of the updated standards and make the necessary adjustments.

Pedagogues involved in designing the program content and teaching would benefit from understanding the ultimate objectives of each subject in the students' professional development and the contextual relevance of those objectives by familiarizing themselves with the corresponding parts of the standards. This understanding can significantly enhance the quality and effectiveness of the subjects and the overall program.

Students, on the other hand, would gain valuable information about the practical professional requirements associated with the skills they can acquire in each discipline, enabling them to make informed choices. This provision of evidential information can boost their confidence, motivation, and ultimately, their learning outcomes.

By incorporating these links between the program and the professional standards, the overall program design becomes more transparent, facilitating communication between stakeholders and improving the educational experience for all involved parties.

Classification of requirements

The subsequent step involves the classification of BIM-related requirements extracted from the selected profession cards. Given the significance of BIM, specific attention was given to requirements directly mentioning BIM (examples of such requirements are presented in Table 1). A total of 217 items were identified. Duplicate requirements were eliminated, while retaining the original indexes as a reference list appended to each corresponding requirement (Figure 2). These requirements will be categorized as either obligatory disciplines, if they include indexes from the majority of professions, or elective disciplines, if they encompass indexes from only a few professions. The resulting list comprises 126 unique requirements.

Notably, it is worth mentioning that out of the identified BIM requirements, 51 of them originate from the "Architect" professional card, which is significantly higher compared to other professions, indicating the prominence of BIM in the field of architecture.

Knowledge of the BIM regulatory and technical documents of the Republic of Kazakhstan in the development and implementation of projects using BIM. 2161-0-002 F1.T1.K8, 2161-0-002 F1.T2.K72, 2161-0-002 F1.T3.K5, 2161-0-002 F2.T1.K8, 2161-0-002 F2.T2.K5, 2161-0-002 F2.T3.K5, 2161-0-002 F3.T1.K11, 2161-0-002 F3.T2.K4, 2161-0-002 F3.T3.K2, 2161-0-002 F4.T1.K4, 2161-0-002 F4.T2.K6, 2161-0-002 F5.T1.K5, 2161-0-002 F5.T2.K5/2164-1-001 F1.T1.K9, 2164-1-001 F1.T2.K3, 2164-1-001 F3.T1.K7, 2164-1-001 F3.T2.K5, 2164-1-001 F3.T3.K3, 2164-1-001 F5.T1.K5, 2164-1-001 F5.T4.K3/2162-0-004 F2.T1.K6, 2162-0-004 F2.T2.K4, 2162-0-004 F2.T3.K3, 2162-0-004 F3.T1.K9, 2162-0-004 F3.T2.K3/2151-2-030 F1.T1.K8, 2151-2-030 F1.T2.K4, 2151-2-030 F2.T1.K4, 2151-2-030 F2.T2.K1/2149-5-003 F1.T1.K8, 2149-5-003 F2.T1.K3, 2149-5-003 F2.T3.K3, 2149-5-003 F3.T2.K3/2151-9-008 F1.T2.K4, 2151-9-008 F1.T4.K3/2144-1-003 F1.T2.K3, 2144-1-003 F1.T4.K2/1323-0-007 F1.T1.K4, 1323-0-007 F1.T2.K5, 1323-0-007 F2.T1.K3

Figure 2. Example of requirement with a list of indexes, matching the exact location of each mentioning.

We have considered these requirements as educational competencies, and their derivation from professional standards ensures the necessary correlation between competencies and the institutional context, which is crucial for designing competence-oriented curricula [31,32].

Professions at the 6th level and higher require practical experience and higher education, including bachelor and master's degrees, according to the national qualification framework [33]. This implies that individuals have three avenues to acquire each of the 126 competencies mentioned in the standard: through a bachelor's program, on-the-job education, or a master's program. Therefore, it is necessary to determine which of these 126 competencies can be effectively learned within the framework of a master's program.

The bachelor's program primarily focuses on providing foundational professional competencies and, in the context of Kazakhstan, may include only a brief course on BIM (such as "Basics of BIM technology" at Satbayev University). Additionally, the proposed master's program should also cater to specialists who graduated before any BIM competencies were included in bachelor's level programs. Consequently, the bachelor's program option was excluded from the analysis. The choice between practical experience and a master's program should be based on assessing the efficiency of acquiring specific competencies in each case.

The academic learning process is well-suited for acquiring substantial theoretical knowledge and general skills that can be applied in various professional contexts. On-the-job education allows individuals to learn specific actions and methods directly applicable to their current work environment without being detached from the workflow. Moreover, practical experience provides valuable opportunities for collaboration and communication with different specialists, clients, suppliers, and more. It also offers real-world tasks that extend beyond general competencies. While academic institutions can implement project-based learning, enterprises can organize courses or establish special education departments, these are individual cases and are not reflected in this work. Therefore, the criteria for differentiating professional standards requirements were defined as follows: potentially long duration of education, a significant volume of information, and general-purpose usage for academic learning; and enterprise-specific dependence, collaboration, communication, and real design process requirements for on-the-job education.

To compare the attachment of competencies, a multicriteria analysis was utilized. This method is widely adopted in various domains to make evidence-based decisions that consider multiple influencing factors [34,35,36]. The applicability of the criteria was evaluated using three grades: slight (-1), medium (0), and strong (+1). Each competence was assessed as belonging to either the master's program or on-the-job education based on the cumulative value of the criteria.

Table 1 illustrates the assessment of competencies using the formulated criteria, taking the first three BIM requirements from the 2161-0-002 profession card for architects as an example.

Table 1. Multicriteria analysis sample

Index of requirement	Differentiation criteria							
	Academic (master-program)				On-work education			
	long duration of education	big volume of information	transferable skills	**Sum**	based on enterprise specifics	multidisciplinary and communication-based abilities	real design process-based expertise	**Sum**
2161-0-002 T1.Z1.Um2*	0	0,5	1	**1,5**	1	0,5	1	**2,5**
2161-0-002 T1.Z1.Um3**	0	0,5	1	**1,5**	1	1	1	**3**
2161-0-002 T1.Z1.Um6***	1	1	1	**3**	0	1	0,5	**1,5**

2161-0-002 T1.Z1.Um2* – Determination of the tools and methods for collecting additional data necessary for the development of the architectural section of the project documentation or the Project Information Model (PIM) (when developing a project using BIM).

2161-0-002 T1.Z1.Um3** – Conducting field surveys to analyse the features of the construction site required for the development of the architectural section of the project documentation or the Project Information Model (PIM) (when developing a project using BIM).

2161-0-002 T1.Z1.Um6*** – Analysis of design, Construction and operation of similar capital construction projects or analysis of the Common Data Environment analogues to ensure the workflow process between the participants in the formation of the Project Information Model (PIM) (when developing a project using BIM).

The results of the assessment of all 126 competencies, as shown in Figure 3, enabled us to clearly categorize them as either "Academic" or "On-work" education. The competencies identified as "Academic" and those that obtained equal results were utilized to form the core disciplines of the BIM in the AEC master program.

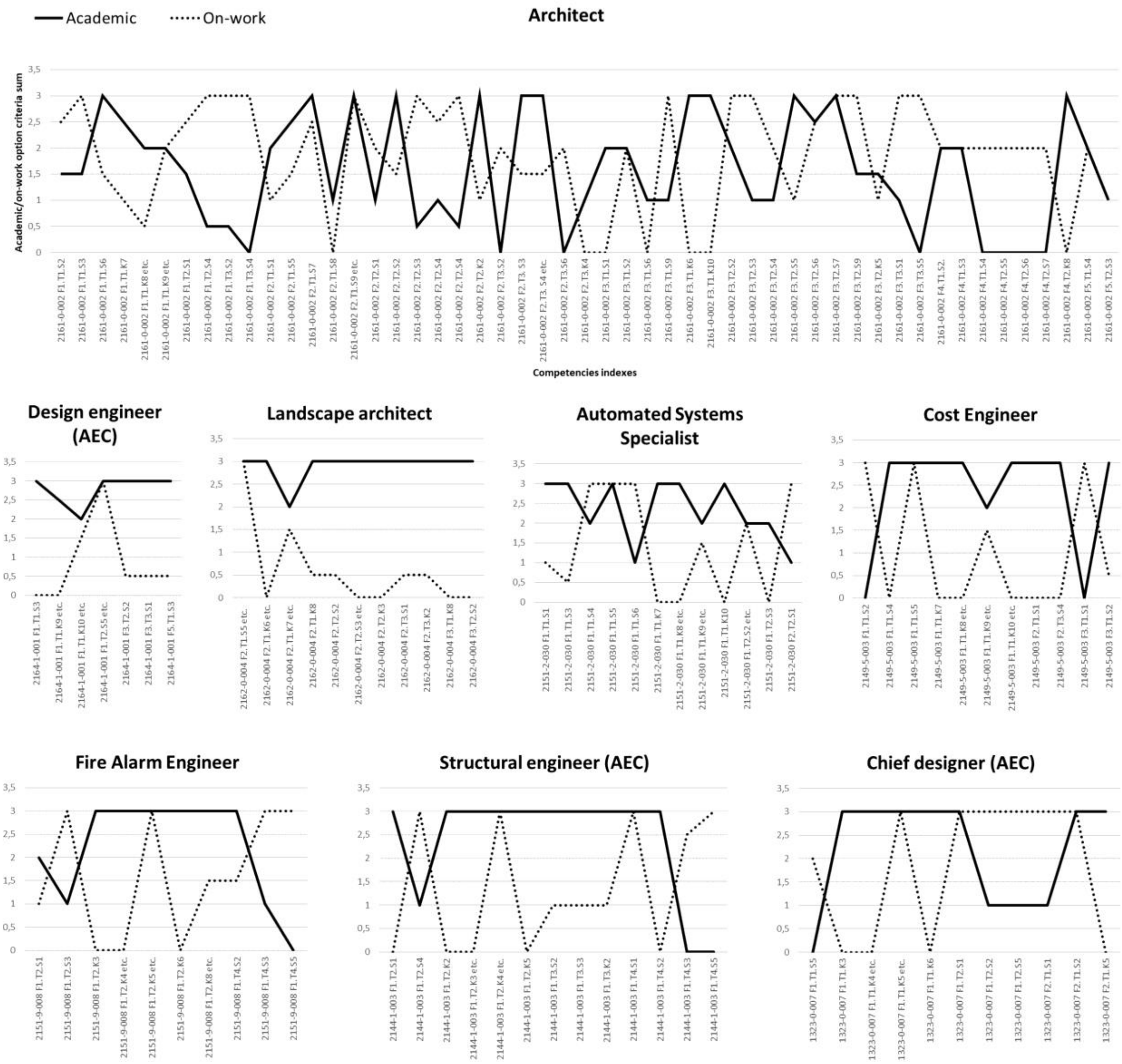

Figure 3. Results of multicriteria analysis for AEC professions requirements, presented in Kazakhstan professional standards. Solid line - Academic criteria sum, dotted line - On-work education criteria sum. Requirements presented with its individual indexes

A total of 68 competencies were categorized as "Academic," while 38 competencies were classified as "On-work" education. Additionally, 20 positions had an equal assessment result for both categories. Based on these findings, we selected 88 competencies to shape the disciplines within the BIM in the AEC master program.

From competencies to disciplines

The next step is to create disciplines based on the defined components. This process involves several challenges: grouping competencies into coherent and comprehensive content for each discipline, determining the sequential order of disciplines, and assessing the volume of each discipline in terms of ECTS credits.

To guide the structure of the program and ensure a gradual increase in cognitive complexity, we utilized Revised Bloom's Taxonomy (2001) [37]. We adapted the taxonomy to the AEC field by mapping its six levels of cognitive learning to the types of activities commonly found in AEC [37-40]. This provided a logical framework for combining competencies into disciplines and establishing a sequential educational process (see Figure 4).

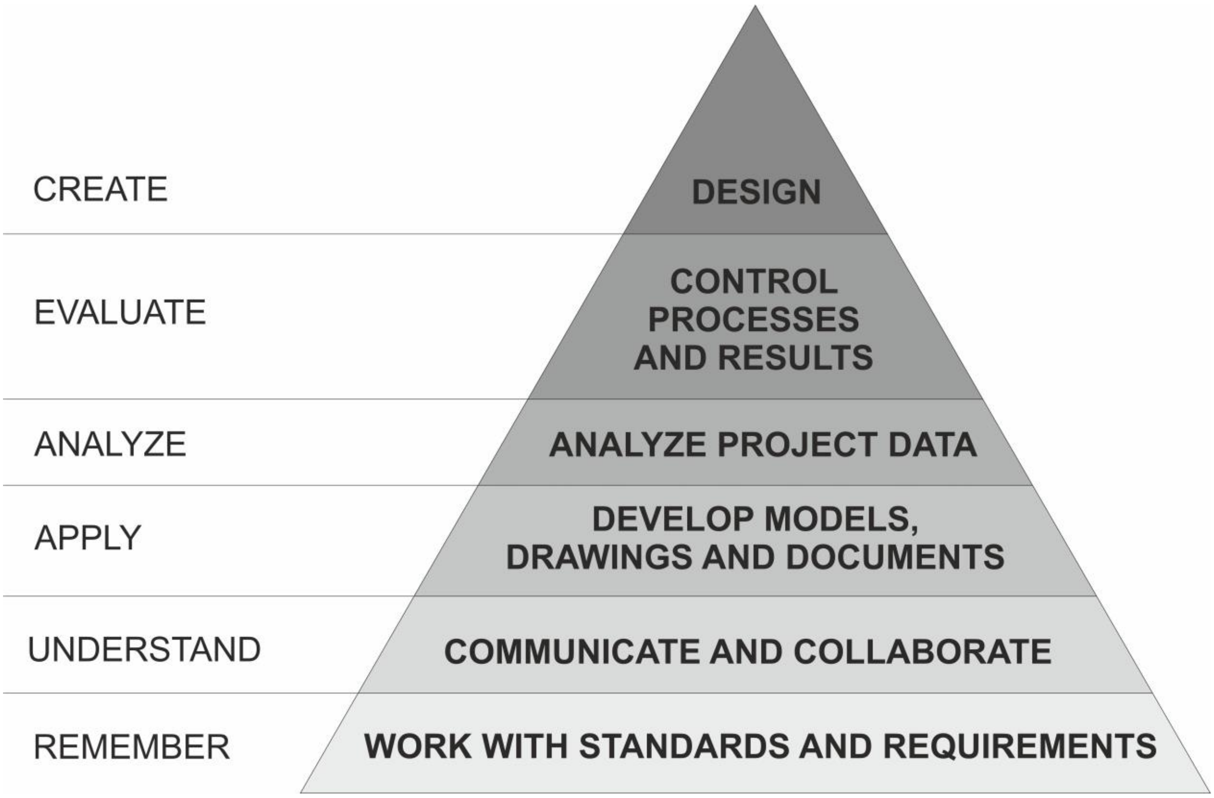

Figure 4. Revised Blooms taxonomy interpreted to the regular types of activities in AEC

In order to compare our findings with international experiences, we analyzed the structure of existing BIM programs. We reviewed programs such as Building Information Modelling and Digital Transformation (BIM-DT) MSc at the University of Liverpool, Building Information Modelling (BIM) in Design Construction and Operations at the University of the West of England, and European BIM A+ MSc. We aligned the components of these programs with the levels of cognitive learning in our proposed taxonomy (Table 2).

Table 2. Content of existing BIM programs through proposing taxonomy levels

Level of cognitive learning	The University of the West of England, Building Information Modelling (BIM) in Design Construction and Operations MSc	University of Liverpool, Building Information Modelling and Digital Transformation (BIM-DT) MSc	BIM A+ European Master Course
1. Theory, Standards and requirements	Construction Contract Law	Bim Theory, Practice and Tools	Management of information and collaboration in BIM
2. Communication and collaboration		Bim Implementation in Collaborative	Advanced BIM data systems
		Environments Virtual Environments for Architecture	and interoperability
1. Developing BIM models and its' components	BIM in Operation and Maintenance BIM in Construction Operation	Parametric Design and Digital Fabrication 1,2 Innovative Technologies and Methods in Construction	Modelling in Architecture and Engineering Parametric Modelling in BIM
2. Project data analysis	Construction Project Management Practice	Research Methodology Bim-enabled Sustainability Thesis: Dissertation	BIM-based rehabilitation and sustainability analysis
3. Control processes and results	BIM in Design Co-ordination	Interoperability and Design Coordination With Bim	4D, 5D, 6D modelling and applications Thesis
4. Design	BIM in Business and Practice Low/Zero-Impact Buildings	Thesis: Research By Design	BIM Design

The volume of disciplines in the reviewed MSc programs ranged from 5 ECTS to 7.5 ECTS. Considering the existing relevant courses at Satbayev University's Architecture department, with a volume of 6 ECTS each, we took this as the base volume for new disciplines.

Groups of competencies organized by cognitive learning levels were divided into disciplines based on educational duration and the variety of professional indexes. Competencies with several professions' indexes were designated as obligatory and became part of obligatory courses, while competencies with single or few professions' indexes were included in elective courses.

The analysis of connections between competencies was visualized in a network diagram, illustrating the relationships and strengths of requirements. Architecture competencies played a central role in the network, and there were concentrated groups that could be considered as core obligatory disciplines, such as National and Corporative Requirements, Project Management, Design Coordination, BIM Tools, Digital Survey, and Common Data Environment Management.

Manually creating the network of competencies for this research (Figure 5), we recognize the potential for automating this process using Natural Language Processing [41]. This technology could facilitate real-time synchronization between professional standards and educational program content.

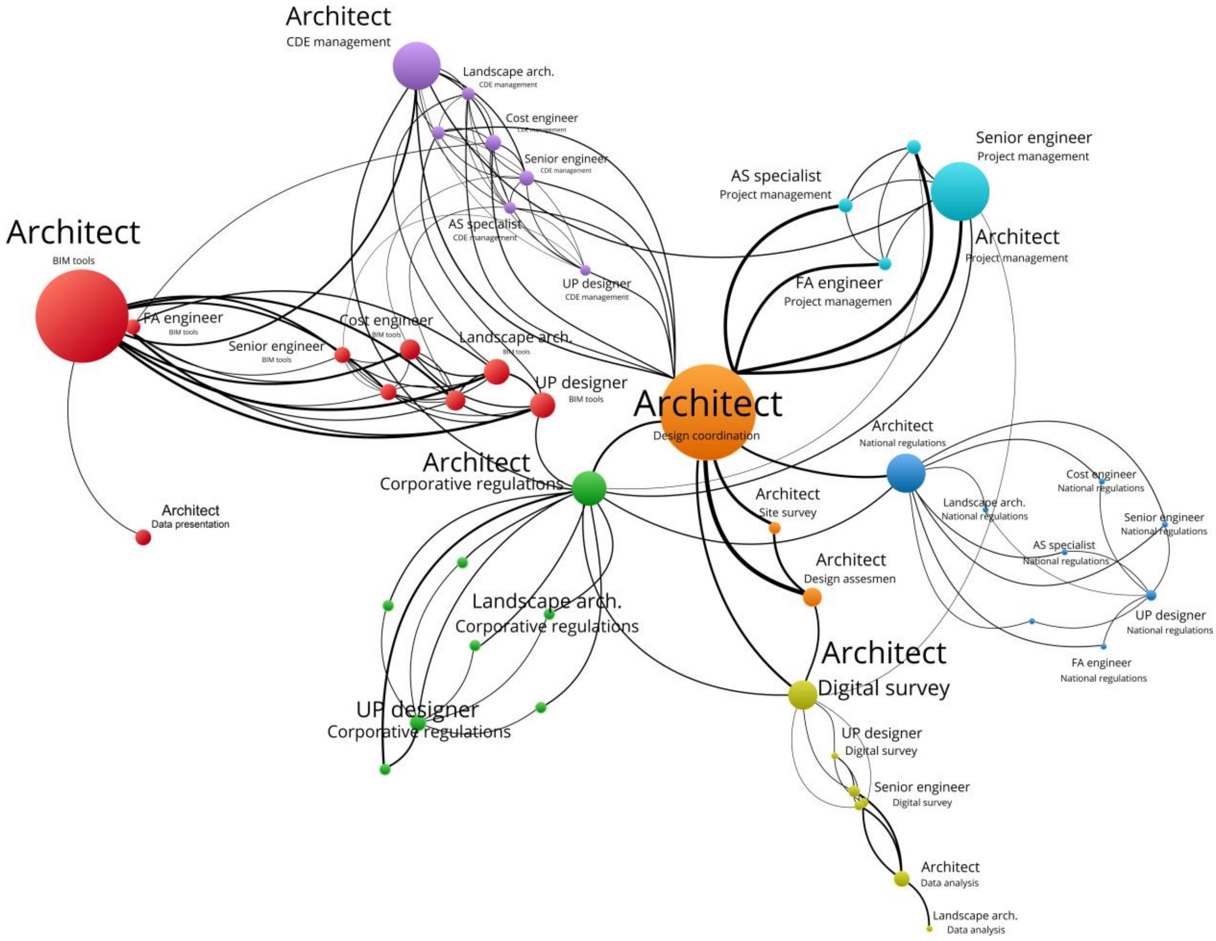

Figure 5. Network of AEC BIM competencies from Kazakhstan professional standards

As a result, we have compiled a list of disciplines that provide the necessary skills to use BIM in the construction and design field in Kazakhstan. Each discipline is accompanied by a description and a list of requirements from professional standards, along with their respective indexes. Higher education institutions can use this list to develop multidisciplinary programs for educating BIM specialists or incorporate these disciplines into existing programs to impart the necessary BIM competencies. (Table 3)

Table 3. Disciplines list

№	Discipline title	Obligate/ elective	Competencies	Professional standard indexes (first mention)
1	BIM regulatory and technical requirements	obligate	Basics of BIM theory and practice	2162-0-004 F3.T1.K8
			BIM national standards	2161-0-002 F1.T1.K8
			BIM corporate standards and their development	2161-0-002 F1.T1.K9
			Corporate BIM standard development practice	2151-2-030 F1.T2.S2
			BIM international standards and frontier practice	2162-0-004 F3.T1.K8
2	Collaboration in a shared data environment	obligate	Development of CDE	2151-2-030 F1.T1.S1
			CDE application in the design process	2161-0-002 F2.T1.S9
			Document management in CDE	2144-1-003 F1.T4.S1
3.1	BIM tools for architects	elective	BIM model preview	2161-0-002 F2.T1.S8
			Presentation of BIM project	2161-0-002 F2.T1.S5
			BIM software using skills	2161-0-002 F2.T3
			Automatisation in BIM design process – theory and practice	2161-0-002 F3.T1.K10
3.2	BIM tools for urbanists and landscape architects	elective	Forecasting design decisions outcomes using BIM tools	2164-1-001 F1.T1.S3
			Automatisation using BIM and GIS in the design process – theory and practice	2164-1-001 F3.T2.S2
			Data collecting, analysis and application	2162-0-004 F2.T1.K8
			BIM and GIS software using skills	2162-0-004 F2.T2.S3
3.3	BIM tools for engineers and constructors	elective	Modelling of structural and engineering elements in BIM	2144-1-003 F1.T2.SS1
3.4	BIM applications for Automated Systems Specialists	elective	Development of algorithms and applications	2151-2-030 F1.T1.S3
			Libraries, templates, classification systems development	2151-2-030 F1.T1.S5
4	Construction design documentation in BIM	obligate	Transfer from approved schematic design to construction documentation	2161-0-002 F3.T1.S2
			Determination of work volume and construction costs	2149-5-003 F2.T1.S1

			Development of detailed construction documentation	2144-1-003 F1.T4.S2
			Execution of data for construction documentation	2151-9-008 F1.T4.S2
5.1	Automated calculations of technical and economic indicators	elective	Techno-economic calculations for architectural design	2161-0-002 F3.T1.S6
			Basics of structural computations	2149-5-003 F2.T3.S4
5.2	Automated calculations of structures and engineering systems	elective	Advanced structural and engineering elements and systems computations	2144-1-003 F1.T3.S2
6.1	BIM and design data analysis	elective	Data collecting methods	2161-0-002 F1.T1.K7
			Analysis of predesign data	2161-0-002 F1.T1.S6
			Analysis of schematic design data	2161-0-002 F2.T1.S1
			Analysis of documentation and data flow	2161-0-002 F3.T1.S1
			Analysis of construction process data	2161-0-002 F4.T1.S2
			Using results of analysis for supporting design decisions	2161-0-002 F2.T3. S3
6.2	BIM and design process control	elective	Planning and control of all design process stages	2161-0-002 F5.T1.S4
			Prepare and control construction documentation assembly and quality	2161-0-002 F3.T2.S6
			Checking for errors collisions and unapproved changes	2161-0-002 F3.T2.S5
			Staff training	2161-0-002 F5.T2.S3
6.3	BIM Design (collaborative, project-oriented)	elective	Using BIM tools, methods, software and technologies in the design process	2164-1-001 F3.T3.S1

Curriculum design

Based on the structured and evidenced list of disciplines, we proceeded to design the curriculum. It's important to note that any program proposed by higher education institutions in Kazakhstan must adhere to educational program standards, which define requirements such as program duration, academic load volume, obligatory disciplines, and more. Satbayev University has developed its own templates in accordance with national and university requirements. For this curriculum, we have chosen the template for a one-and-a-half-year "professionally-oriented master program," which requires a minimum of 92 European Credit Transfer and Accumulation System (ECTS) credits, with 64 credits allocated to classroom activities.

The template includes two obligatory basic disciplines: foreign language (5 ECTS) and project management (3 ECTS). Additionally, there are two obligatory profile disciplines determined by the department (8 ECTS), an experimental research work component for master students (18

ISSN: 2616-7263. eISSN: 2663-1261

ECTS), a practical internship (10 ECTS), and the processing and defense of a Master's degree thesis (12 ECTS). The remaining six modules, totaling 36 ECTS, are dedicated to core courses that provide the necessary professional experience for master students.

As the list of disciplines obtained in the previous stage consists of six modules, it aligns perfectly with the template and serves as the core structure of the final program. The detailed curriculum will be presented in the results and discussions section, providing a comprehensive overview of the program's components and their respective ECTS credits.

Feedback from Kazakhstan's AEC companies

The final curriculum was sent to several companies that have already implemented BIM technology in Kazakhstan, including "KAZGOR," "KazNIISA," "BI-Group," "Bazis-A," and "Ink-Architects." The response from the companies was positive, and three of them provided recommendations and expressed their support. A live discussion was also held with representatives from KAZGOR.

KazNIISA, being a national company that initiates the development of BIM standards, supports and appreciates the program as an essential step in BIM development. They recommended changing the abbreviation "BIM" to "TIMSO" (Technology of Information Modeling of construction objects) in national BIM standards.

KAZGOR, on the other hand, supports the program as the first BIM-related program in Kazakhstan and emphasizes its high demand due to the shortage of BIM specialists in the AEC field. They recommended adding disciplines that cover the building life cycle's operational phase and incorporating new technologies such as augmented reality and 3D scanning as additional elective components. While these skills may not be immediately relevant in Kazakhstan, KAZGOR believes they will be crucial in the near future. They also discussed the possibility of adding a separate discipline on the basics of BIM for students who have no prior knowledge of it. Unlike KazNIISA, KAZGOR supports the use of the term "BIM" in the program's titles, as it is internationally recognized and considered more attractive.

The other companies provided positive feedback and expressed their support for the development of such a program. Overall, the responses and recommendations from the companies validate the significance of the program and its alignment with industry needs in Kazakhstan.

Findings/Discussion

The main result of the research is the method to convert requirements from professional standards in AEC to the master level curriculum – BIM in AEC, described in the Methodology section (see Fig. 6). We consider it as a first attempt to use professional standards as a direct basis for BIM educational programs. The most beneficial issue of this method is a synergy between governmental, practical and educational efforts that may cause a spiral development of all connected processes. Students and pedagogues will feel confident about objectiveness and demand of program content, AEC practice will receive specialists according to their request formulated in standards – on the one hand, graduates will fit necessary requirements. On the other hand, companies will feel responsible for their contribution to creating standards and pay more attention to them. Such synergy will help to move BIM development forward.

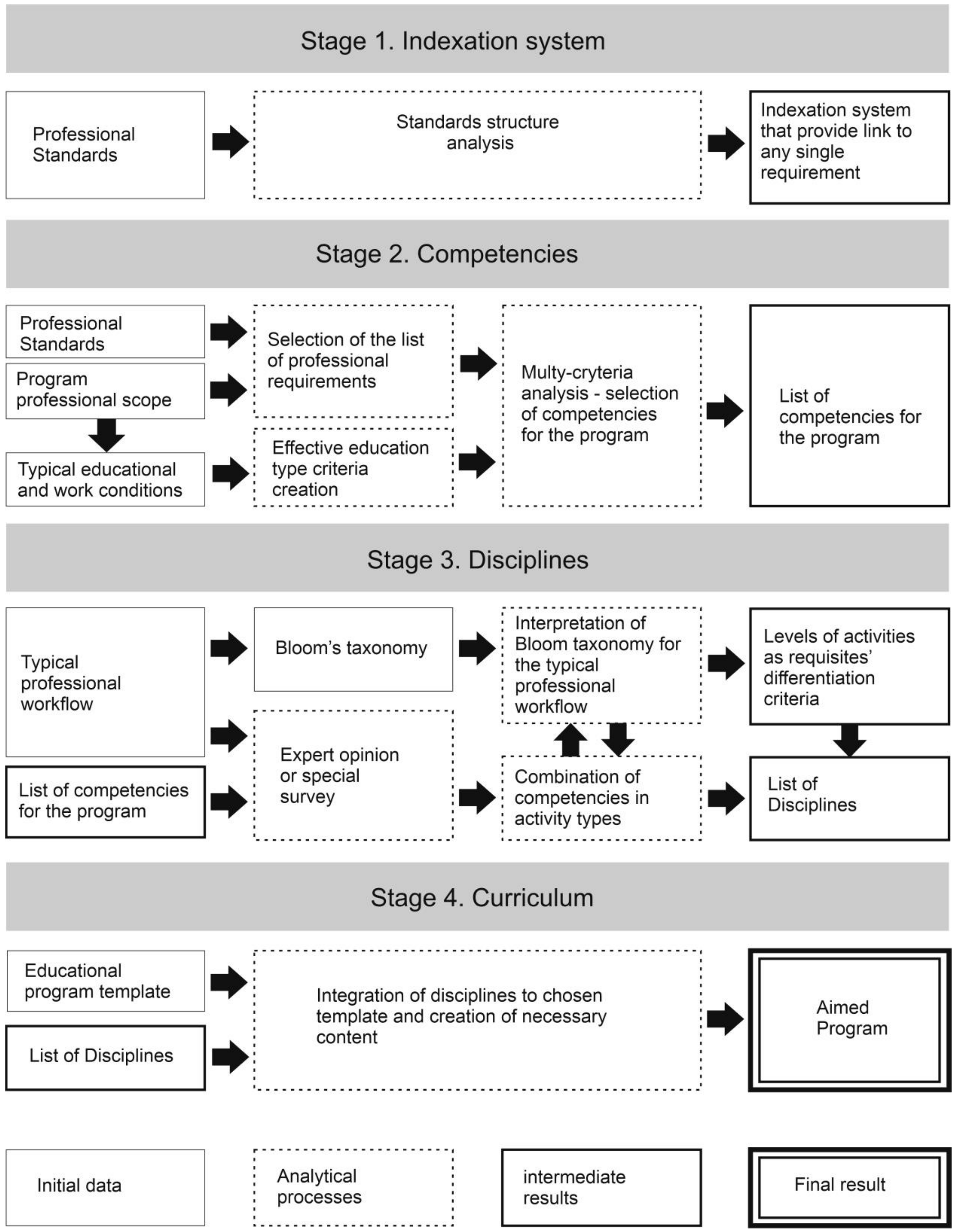

Figure 6. The scheme of the four steps method to convert professional standards in AEC requirements to the master level curriculum – BIM in AEC

ISSN: 2616-7263. eISSN: 2663-1261

Besides, the usage of standards allows avoiding long-term and complicated separate surveys aimed at determining the actual requirements of the field. Creating the curriculum involves several logical steps that can be realized in relatively short terms and do not require complex analysis. The availability of this method can be crucial for the regular updating and development of the program.

Initially, we used the described method in the case of the BIM master program. However, it has already been applied to design new practice-oriented master-level curriculums for Architecture and Urban Planning, Civil Engineering, and Engineering Systems and Networks. The only difference is that, due to the usage of the same professional standards, the first stage was omitted. It should be noted that faculty methodologists initially had difficulty accepting even this relatively straightforward method, indicating that more complex methods may be inefficient for widespread application.

The most critical issue with the standards-based method is the quality of professional standards. For example, in our survey, we found that the current standards lack requirements for engineering systems and networks specialists, who are a vital part of achieving high standards in BIM, particularly in AEC projects as a whole. However, if educational institutions use professional standards to develop curricula, it will uncover such shortcomings and help improve the standards and, consequently, the AEC field.

Another challenge is the lack of experts and low communication between departments in Kazakhstan's higher education institutions. Initially, the BIM in AEC master program was proposed for a wide range of professions, from architects to IT engineers, and implied a high level of collaboration during the courses. However, during discussions at the faculty level, it was decided to initially limit the implementation of the program to architects and construction engineers due to organizational issues and the incompleteness of standards. For example, to date, there are no experts in fire alarm systems or IT engineers with the necessary expertise among the faculty or staff of Satbayev University. However, recognizing these problems is the first step towards solving them. We look forward to overcoming these challenges in the future.

The second main result is the educational program "BIM-technologies in AEC." (Table 4) It is a master's degree program designed for Satbayev University to provide necessary competencies to architects and engineers, as well as new graduates from bachelor programs who want to work on BIM projects (36 ECTS credits). It also aligns with national and university standards for master students' analytical skills (30 ECTS credits) and management skills (18 ECTS credits). To develop general professional skills, two elective disciplines (12 ECTS credits) were added in the basic component, which can flexibly fit the requirements of a particular professional field (Table 5).

Table 4. Working curriculum for Educational program "BIM-technologies in AEC."

year of study	Code	Discipline title	Component	ECTS	Lc/lb/pr	Code	Discipline title	Component	ECTS	Lc/lb/pr
	1 semester					**2 semester**				
	LNG 201	Foreign language (professional)	BD HSC	5	0/0/5	1103	Elective	P.D. E.C.	6	2/0/4
1	MNG230	Project manage-ment (Manage-ment+ manage-ment psychology)	BD HSC	3	1/0/2	ARC 203	Construction design documentation in BIM	PD E.C.	6	4/0/2
	ARC 201	BIM regulatory and technical requirements	PD HSC	6	2/0/4	1204	Elective	P.D. E.C.	6	2/0/4
	ARC202	Collaboration in a shared data environment	PD HSC	6	0/0/6	1205	Elective	P.D. E.C.	6	2/0/4
	1101	Elective	B.D. E.C.	4	6/0/0	AAP 207	Experimental research work of a master student	ERW-MS	6	4/0/2
	1102	Elective	B.D. E.C.	4	0/0/6					
	AAP207	Experimental research work of a master student	ERW MS	6						
		Total:		34			Total:		30	
	3 semester									
2	AAP207	Experimental research work of a master student	ERW MS	6						
	AAP208	Practical internship	P.I.	10						
	ECA 501	Processing and defence of Master degree thesis (PDMDT)	F.A.	12						
		Total:		28						
		Sum-total:		92						

Table 5. Elective disciplines catalogue for Educational program "BIM-technologies in AEC."

Basic Disciplines Elective components - 5 credits (R.K.)					
	Code	**Discipline title**	**ECTS**	**Lc/lb/pr**	**semester**
1101	BIM	The architecture of civil buildings – theory	4	4/0/0	1
	BIM	Project engineering – theory	4	4/0/0	
	BIM	Landscape architecture – theory	4	4/0/0	
	BIM	Automated Systems – theory	4	4/0/0	
	BIM	Cost engineering – theory	4	4/0/0	
	BIM	Fire Alarm engineering – theory	4	4/0/0	
	BIM	Structural design – theory	4	4/0/0	
1102	BIM	The architecture of civil buildings – practice	4	0/0/4	1
	BIM	Project engineering – practice	4	0/0/4	
	BIM	Landscape architecture – practice	4	0/0/4	
	BIM	Automated Systems – practice	4	0/0/4	
	BIM	Cost Engineering – practice	4	0/0/4	
	BIM	Fire Alarm Engineering – practice	4	0/0/4	
	BIM	Structural design – practice	4	0/0/4	
		Total	**8**		
Professional Disciplines Elective components - 5 credits (R.K.)					
	Code	**Discipline title**	**Credits**	**Lc/lb/pr**	**semester**
1103	BIM	BIM applications for architects	6	2/0/4	2
	BIM	BIM applications for urbanists and landscape architects	6	2/0/4	
	BIM	BIM applications for engineers and constructors	6	2/0/4	
1104	BIM	Automated calculations of technical and economic indicators	6	2/0/4	2
	BIM	Automated calculations of structures and engineering systems	6	2/0/4	
1205	BIM	BIM and design data analysis	6	2/0/4	2
	BIM	BIM and design process control	6	2/0/4	
	BIM	BIM Design (collaborative, project-oriented)	6	2/0/4	
		Total	**18**		

Table 6. Example of discipline description

Title of discipline	**Collaboration in a shared data environment**
Purpose and objectives of the course:	Explore and practice collaboration in a shared data environment

Brief description of the course:	The course is designed for all specializations. Based on Revit and One Drive cloud storage, students will learn and practice the principles of creating a shared data environment and the rules of collaboration in it.
Knowledge, ability, skills to complete the course:	
Knowledge:	Knowledge of tools and rules for collaboration in a shared data environment
Skills:	Application of the General Data Environment of the Project Information Model (PIM) (when developing and implementing a project using BIM). 2161-0-002 T2.Z1.Um9, 2161-0-002 T2.Z3.Um5, 2161-0-002 T3.Z1.Um8, 2161-0-002 T3.Z2.Um8, 2161-0-002 T3.Z3.Um4, 2161-0-002 T4.Z1.Um5 / 2164-1- 001 T1.Z2.Um5, 2164-1-001 T3.Z1.Um4, 2164-1-001 T5.Z1.Um5 / 2162-0-004 T2.Z1.Um5, 2162-0-004 T2.Z2.Um4 , 2162-0-004 T2.Z3.Um3, 2162-0-004 T3.Z1.Um7, 2162-0-004 T3.Z2.Um5) / 2149-5-003 T1.Z1.Um5
	The organisation of a common data environment (when implementing a project using BIM). 2151-2-030 T1.Z1.Um1
	Teamwork and the use of the Common Data Environment to support the workflow process between the participants in the design process (creating documents; monitoring decision approval; organising the storage and transfer of documents; prompt preparation of reports) and entering information about changes in any design decisions (indicating the reasons and responsible persons) (when implementing a project using BIM). 2144-1-003 T1.Z4.Um1 / 1323-0-007 T1.Z2.Um1

Additionally, the program may include a list of 38 requirements that were identified as "on-work" competencies through multicriteria analysis (Figure 3). These competencies are considered to be learned during internships and can be mastered in the short term without separating students from their workflow (Table 6).

The research also yielded secondary findings, including:

• An indexation system that establishes a transparent and student-oriented connection between the educational program and professional standards. The current indexes can be utilized in Kazakhstan, but the principle behind the system is universal and can be adapted to other national resources.

• The AEC interpretation of cognitive learning levels can aid in organizing a logical sequence within the AEC curriculum.

• A list of disciplines necessary to attain the required level of BIM competencies as mandated by state regulations for the 6th and 7th levels of qualification. This list can be integrated into existing courses offered by Kazakhstani universities or used to develop separate commercial training programs.

These secondary findings contribute to the overall understanding and development of BIM education and professional standards in the AEC field.

Conclusion

In conclusion, the successful implementation of BIM technology in the AEC industry relies on an effective education system that produces highly skilled professionals capable of meeting the evolving demands of the field. To achieve this, close collaboration between AEC companies, governments, and universities is crucial in formulating and sharing regulations, requirements, and frameworks. Professional standards can serve as a valuable instrument in establishing this connection.

This article proposes an appropriate and innovative method for creating and developing a BIM education curriculum, specifically in Kazakhstan and other countries with professional standards. It represents one of the initial steps taken by Kazakhstani higher education institutions to bridge the gap between government efforts in collecting factual information about institutional requirements (reflected in professional standards) and the development of an educational process.

The finalized BIM program encompasses all the necessary BIM competencies outlined by institutional requirements. It encourages universities to introduce new and highly demanded skills training, identify emerging professions, and facilitate collaborative development between departments and faculties. It is anticipated that the BIM in AEC program will be successfully launched the following year and contribute to the advancement of the AEC industry in Kazakhstan.

The described methodology can be applied to other professional fields and is particularly effective in rapidly developing areas such as biotechnology, information technology, robotics, and more. Furthermore, advancements in natural language processing allow for automatic analysis of standards and documents. This technology can be utilized to integrate standards and requirements data into BIM tools, as well as to automate the execution of the proposed methodology and synchronize programs with standards.

Ultimately, it is hoped that these findings will assist higher education methodologists in identifying optimal approaches to create and enhance curricula for BIM and other innovative technologies. The development of educational programs, in turn, will contribute to the advancement of technologies and related areas of human activity.

The contribution of the authors:

V.V. Yaskevich: Developed the research framework, defined methodologies and approaches, including the indexing system and multi-criteria analysis. Conducted all stages of the study, which encompassed examining professional standards, analyzing and processing competencies, creating the final program, and documenting all research algorithms. These tasks were performed under the guidance and with the support of the co-authors.

B.U. Kuspangaliev: Proposed the research idea and provided overall supervision throughout the project.

L.C. Tagliabue: Contributed to the final stages of the study by providing recommendations on leveraging a network of competencies. Additionally, she conducted expert evaluations and adjustments to the research process and its outcomes.

T. Umar: Played a key role in preparing the article for publication by improving its structure and logical flow. He also contributed insights from the British experience with BIM technologies.

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Қазақстанда ұлттық кәсіби стандарттар негізінде құрылыс ақпараттық үлгілеу (bim) бойынша магистратура бағдарламасын жобалау: зерттеу жағдайы

Аңдатпа. Бұл мақалада Қазақстанда «Сәулет, құрылыс және инженерия (AEC) саласындағы ақпараттық модельдеу (BIM) технологиялары» бойынша магистратура бағдарламасын жобалау ұсынылады. Мұндай бағдарламаның қажеттілігі BIM енгізу бойынша білікті мамандардың жетіспеушілігімен байланысты, бұл тек Қазақстанда ғана емес, бүкіл әлемде байқалады.

Ұсынылған әдіс негізгі құзыреттерді анықтау үшін ұлттық кәсіби стандарттарды сенімді дереккөз ретінде пайдаланады. Бұл кәсіби стандарттар жоғары оқу орындары, үкімет және AEC компаниялары арасындағы ынтымақтастықты дамытуға бағытталған. Бағдарламаны жобалау процесінде әртүрлі әдістер қолданылады, соның ішінде талаптарды бағдарлама аясында қадағалау үшін индексация жүйесі, құзыреттерді таңдауда көпкритерийлі талдау, сондай-ақ бағдарламаны тиімді құрылымдау үшін когнитивтік деңгейлер таксономиясы қолданылады.

Түйінді сөздер: BIM-технологиялар; оқу жоспарын құру; кәсіби стандарттар; көпкритерийлі талдау; индексация жүйесі; Блум таксономиясы

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Разработка магистерской программы по информационному моделированию зданий (bim) с использованием национальных профессиональных стандартов: казахстанский пример

Аннотация. В данной статье представлена разработка магистерской программы по теме «Технологии информационного моделирования зданий (BIM) в архитектуре, инженерии и строительстве (AEC)» в Казахстане. Необходимость такой программы обусловлена нехваткой квалифицированных специалистов, владеющих внедрением BIM, как в Казахстане, так и во всем мире. Предложенный метод использует национальные профессиональные стандарты как надежный источник необходимых компетенций. Эти профессиональные стандарты направлены на укрепление сотрудничества между вузами, правительством и компаниями AEC. Процесс разработки включает использование различных методов, таких как система индексации для отслеживания требований стандартов в программе, многокритериальный анализ для выбора подходящих компетенций, а также применение таксономии когнитивных уровней для эффективной структуры программы.

Ключевые слова: BIM-технологии; разработка учебных программ; профессиональные стандарты; многокритериальный анализ; система индексации; таксономия Блума

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ISSN: 2616-7263. eISSN: 2663-1261