A Systemically Synergistic Approach to the Design of Integrative Advanced Training Courses in the Field of Cross-Cutting Technologies

Alexey Dukhanov
Fuculty of Digital Transformations
ITMO University
Saint Petersburg, Russia
dukhanov@itmo.ru

Anna Lutsenko
National center of cognitive research
ITMO University
Saint Petersburg, Russia
anna.lutsenko@itmo.ru

Alexandra Klimova
Fuculty of Digital Transformations
ITMO University
Saint Petersburg, Russia
alexandra.klimova@itmo.ru

Simon Kraev
Fuculty of Digital Transformations
ITMO University
Saint Petersburg, Russia
simon.kraev@itmo.ru

***Abstract*—This paper presents an approach to designing advanced training courses (ATC) in digital cross-cutting technologies (CCT) implementation to solve interdisciplinary problems in different industries. The courses are designed for domain professionals and leaders who are interested in digital transformation of their businesses. The main feature of our research is the strictly limited time available to the course team and students. Teachers must rapidly design and provide a course with learning content, and students cannot devote extended time to learning. Additionally, courses should be client-centered, meet student expectations, and be based on the multi-scale synergy of interdisciplinary, science-intensive solutions. Our approach contains two main steps for the design of ATC. The first step is to build a map of problem areas at the intersection of CCT and the project life cycle stages. The second step is to build an X-matrix containing the intracorporative needs of the project, the new skills of the trainees, the technologies studied in the course, and a list of course topics. Using our approach, we have designed three continuing education courses. We received high expert evaluations and positive feedback from most graduates.**

Keywords—advanced training courses, instructional design, problem areas map, X-matrix

I. Introduction

Rapid changes in technology determine the continuous demand for relevant educational services. Modern information and communication technologies allow us to respond quickly to these changes and provide students with the appropriate competencies. However, the wide variety of and rapid changes in technologies make it difficult not only to understand them, but also to choose and apply them to solve modern problems. Therefore, a new type of course is needed, one based on expertise regarding the capabilities and limitations of the latest technologies.

This paper is devoted to the development of such integrative courses, as well as an analysis of the relevant learning outcomes. This development follows a strict set of principles. First: customer-centricity and problem-oriented—the focus is not on technology, but on the use of a set of high-tech solutions that are useful for solving real customer problems and tasks; the focus is not on earnings, but on expanding the customer base of the NCCR. Second: consistency—synergy of science-intensive solutions. Third, the relevance of modern trends—the content offered in the course may not always be in demand in production. For the relevant organizations, the course should inspire the trainees to make appropriate corporate changes.

Thus, the topics of the course are either in the established scientific and technical areas, or in the classes of problems in which the course teachers have accumulated significant experience. The technologies here are used as building blocks from which approaches to solving these problems are formed.

The development of such integrative courses is a complex process that includes comprehensive marketing research, analysis of CCT in the projection of the subject, and industrial “planes” and pedagogical design. The development should be completed rapidly to ensure the relevance of the proposed course.

In this article, we will answer the following questions: First, how is it possible to identify problem areas in production for building up-to-date educational content? Second, how can the requirements for the course and its structure be formed quickly and clearly?

II. Background and Related Works

Our research belongs to the area of instructional design (ID). Solutions in this area have been emerging since the second half of the 20th century. Instructional design approaches became one of the responses to the various significant challenges and events of that era, including the launch of the Soviet Sputnik in 1957 [1]. The timeline of the development of instructional design is presented in [2]. Contemporary studies have demonstrated the application of various modern technologies to design course structures and content. According to [2], ID has developed over the last six years under the influence of ICT, especially bigdata technologies. The research in [3] discussed using agile technologies to design courses for online education. Approaches to building and filling multimodal ATC were considered in the book chapter [4]. The significance of the presented approach is in the self-mapped pathways of students, which are formed both with and without the participation of teachers.

Note that contemporary research devoted to the design of ATC pays particular attention to the collaboration and discussions between teachers, students, and employers. Thus, the professional paper [5] illustrated a design and refresher course in English for specific sources based on the negotiation approach. The approach presented in the paper considered the stressful situations that arise due to the limited time allocated for the development of the course. The work [6] emphasized the need to assist teachers in course design. This assistance should consist of solutions for technical issues and scaffolding at all stages of the design and realization of the learning course.

Such support is due to the steady rising trend in developing the institution of interdisciplinary courses [7,8] and educational programs [9,10]. This requires a significantly greater coverage of complex, multiscale, and quickly updated knowledge. This knowledge should be associated with the pedagogical elements of the course. Connections between concepts and tasks of mono- and interdisciplinary domains, learning outcomes, and course elements are proposed to be formed using modeling based on the IMA-CID ontology [11]. Consequently, this approach allows us to perform automatic generation of electronic educational content [12] suitable for multiple platforms, including mobile devices [13]. The formation of educational content using the concept of abstract hybrid learning resources [14,15] allows us to cover numerous interdisciplinary issues appropriate to many different learning outcomes.

The work presented in the previous research approaches allows us to list the following features and requirements which face teachers and methodologists throughout the design of systematic client-centered ATC devoted to CCT: (a) an agile approach to ATC design; (b) use of the negotiation approach; (c) multimodal ATC (including self-mapped pathways); (d) limited time allocated to course design; (e) the need to assist teachers (scaffolding for teachers); (f) the need for the course to present the use of CCT in the projection of the subject and industrial areas; (g) the need for the course to be designed with customer-centricity and problem-oriented structure; (h) the need for the course's structure to be based on synergy of science-intensive solutions.

To apply the solutions mentioned above, teachers need to be proficient in information modeling methods. At the same time, the resulting schemes become very complex, contradicting the scaffolding approach. The presentation of the course structure should be concise, but should also be in the form of a compact flat design (presentation of the course's idea in the matrix form – matrix approach), preferably in tabular form. This form should allow us to prepare a relevant, attractive course description rapidly, with detailed attention to the features and requirements listed above (a–h). Our work is devoted to this issue.

The rest of this paper is organized as follows. The third part describes an approach to the design of ATC in the compact tabular form. The fourth part contains the description of designed ATC in CCT's: bigdata, machine learning, and computer modeling. The fifth is devoted to a short analysis of graduates' feedback and results of the expert survey.

III. Proposed Approach

To comply with the features and requirements described above, our work uses a general matrix approach. First, we will propose a technique to fill matrix of problem spheres placed on intersections of the stages of the project life cycle (SPLC) and CCTs (matrix of problem areas). This technique will allow us to receive the influence of technologies in different domain areas in the context of SPLC to be considered in the future course. Second, we will describe the X-matrix with technologies, intracorporative needs (ICN), learning outcomes (LO), and course topics (CT). This matrix allows us not only to present the course's structure and features, but also to show the relationships between the course's content, competencies, and ICN's.

A. Matrix of problem areas

The central idea of this project is based on the matrix approach, and specifically the Applicability Matrix (ISO 9001 & IATF 16949 [16]), in which key processes intersect with locations and cross-cutting technologies (for example, cross-cutting technologies of the National Technology Initiatives of the Russian Federation [17]), the application of which can find a place in almost any key process.

In our case, the matrix is constructed as follows. The SPLC are laid out horizontally: design, data collection and analysis of the current situation, design, project evaluation, project implementation, data acquisition, and evaluation of the quality of project implementation. Cross-cutting technologies are placed vertically. We selected the technologies of big data, machine learning, and computer modeling as the main drivers of modern digital transformations. Each cell of the resulting matrix defines the area of scientific and technological problems and tasks. In turn, such problems and tasks determine the pool of relevant scientific tools and technologies (including unique ones) used to solve them.

The matrix forms a problem areas map (PAM – figure 1) that can be used to plot learning paths. The resulting course can be general (including with applied examples) or adapted for a given subject area or industry, both individually and in aggregate. In particular, the course's being developed to order by a particular company will simultaneously affect both the industry in which the company operates and the relevant subject area.

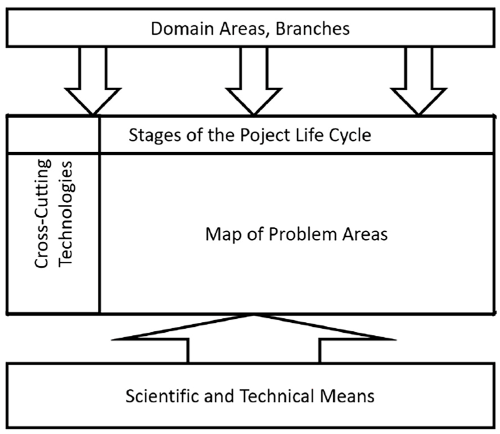

Fig 1. Scheme of formation of the PAM for the designing of ATC.

The proposed approach does not limit the development of ATC to one industry and/or one subject area. Thus, for example, the course "Digital Urbanism" covers the interdisciplinary direction "Urban Planning" ("Urbanism"), which can address social, medical, transport, and other issues. Branches and subject areas form planes that "permeate" the matrix and can intersect with each other. The number of scientific tools and technologies covered in the course depends on both the chosen trajectory (the number of matrix cells covered by it) and the planes themselves.

When the PAM is built to take into account the subject and industry "planes" defined on it, then it remains to fill in the resources intended for training. According to the work of [15] and [18], such resources are divided into two main types: informational and educational. Informational resources are built from information objects, which, in turn, are divided into executable (various types of software implementation, including cloud services and data sources) and documentary (scientific articles, software, and experimental documents).

The second type of resource can be presented both in the form of classical educational tools (e.g., textbooks, lecture courses, guidelines) and in the form of ready-made reusable educational objects, including those packaged in the form of online courses. If the trainees have the competence to work with scientific and technical information sources, the trainees can be provided with direct access to them. The definition of the branches and subject areas that should be chosen during course development depends on the potential learning audience—those who will be trained. If there is an order from an enterprise or department, the industry and subject areas are determined at the order formation stage.

When planning a public professional development course, an analysis of industries and the public sector of the economy should be carried out to ensure the relevance of the technologies. This topic is a separate study, so this paper presents the main aspects of this issue briefly. For this analysis, a variety of foresight materials can be used, including descriptions of hype cycles, road maps of technological development, and relevant regulatory documents. At the same time, it is necessary to use the documents of existing development programs, not only at the international and national levels, but also at the level of industries and large enterprises. Russia uses both Hype Cycle of Emerging Technologies diagrams [19,20] and the results of its own research, including maps of the future—for example, NTI Platforms [22], the Atlas of Emerging Jobs [23], the Strategy of National Technological Development (http://kremlin.ru/acts/bank/41449, in Russian), and the National Technology Initiative (NTI) [24].

From the analysis of the above types of documents, a list of subject areas and industries is formed. By superimposing the selected areas and industries onto the map of problem areas, the corresponding challenges in production are identified. In addition, after such an "intersection," the scientific and technical means (technologies) that can be used to meet these challenges are specified. Technologies may be well known and widely used, alongside new and unique ones, including those developed on the basis of a training organization. The specifics of their use are presented in the public course of professional development, and they can be studied in detail using the above-mentioned types of information and training resources.

B. X-matrix

To develop a course description with classes and relevant competencies, we propose our Course X Matrix, which we developed based on the Hoshin Kanri X Matrix [25] (Fig. 2).

On the right (east) side, the competencies that are meant to be developed and delivered by the students within the course are indicated. At the bottom (south) of the matrix, classes or modules are indicated; these are determined based on the problem-technology areas formed on the map. At the top (north), the production calls (internal needs) are entered. On the left (west) side, the technologies or groups of technologies that are considered parts of the course are recorded. At the same time, cross-cutting technologies are not specified among them, since a map of problem areas is developed on their basis. The technologies that, in the opinion of the course developers, are effective at the intersection of a given problem technological area and the corresponding "planes" are indicated.

In the corner areas of our matrix, the correspondence of the above entities is noted. In the north-eastern (NE) part, the degree of coverage of the graduate's competence in the course of calls in production is noted (the compliance of the graduate's qualifications with the specified calls is checked). In the south-eastern (SE) part of the matrix, the coverage of competencies by classes or modules is marked (the competence matrix). In the south-western (SW) part, it is noted that classes (modules) are provided with appropriate scientific tools and technologies. Finally, the north-western (NW) part is noted as meeting the challenges in manufacturing covered by the scientific facilities and technologies highlighted in the course.

The matrix is filled in at the top (intra-corporate needs), since the value of the course lies in its application in the relevant industries. At the same time, it is necessary to consider the allocated technologies and tools after analyzing the intersections of the map of problem areas and "planes" (subject areas and industries).

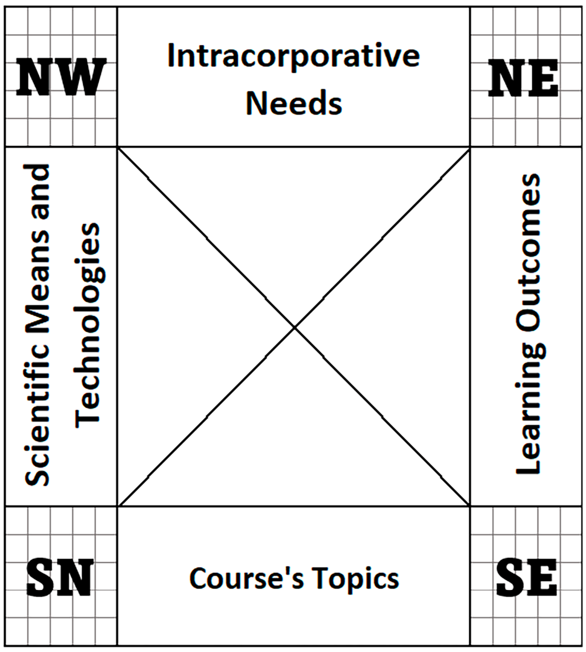

Fig 2. X-matrix of the description of the ATC.

If it is possible to select a subset in the pool of these technologies and tools that covers a specific need, then these technologies and tools are entered in the left part of the matrix. In the NW corner of the matrix, their significance for covering the needs is indicated. The scale of significance is set by the program developers—from binary to any complex point system. When the needs, technologies, and funds are written out, it is recommended to proceed to the competencies (Learning Outcomes). These competencies should cover the relevant needs. For example, the need to "Prepare predictive information based on production and external data" is partially covered by the competence "Choosing a machine learning model."

In the NE part of the matrix, the degrees of coverage are indicated according to the scale set by the course developers. It is desirable to sort the competencies from left to right in order of increasing complexity, which is qualitatively evaluated by the program developers. The lower part is filled in last: classes are built based on the trajectory or trajectories built on the map of problem and technological areas, taking into account the recorded competencies, technologies, and tools. By covering technologies and tools, the course covers the relevant competencies.

The process of filling in and adjusting the matrix can be iterative, as what allows you to refine the course based on consistently received information and/or requests. We now consider the work of our methodology on the example of courses developed and conducted by the staff of the National Center for Cognitive Research (NCCR).

C. Steps of approach

To design a course with the use of our approach, we recommend applying both matrices simultaneously. Our approach can be applied using the following steps.

Step 1. Determining SPLCs or other invariant processes where CCT can be applied, as well as choosing CCTs.

Step 2. Formulating and analyzing problem areas at the intersections of CCTs and SPLCs. After performing analysis, a list of technologies to solve these problems should be received. The developer should unite (consolidate) received list items by areas such as domain areas, level of skills (competencies), and SPLCs. Hence, we facilitate the process of definition of skills and course topics.

Step 3. Defining general intracorporative needs involving companies' representatives or related experts.

Step 4. Choosing of jobs and relevant competencies necessary for meeting intracorporative needs using the selected technologies. We recommended exploring descriptions of future jobs (using, for example, the *Atlas of Emerging Jobs* [23]). Even if a specific position is not part of a company yet, we nevertheless recommend including the corresponding skills in the X-matrix. Therefore, we can not only teach company employees and management, but also motivate top management to revise the nomenclature of positions.

Step 5. After performing the above-mentioned steps, we have lists for the north, west, and east parts of X-matrix. In this step, we recommend determining the strength of the relationships between groups of technologies and intracorporative needs by filling in cells in the NW part of the X-matrix. For example, we may define "XXX" as strong, "XX" as medium, and "X" as weak relation. Empty cells indicate "No relation."

Step 6. Determining the strength of the relationships between competencies and intracorporative needs (NE part of X-Matrix)

Step 7. Defining course topics and determining the strength of the relationships in the SW and SE parts of the X-matrix. Course topics should be related between previously determined, domain-specific technologies and skills.

It is recommended to perform the above steps while involving companies' representatives or related experts with the use of the approach, specifically including the negotiation approach (b). Thus, the results received will be immediately agreed upon by the problem owners. The X-matrix obtained through this process contains in a concise form the information necessary for the preparation of a textual description of the course. Intracorporative needs, CCTs, and DSTs allow us to describe the relevance and demand of course. The east part of the X-matrix is the source for the correspondence between the course's topics, competencies, and intracorporatives needs.

D. Compliance with features and requirements

Consider the compliance of our approach with the features and requirement of (a–h).

Every step or partial step can be performed in the form of a sprint (scrum approach). Parts of a step may be parallelized. Using the scrum approach allows us to analyze related results and make the required reflections in (a). The negotiation approach presented above fulfils (b). Teachers and methodologists may specify list of DSTs and levels of skills for each student depending on intracorporative needs and job position. All students can perform the above-mentioned action on their own. Therefore, we can make multimodal ATC (c). Structured design of ATC with the use of the matrix approach allows us to split related processes into clear steps (sub-steps) and reduce the time spent (d, e). A map of problem areas is a tool to receive a list of DSP, which are contained in CCTs, and to consider DSPs in the industrial and domain planes (f). Involving companies' representatives, analysis of futures job creation, and analysis of problem areas in the planes of industries ground the course in science-intensive solutions, customer-centricity, and problem-oriented approaches (g, h). A course received is based on the system's invariants, CCTs, and joint application of domain-specific technologies. Hence, this course has synergy potential (h).

This paper now presents the application of our approach in the design of courses at the National Center for Cognitive Research of ITMO University.

IV. Application of the Approach in the Courses of the National Center for Cognitive Research

The National Center for Cognitive Research conducts investigation and development into relevant high-tech services in the field of cross-cutting technology of the NTI "Machine Learning and Cognitive Technologies." Hence, three cross-cutting technologies are given as composite and intersecting components: (1) Big Data, (2) Machine Learning, (3) Computer Modeling. The list of stages of the project life cycle is determined by the orientation of the course within the generalized stages of project activity.

Based on the above-mentioned technologies, we have built three ATC: “Digital Urbanism” (DU), “Big Data and Machine Learning for the service of a qualified customer" (BD&MO), and “Digital Object as an object of intellectual activity: from idea to implementation” (DO). The following sections consider these courses in more detail.

A. “Digital Urbanism” course

The advanced DU course was developed and conducted by the Institute of Design and Urban Studies with the participation of the scientific group “Intelligent Decision-Making Technologies” of the NCCR. It is the most complex of the presented courses, since, in addition to one interdisciplinary area, “Smart City” covers the following industries: “Healthcare,” “Transport,” and “Social Issues.” The complexity of this design was aggravated by the time limit—no more than five days, in each of which the volume of simultaneous classes should not exceed six academic hours. Under such conditions, the course can be designed as an overview, but with a detailed analysis of critical technologies for a smart city, including geoinformation, and a clear navigation to scientific and technical means (research engineering) in the fields of big data, machine learning, and cognitive technologies. Figure 3 shows a map of the problem areas for this program.

The following abbreviations are used in the figure: ML—Machine Learning, SmC—Smart City, CM—Computer Model, PSt—Problem Statement, DC&P—Data Collection and Processing, GIS—Geographic Information System, H&CB—Human and Communities' Behavior, DM—Decision Making, HC—Healthcare, MD—Medical Data, CC—Clinical Course, and MP—Medical Prescription.

The list of technologies used to solve issues from the problem areas is determined not only on the basis of the received map, but also by studying the results of a number of works. In addition to the above-mentioned literature (part III, A), we analyzed the development strategies of large cities, including Moscow and St. Petersburg [25,26], the concept of a smart city [28], and sources in the field of “City 4.0,” in particular [28] and [29].

Based on the results of the study, the following list of technologies was obtained: Optimization and Decision Making; Computer Modeling, Including Digital Twins Machine Learning; Data Analysis (Including Statistics); Geographic Information System; Data Gathering; and Cleaning and Preprocessing.

Based on the problem areas and technologies, and taking into account the short duration of the course and its overview nature, the following list of challenges was determined: City Processes Monitoring; Predictive Analytics of Urban Scenario Development; Urban Decision Making; and Design of Urban Scenario.

With simple formulations, they require the use of previously specified technologies and the formation of appropriate competencies at the level of understanding: Smart City and Digital Urbanistic Problem Statement; City Data Collection, Processing, and Visualization; Features ML in Smart City Problems; Computer Modeling for Urban Studies; and Optimization for Decision Support.

Figure 4 shows the corresponding X-matrix. The "X" sign indicates the degree of coverage and relation—for example, the topic of the competence course (skill). This degree (with three characters “X” signs, the maximum) is determined by experts. The six topics of the course begin with an introduction to digital urbanism and the smart city. This topic corresponds to the first stage of the development and decision-making life cycle (basic analysis of target of research) in the prism of the presented cross-cutting technologies. In this case, it defines the input class (prerequisite class) and can become an introductory one (the left triangle in Figure 2). However, when pointing to the stack of technologies that are taken into account by tasks setting, this topic should be included in the main part of the course. After completing the topic in the field of decision support, a weekend session for reflection is held. Before then, students are invited to write down a few key words in the direction of the course, placing them in descending order of importance, and to write a short essay about how the course meets expectations and what useful things they learned from it.

B. Big Data and Machine Learning for a qualified customer service” course

This course is focused on factories of different industries. The same triad of cross-cutting technologies was used to map the problem areas. Here, however, specific

		Idea & Problem Statement	Data Collection & Processing	Analysis	Imitation & Verification	Decision Preparing & Making
cross-cutting technologies	Big data	**Bigdata for SmC**	**Basics of Urban Informatics** Digitizing of Spatial Urban Data	**Input Data and Models' Outputs Analysis in the Sphere of Smart City**	**SmC Data Verification**	**Use Data Models for DM**
		PSt of HC description	Medical DC&P for SmC Environment	MD Analysis in the Sphere of Smart City		
			Transport DC&P	Transport Data Analysis		
		PSt of H&CB description	H&CB DC&P	H&CB Data Analysis		
	Machine Learning	**Machine Learning for SmC**	**Features of DC&P for ML in SmC**	**Features of ML for Data Analysis in the Sphere of SmC**	**ML for SmC**	**Use ML Results for DM**
					Evaluation of City HC Scenario.	
						Evolutionary Algorithms in Transport Planning
					Modeling of H&CB	
	Computer Modeling	**PSt of CM in SmC**	**Features of DC&P for CM in SmC**	**Features of CM for Data Analysis in the Sphere of SmC.** Using GIS for Terrain Analysis	**Digital Models, Digital Twins in the SmC.** GIS Technologies in Simulation	**Use of CM for DM in SmC development**
					Simulation of City HC Scenario. Simulation of City HC Infrastructure	
					Continuous Modeling and Discrete Simulation of Transport Processes	Use of CM for Urban Transport Systems Planning
				Analysis of H&CB	Simulation of H&CB	Use H&CB Simulation and Analysis in SmC Development

Fig. 3. Map of problem areas formed for the course “Digital Urbanism.”

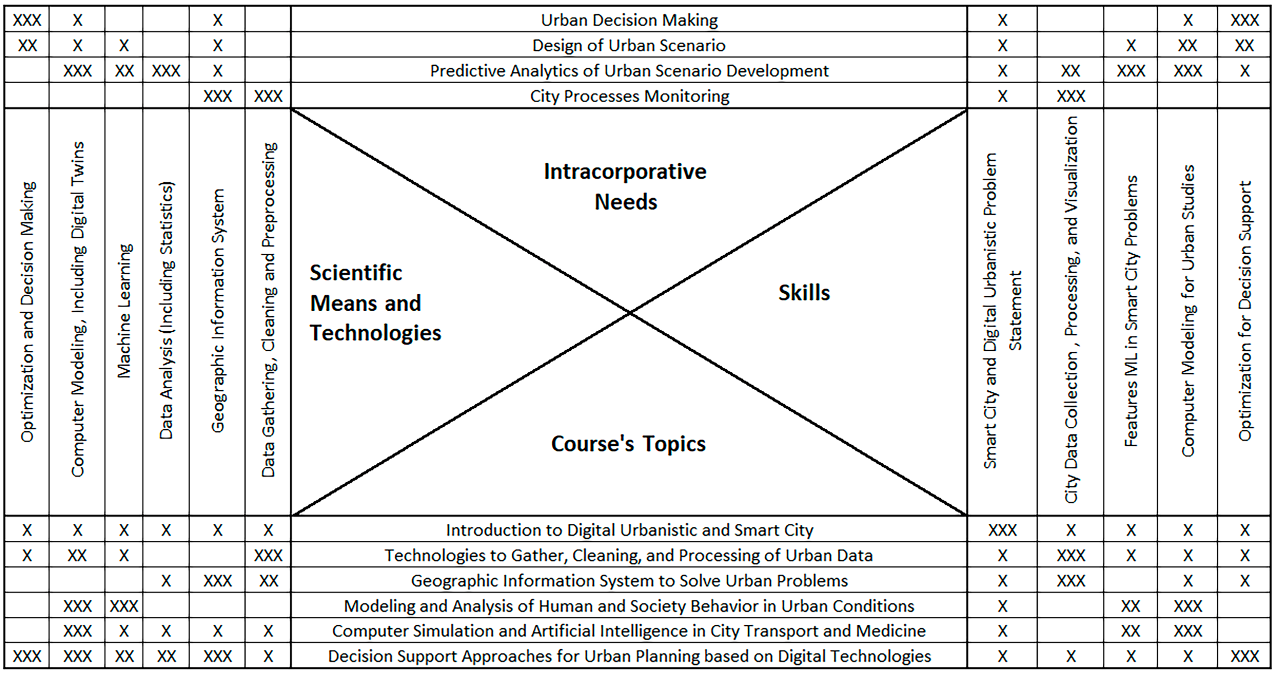

Fig. 4. X-matrix of the course "Digital Urbanism."

industries and subject areas were no longer singled out in order to reach the maximum audience. Therefore, the technologies are determined based on the analysis of the sources specified in the part III-A, relevant to the concept of "Industry 4.0," as well as the experience of the relevant scientific groups of the NCCR: "Industrial artificial intelligence," "Intelligent decision-making technologies," and "Modeling of natural systems." The participation of the latter group is not strange, since a number of industrial tasks are in one way or another related to the modeling of natural phenomena at the micro and macro levels. The experience is reflected in hundreds of publications, including [30–33]. Modern public and educational literature was also taken into account, including [34–37].

The list of lifecycle stages for the problem area map is identical to the list that was compiled for the previous program. The uniqueness of technological processes in modern industrial enterprises is not determined by the development of special software or the acquisition of ready-made solutions with flexible and deep customization capabilities; instead, the specifics of such enterprises are that they already contain departments and relevant specialists who have knowledge in big data and machine learning, and even how to develop and implement software.

Therefore, the task of the course was not to provide an understanding of the relevant technologies, but of the features of the application of the relevant scientific and methodological tools, technologies, and specialized software libraries (research engineering and specialized libraries, including Apache Spark, PyTorch, and AirFlow). At the same time, it was necessary to highlight the real line between the possibilities of developing digital services based on low-code or no-code and the need to develop traditional software code in a high-level programming language.

As a result of this analysis, the lists of production challenges, technologies, and relevant competencies are determined, which are reflected in the corresponding X-matrix (Figure 5).

Despite its overview nature, the course turned out to be very rich in approaches and technologies of BD&MO for digital transformations in industrial enterprises. Highlighting the features of data technology, as well as related derived technologies and digital smart products (including generative design and digital doubles), promotes listeners to a new level of motivation in managing change in their enterprises.

Instead of an entrance class, students were asked to study specialized literature, from textbooks to contemporary scientific papers (links to more than 50 sources and online courses). The last lesson can be positioned as an output: it provides an overview of national and international standards, and allows the student to organize the knowledge gained in previous classes. The course is also a "bridge" between this course and the DO course.

C. *"Digital Object as a result of intellectual activity: from idea to implementation" course*

This course is based on the same cross-cutting technologies as before, but here they are considered as a whole. The reason for this is that the map of problem areas is overlaid with a "plane" corresponding to the legal subject area, as well as elements of marketing. Therefore, the table converges to one line: cross-cutting technology and "Big data, machine learning, and cognitive technologies" in the following stages: (1) development of a digital intellectual object (DIO); (2) recognition and financial evaluation of this object; (3) registration of it as intellectual property and the formation of a legal protection mechanism; (4) promotion of the object in markets and sales. In fact, these stages have become production challenges that Russian universities are currently experiencing (Figure 6).

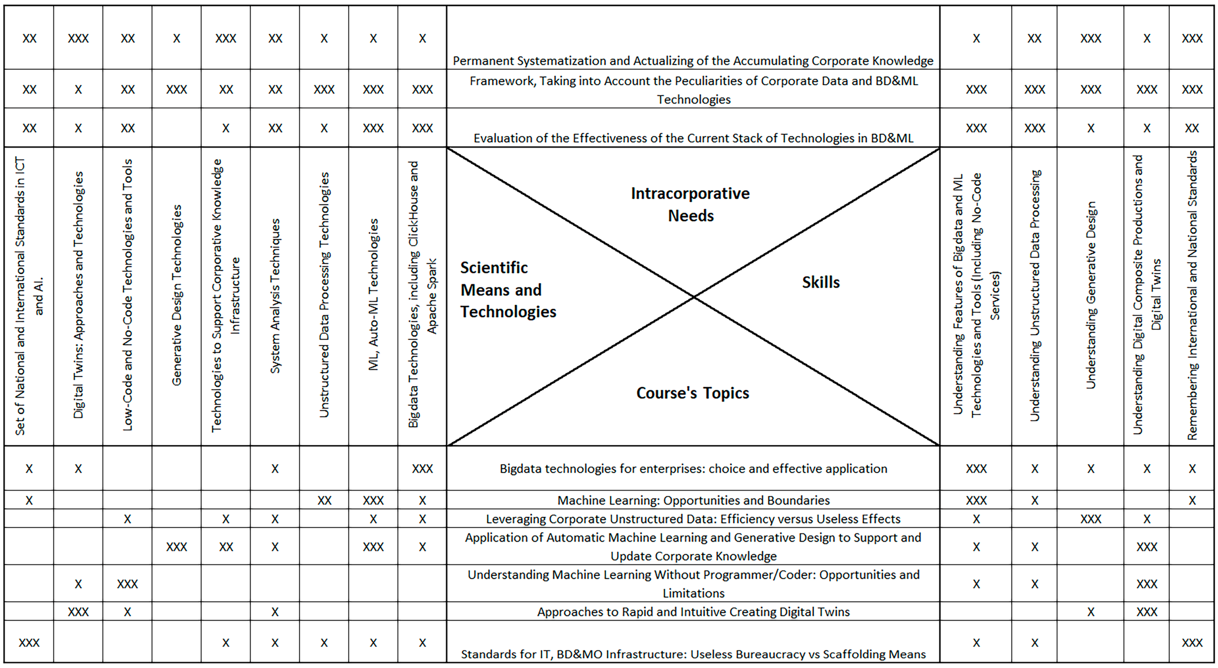

Fig. 5. X-matrix of the course "Big Data and Machine Learning for a qualified customer service."

The focus of the course in favor of legal issues of recognition and the protection of intellectual property and sales of digital intellectual objects determined the specifics of the choice of departments that developed and conducted the course: the executive directorate of the NCCR, the legal services of ITMO University, and the administration of the Faculty of Digital Transformations. At the same time, international-class patent attorneys were involved.

Like the previous courses, the DO is an overview course that outlines the main aspects of digital transformation and the corresponding role of the above-mentioned cross-cutting technologies; it provides insights into the digital intellectual object and its development lifecycle models, as well as technological and legal mechanisms for its financial assessment, registration, legal protection, and market launch.

V. Review of the Program's Results

The ATC presented above were held from December 2020 to March 2021. In total, we have trained about 700 specialists [39]. Table 1 contains information about each course: data on the contingent, and data on graduates' opinions based on the results of relevant surveys (acronyms: RU—number of registered users, App—number of applications, and Gr—number of graduates).

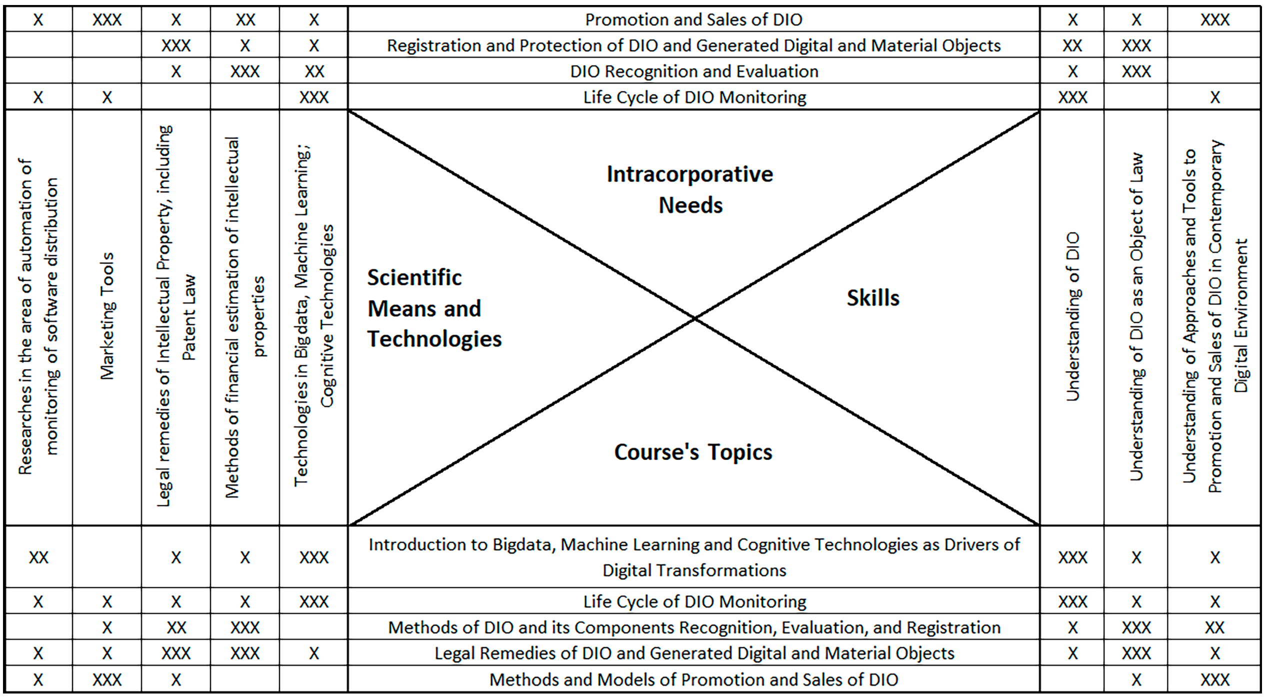

Fig. 6. X-matrix of the course "Digital Object as an object of intellectual property: from idea to implementation."

TABLE I. COURSES' CONTINGENT AND GRADUATES' FEEDBACK DATA

#	Course	Learning Contingent			Survey Results (Graduates' Expectations, %)		
		RU	*App*	*Gr*	*Sur-pass*	*Meet*	*Under-whelming*
1	DU	719	612	480	70	28	2
2	BD&MO	325	196	150	65	31	4
3	DO	152	94	60	61	34	5

The table shows that the courses exceeded the expectations of most graduates. As it turned out, apart from the quality of the course itself, there is a second reason for such a questionnaire result—a significant gap between knowledge and competencies in cross-cutting technologies among specialists from our university and graduates, who are representatives from different companies not yet sufficiently familiar with CCTs. Detailed analysis of questionary results shows that graduate employees of companies believe that the course is timely and in demand.

To compare presented courses with courses designed before our approach, we asked five experts to evaluate following criteria: compliance of the course topics with modern trends (CR1); compliance of the course topics with the general needs of enterprises (CR3); and opportunity to prepare individual practical sub-courses with detailed content (CR3). Every criterion was evaluated using a ten-position scale: from 1 (No) to 10 (full compliance or opportunity to prepare many courses: more than number of topics in the course received). We presented the experts with descriptions of the above-mentioned courses and three other courses: PC1: "Predictive Big Data Analytics as Support in Financial Sector Decision Making;" PC2: "Teaching Machine Learning in Higher Education, Intelligent;" PC3: "Intelligent Technologies for Urban Environment Planning."

Table 2 shows the results of the expert evaluations (rank sums) and time spent on course design (DT in m/hr). The last column contains values of concordance coefficient (CC). Pearson criteria with the coefficient 0.05 passed for all CR1-3.

The results presented in Table 2 show that new courses are better than courses PC1-3 according to all criteria, including learning contingent and time spent on design.

VI. CONCLUSION AND FUTURE STUDIES

In this paper, we propose an approach to the systematic design of ATC for domain professionals and leaders who are interested in digital transformation of their businesses. The approach considers cross-cutting technologies in the prism of the project life cycle stages in production and the specifics of the subject areas and industries on which the trainees are focused. It identifies the problem areas and the stack of relevant technologies that the course should cover. The resulting X-matrix is a compact representation of the dependencies between intracorporate needs, new graduate skills, course topics, and technologies covered by the graduate. This X-matrix is the basis for quickly compiling a client-oriented marketing course description. The attractiveness of the courses and the positive feedback from most graduates show the high efficiency of the approach. The expert approach shown that presented courses are better than previous ones according criteria in the field of trends, need of companies and possibility to design new practical courses.

TABLE II. RESULTS OF EXPERT EVALUATION PROCEEDINGS.

	Criterion	PC1	PC2	PC3	DU	BD&MO	DO	CC
1	CR1	16	5	14,5	25	28	16,5	0,83
2	CR2	13	8,5	12	22	29	20,5	0,76
3	CR3	14	6	11,5	26	29	18,5	0,92
	Graduting students	45	55	23	480	150	60	
	DT	24	17,5	22,5	6,5	11	9,5	

At the same time, we identified the directions for the development of the approach. We plan to re-run the designed courses and collect additional feedback to refine the effectiveness assessment of the proposed approach. We also intend to develop a technique for assessing the degree of connection between the elements of the X-matrix, which is now being evaluated by experts. This technique will make it possible to determine the content of such links.

In particular, the content of the relations between the topics of the course and technologies will be filled by the initial scientific [40] and learning [41] materials. Thus, we plan to create a set of tools to scaffold the full cycle of development and implementation of the course: from the concept stage to analyzing the feedback received.

ACKNOWLEDGMENT

This work is financially supported by the National Center of Cognitive Research of ITMO University.

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