https://doi.org/10.53656/ped2022-2.04

Research Insights
Изследователски проникновения

UNIVERSITY LEARNING OUTCOMES: STATEMENT OF THE ISSUE WITHIN THE THEORY OF ILL-POSED PROBLEMS

Dr. Alma Turganbayeva
Al-Farabi Kazakh National University (Republic of Kazakhstan)
Prof. Maktagali Bektemessov, DSc.
Abai Kazakh National Pedagogical University (Republic of Kazakhstan)
Prof. Dr. Marina Skiba
Financial Academy (Republic of Kazakhstan)

Abstract. The article discusses the problem of determining the learning outcomes for educational programs of the university, including at the program level and the level of individual disciplines included in the program. The goal is to substantiate the understanding of the definition of learning outcomes at a university as an inverse ill-posed problem within the framework of the theory of ill-posed problems, which will allow further reengineering of the educational process at a university based on models of inverse and ill-posed problems. The article identifies the types of uncertainty inherent in education, which affect the possibility of an incorrect decision. The publication substantiates a new understanding of the educational process focused on learning outcomes at a university, as a process of finding a solution to an inverse incorrect problem. In this case, the learning outcomes formulated for a specific educational program are considered as an available solution to the inverse problem. The research carried out by the authors made it possible to construct a mathematical model of the educational process at the university and identify its components. The authors demonstrate that the optimal way to design the educational process is to design it as an inverse problem, and the list of disciplines, their content and the corresponding learning outcomes are determined and developed at subsequent stages, focusing on the goals of the program.

Keywords: university management; inverse problems; incorrect problems; incorrectness of the educational process; classification of types of uncertainty and incorrectness; learning outcomes; design of the educational process; mathematical models in education

Introduction

Current trends in the university system of post-Soviet countries are characterized by an increase in academic freedom, which, first, is expressed in the transition from

the presence of a rigid learning path with an indication of a fixed list of academic disciplines to the emergence of a list of learning outcomes. That is, not compliance with individual parameters of the educational process, but achievement of the expected learning outcomes as a goal becomes fundamentally significant. It is the learning outcomes that become the main criterion for the success of an individual in society, the importance of having formal confirmation fades into the background. The set of necessary learning outcomes can be formed through various educational paths / tracks, with the important role played by technology and teaching methods, and not just the content of education.

Changes in the information environment, the advent of the Internet led to revolutionary changes in the educational sphere, led to an increase in the availability of education, competition, and globalization (Oke & Fernandes 2020; Gonzalez-Sanmamed et al. 2020; Roblek et al. 2020; Rapanta et al. 2020). Universities are no longer unique sources of information, knowledge, and new technologies. It has become possible to obtain knowledge through alternative sources of information. The presence of a diploma ceases to be the main criterion for employment. The main shift occurred in the presence of confirmed learning outcomes, rather than formal ways to obtain them.

The difficulty in determining the model of a bachelor's graduate lies in the fact that the period of study at a university under bachelor's programs (for the Russian Federation and Kazakhstan – 4 years) already exceeds the half-life of information, that is, information and, accordingly, students 'knowledge become outdated even before the completion of the educational program. This circumstance led to the emergence of the phenomenon of "micro-degrees" (micro-credentials), which involves intensive retraining, considering the changing needs of the labor market.

The availability of information, the ambiguity of its reliability, the rapid growth of its volume, have created new approaches to the processing of information flows. All this led to the need to search for true reliable information and real facts that underlie the decisions made. Thus, the redundancy of information was an incentive for the development of the theory of inverse problems and application for the search for initial motives and reliable initial solutions.

The expansion of academic independence creates maximum freedom to create individual educational trajectories aimed at mastering learning outcomes, that is, ensuring the sustainability of the processes of changes in the level of mastering learning outcomes, regardless of the specifics of the educational process and individual characteristics of students.

During the educational process, a huge number of interference and uncontrolled influences arise when promoting a person along educational paths in educational environments and global information networks. The expansion of educational spaces and educational opportunities leads to the appearance of ill-posed problems

in educational systems. Thus, mathematical modeling in education early was used mainly to build models of systems, not processes.

Methodology

Theoretical research methods included the analysis and study of both methods of mathematical modeling in the framework of the theory of inverse and ill-posed problems, as well as the analysis and study of research in the field of higher education. In addition, the study of the practice of designing the educational process was carried out, including in the framework of the participation of the authors of the publication in various stages of the procedures for assessing the quality of education. There was also a series of discussions with experts, 20 in-depth interviews with representatives of universities in the Bologna process countries, including Kazakhstan and Russia.

The theory of inverse and ill-posed problems is widely used in various fields of science, in particular: physics (astronomy, quantum mechanics, acoustics, electrodynamics, flaw detection, etc.); geophysics (seismology; electrical, magnetic and gravity exploration); medicine (x-ray examination and tomography, ultrasound, pharmacokinetic, immunological and epidemiological problems); ecology (water and air quality control, sustainable development, etc.); biology (study of populations); economics (theory of optimal control, model of economic growth, logistic production functions, spatial production functions), psychology (analysis of motives of behavior, theory of pattern recognition).

Various aspects of the idea and research results were discussed during a number of congresses, forums and conferences. For example, such as: the International Scientific and Practical Conference "Active Teaching Methods" (Almaty, KazNU named after al-Farabi, November 22 – 24, 2017), the World Congress of Engineers and Scientists "Future Energy: Innovative Scenarios and Methods for Their Implementation" WSEC-2017 (Astana, June 19 – 20, 2017), VI Congress of the Mathematical Society of Turkic-speaking countries (Astana, October 2 – 5, 2017) , II Central Asian Forum on Quality Assurance in Education (Astana, October 16, 2018), 5th International Conference "Governance and Open Society: Challenges in Eurasia", EGOSE2018 (St. Petersburg, Russia, November 14 – 16, 2018), VIII International Scientific and Methodological Conference "Mathematical Modeling and Information Technologies in Education and Science" (Almaty, Kazakhstan, October 3 – 4, 2018), International Scientific Conference "Inverse Problems in Finance, Economics and Life Sciences" (Almaty, Kazakhstan, August 31 – September 4, 2019), IX International Scientific and Methodological Conference "Mathematic modeling and information technology in education and science" (Almaty, October 1 – 3, 2020).

Within the framework of the study, the following understanding of terms was used within the framework of the theories of ill-posed and inverse problems and the assignment of problems to this class.

Incorrectness is especially pronounced in transformable, unstable, poorly organized systems due to incompleteness, timeliness, non-standartization and low reliability of information. Any attempt to expand the boundaries of the direct (visual, auditory, etc.) perception of the surrounding world leads to ill-posed problems.

Traditionally, the following signs of classifying a problem as a class of ill-posed problems are distinguished:

– the problem does not have a solution in the class of interest / given class,

– the problem has many solutions (at least two),

– the instability of the finding solutions process characterizes the problem.

If we consider cause-effect relationships in mathematical modeling problems, then all problems are conditionally divided into two classes – direct and inverse problems. In direct problems with known causes, it is necessary to determine the consequences, in inverse problems it is the other way around: it is necessary to find out the causes that caused these or those consequences. The inverse problem involves the search for initial, incoming data and conditions in the presence of a known solution (Kabanikhin 2018).

Uncertainty is understood as incompleteness and inaccuracy of information about the conditions for the implementation of the process, the presence of randomness or reaction factors. Uncertainty is most pronounced in soft, humanistic systems with many participants. Uncertainty can be classified as follows: uncertainty, incompleteness, incorrectness, inadequacy, insufficiency, uncertainty of interaction within the system and uncertainty of behavior, ambiguity, false information, physical uncertainty, inaccuracy, randomness, variability, linguistic uncertainty.

The inverse problem is a type of problem that often arises in many branches of science, when the values of the model parameters can be obtained from the observed data. Inverse problems often are ill-posed problems.

The formulation of the problem of designing the educational process in general and learning outcomes, as a rule, turns out to be incorrect, since it is often formulated in conditions of unpredictability of the system's behavior in non-standard and especially in extreme situations. It should be noted that the approach to the design of the educational process as to the solution of the educational problem is not traditional and generally accepted, since the old approach is still preserved, which consists in designing the process in accordance with the previously available standards.

Results

Changes in education and the emergence of new technologies have led to a change in the role of education in human life, and, consequently, it became necessary to model the educational process itself and the accompanying and supporting processes. All this led to the emergence of a need to create models and processes that take into account the uncertainty and incorrectness of educational processes (Abassian et al. 2020;

Conaway & Goldhaber 2020; Maass et al., 2019), using the methods of mathematical modeling in social processes, soft systems, random phenomena, and, consequently, in education, which we understand as a social the phenomenon of transferring the culture of society to an individual, which is open in nature, with a high level of uncertainty, risks and the active influence of random processes. However, at present, there are practically no studies that allow using the methods of mathematical modeling for the construction, analysis and reengineering of education and optimization of the processes themselves, which is caused by both insufficient funding of the educational sphere and the conservatism of participants in the educational process.

The Google trends tool demonstrated a virtual lack of information on queries like "mathematical models in education" and "inverse problems in education" in both Russian and English; up to 100 queries daily, "mathematical modeling" is also mainly from 25 to 100 in Russian and from 0 to 50 in English. The analysis of individual keywords in the RSCI database showed the prevalence of the basic term "mathematical models" in 3433 RSCI articles, 205 of them in WoS and Scopus articles. The next most frequently mentioned "economic and mathematical models" – 562, and "physical and mathematical models" – 25. The first mention of the term related to education "mathematical models of pedagogical measurements" is ranked 57th and refers to 3 publications.

Large-scale studies of the state of the level of education led to the use of Big Data methods in education, as well as to the use of the Rush model and ITR (subject response theory) for studying the state (Fischer et al. 2020).

The theory of fuzzy sets is used to build models of the state of soft humanistic systems in the educational sphere (Sim et al. 2018; Yao 2019). It is used to assess the development of learning outcomes, build models of personal system characteristics and assess the degree of their formation, such as education, competence, and readiness for professional activity. When designing an educational trajectory in conditions of academic independence, the theory of graphs (Tatsuoka 1986) was used.

The educational process at the university was viewed mainly as a linear process. For example, Ponomareva L.A., Golosov P.E. (2017) built a model of the educational process, understanding it as a direct problem describing a continuous deterministic process with limited resources.

Regression analysis based on linear equations was used by A.K. Kolesnikov, I.P. Lebedeva (2011) to predict learning outcomes.

It should be noted that there are many works by various authors devoted to the construction of mathematical models for assessing quality, including based on the theory of fuzzy sets, as well as a number of works describing educational systems and objects as fractals (Enríquez 2017).

The analysis and study of research in the field of higher education, the study of the practice of designing the educational process, including in the framework of the participation of the authors of the publication in various stages of the procedures for

assessing the quality of education, series of discussions with experts, 20 in-depth interviews with representatives of universities in the Bologna process countries, including Kazakhstan and Russia allowed to identify the following problems in the field of education (Staley & Barron 201; Goldhaber et al. 2020; Grinshkun & Krasnova 2017; Kincade et al. 2020):

1. In the field of technology development:

– the availability of virtual education in the best universities and with famous professors;

– priority of virtualization in students' activities;

– insufficiently developed means of assessing competencies and learning outcomes;

– insufficient use of the opportunity to recognize the results of non-formal and informal learning.

2. In the field of management:

– closed leadership of universities from real problems in the field of education;

– the unwillingness of university leaders to engage stakeholders in corporate governance, including students, teachers, and employers;

– authoritarian management systems and lack of readiness for delegation of responsibility;

– the unwillingness of students to express and make complaints about the quality of the educational process;

– the possibility of corrupt influence on the adequate assessment of learning outcomes;

– low degree of trust in students as equal members of the educational process.

3. In the field of teacher development:

– insufficiently developed methods for using interactive communication technologies at a university;

– aging of graduate teaching staff;

– attracting graduates of our own university as teachers leads to a lack of new ideas and a lack of exchange of experience;

– attracting teachers who do not have experience in the professional field;

– insufficient recognition level of teachers, which leads to a leak of personnel from the field of education.

– In the field of human capital development:

– insufficient willingness of students to play an active role in the educational process;

– insufficiency of personal verbal communication skills of students, due, inter alia, to the massive introduction of testing;

– incompetence of students in assessing the quality of education;

– poor understanding of the impact of selected disciplines on the achievement of learning outcomes.

Thus, the main role in setting the framework that determines the learning outcomes is played by employers and university professors. In this regard, the following problems can be identified that arise in the system of higher education in the context of employers and teachers, presented in Figure 1, which can be represented using the intersection of sets.

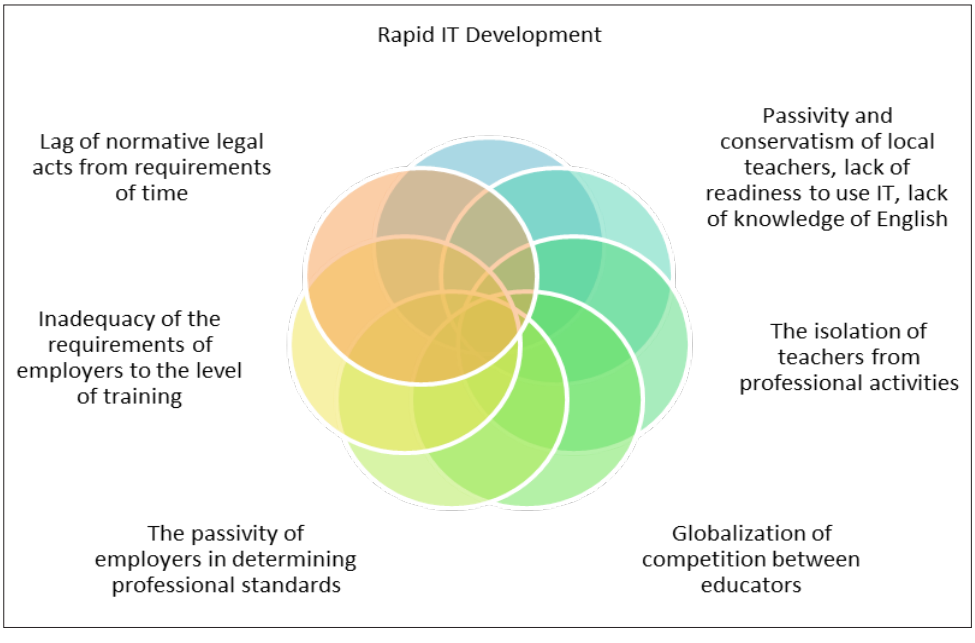

Figure 1. Problems in the higher education system in the context of employers and teachers

The resolution of these problems is an urgent need regarding the development of higher education, a transfer to a fundamentally new level of quality assurance and ensuring its competitiveness as a social institution of training. One of the possibilities of maintaining and developing the status of higher education as a social institution is the emphasis on student-oriented educational process, when a man as a person and a professional is the goal of the learning process. Employers cease to be interested in graduates with diplomas, they need trained workers with specific competencies in the professional and communication fields that they can develop. Student-centeredness, as a relatively new trend in education, involves focusing on the student's capabilities and on the needs of society and stakeholders, as recorded by the university in the graduate model (Berdrow & Bird 2018; Blazar & Archer 2020). Student-centered education is understood

as an approach to education, which is aimed at overcoming several problems inherent in more traditional forms of education, focused on students and their needs, rather than on the contribution of the teacher. This approach determines the flexibility of the curriculum and its development, the content of the course and the interactivity of the learning process. However, this sets certain requirements for the minimum level of learning outcomes mastered by each graduate of the educational program.

Describing learning at the university as a process aimed at achieving learning outcomes and expanding the academic freedom of universities, we come to understand it as an incorrect task consisting of various parameters connected by fuzzy relationships and characterized by various types of uncertainty. Below is the rationale for understanding the educational process in a university, focused on the result, as an ill-posed problem.

Understanding the result-oriented educational process as ill-posed problems is based on the above classification of incorrect tasks. Given the need to perform at least one of the signs listed above to classify the task as incorrect. We describe the possibility of manifestation of signs of incorrect tasks during the organization and implementation of the educational process at the university.

1 sign of ill-posed problem – there is no solution in the interest / given class. Obtaining a diploma does not guarantee the formation of graduate learning outcomes that meet professional standards and the needs of the economy and the individual. Including the inability to continue training and / or employment in the specialty.

In addition, the learning outcomes, especially those associated with "soft skills", are formed through teaching methods and technologies used in teaching disciplines. Such learning outcomes include learning outcomes involving critical thinking, teamwork, decision making in the face of uncertainty and incorrect information, time management, etc.

2-d sign of an incorrect task: the problem has many solutions (at least two). There are various educational trajectories, following which the student will be able to generate learning outcomes that ensure readiness for professional activity and implement personal development. These trajectories include both formal and non-formal and informal learning. The selectivity of the disciplines allows us to ensure complete "coverage" of the projected learning outcomes by choosing different paths, and these paths consider the learning outcomes generated earlier in the previous training phase.

Different universities for similar educational programs in conditions of academic independence determine unique learning outcomes based on Dublin descriptors, the National Qualifications Framework, and professional standards. Moreover, the more accurately the learning outcomes are tuned to the diverse needs of the labor market, the higher the chance of employment for graduates of the program, the more effective it is. Namely, uniqueness focused on meeting the needs of

interested parties, including employers and students, is a determining factor in the competitiveness of the program.

3-th sign of an incorrect task is the instability of the process of finding solutions. The same educational trajectory of study at the university, the same educational program can lead to different levels of formation of learning outcomes from graduates. The learning process is determined by the various educational opportunities and abilities of students, as well as various levels at the entrance to the learning process. Educational trajectories and the choice of academic disciplines and additional educational programs (Minor) also affect the instability of the decision-making process. Since each choice opportunity creates a different educational trajectory, and may entail a change in the list of learning outcomes.

The student, as an active participant in the educational process, also contributes to the creation of instability in achieving learning outcomes: personal qualities, the rate of assimilation of the material, the characteristics of the learning style and assimilation of information, the psychological attitude, and the possibility of internalizing knowledge.

Considering that incorrectness is especially pronounced in transformable, unstable, poorly organized systems, including educational ones, due to the incompleteness, timeliness, lack of standardization, and low reliability of information, we illustrate below the affiliation of the educational system that arises when studying at a university to such systems kind of. Educational systems are open humanistic systems, as they depend on the behavior of various participants in the educational process and stakeholders, the level of preparedness and knowledge. Constant reforms in the field of education do not allow tracking the influence of various factors on the educational process itself and on learning outcomes, changes in the content of educational programs and educational technologies occur almost annually. The requirements of society and employers for the content of educational programs for the list of learning outcomes are also changing rapidly, as there are changes in requirements in the labor market. In fact, the following requirements for employees, and, consequently, for university graduates become the only stable ones: manage changes, make decisions in conditions of uncertainty and incorrectness, and can provide self-directed training. The transition from the concept of knowledge, skills to the concept of learning outcomes leads to the need for changes in teaching methods, as well as assessment methods. Basically, the current forms of knowledge assessment are focused on the diagnosis of knowledge and skills, especially this applies to widely used testing. The independent work of the student in the framework of the discipline is poorly regulated and there are practically no clearly defined criteria for assessing its real labor intensity in the context of all academic disciplines.

One of the main characteristics of learning outcomes correlating on the basis of a model of professional competence as a system is the uncertainty in the behavior of

objects of the educational system, which leads to incorrectness in solving problems (Krieger 2014; Chirkova & Kochneva 2011).

In connection with the foregoing, the following specific types of uncertainty inherent in education can be identified that affect the possibility of an incorrect decision:

– the fuzzy boundaries of educational systems, in particular the fuzzy description of educational objects (education, competence, etc.), the use of dichotimous attributes "formed – unformed", "high – low";

– the ambiguity of the semantics of individual terms that are used in constructing conceptual models of systems, such as education, competence, training, quality;

– incompleteness of model ideas about education, in connection with the solution of poorly formalized problems both about education as a process and its laws, and about educational systems, including incomplete representations for both successfully forecasting a university development strategy and adequate design of learning outcomes, a sharp increase in information , change of information technologies and production processes;

– the inconsistency of the individual components of model representations and requirements that the model of education must satisfy. So, for example, fulfilling the social order of society and satisfying personal needs, compliance with regulatory documents governing the educational process; formation of professional competence in accordance with professional standards and individualization of education;

– stochasticity (the uncertainty of the onset of certain events), in particular, the uncertainty of the point in time at which the formation of education, achievement of projected levels of learning outcomes, the uncertainty of the formation of the necessary level of education depending on the educational trajectory of different students;

– the uncertainty of the goal, caused by: 1) the presence of interested parties, various goals and different ideas about the significance of the results of the educational process. In this case, there is a need to solve multi-criteria problems, especially when managing a university, so there is a risk that the learning outcomes will not be fully achieved, due to the need to solve other problems, for example, providing employment that does not fully meet modern requirements of teachers of retirement age, a shortage of qualified teachers in certain areas and/or academic disciplines in the labor market, the inability to attract teachers of practitioners due to restrictions caught by qualification requirements; 2) a verbal and insufficiently accurate mathematical description of the characteristics of the educational process and the formulation of learning outcomes;

– inaccuracy of information on the state of educational systems and persons involved in the educational process, distorted statistical data, corruption influence on the assessment of students' achievement of learning outcomes. The lack of

information about the conditions under which a decision is made is often caused by the low efficiency of the system for collecting, exchanging, and storing information inside the university or its absence. In addition, in universities with a strong leader and a lack of corporate governance, decisions can be made based on personal beliefs and preferences, and not based on collegial discussions and analysis of facts;

– the uncertainty of targeted opposition can be observed in a situation of interaction of two or more parties, each has incomplete, inaccurate information about the motives and behavior of the other side. Such opposition occurs: with passive participation in the educational process or with corruption manifestations between teachers and students, with changing requirements for the conditions and nature of work at the university and upcoming cuts between teachers and the administration, in determining the content of education between employers and the teacher. And also, multilateral oppositions are possible with the active involvement of all interested parties in the educational process and with the development of corporate governance in universities;

– incompleteness and inadequacy of assessment tools, particularly, not all learning outcomes are evaluated through assessment tools used at the university (for example, through tests), insufficient tasks for assessing competencies, applying skills, rather than knowledge, formality of assessing competencies / learning outcomes during practice, subjective attitude when evaluating.

In this case, the analysis of the system's behavior does not give a clear answer to the question "Will the learning outcomes of the graduate of the educational program at this level be formed at a certain point in the future?".

In addition, the current period is characterized by the uncertainty of the models of professional functions themselves, reflected in professional standards. The professional community itself is not able to adequately and unequivocally formulate its future needs in the formation of models of the results of graduate training, models of professionally significant competencies that will be in demand in four years.

In fact, when planning the educational process, the task is reduced to an incorrect one, consisting of four tasks corresponding to the main stages of design.

The first step is to design learning outcomes. Based on the information recorded in the professional standard, the opinions of experts and interested parties, as well as in the predictive model of the need for professionals, it is necessary to determine the learning outcomes. This task is incorrect and direct, suggesting the presence of many solutions.

f (professional standard, expert opinion, regulatory factors, limitations, time) = projected learning outcomes

$$LO\ (x_1, x_2, x_3, x_4, x_5) = y, \quad (1)$$

there y – projected learning outcomes, x_1 – professional standard, x_2 – expert opinion, x_3 – regulatory factors, x_4 – limitations, x_5 – time.

The second stage of design is to solve the inverse problem of designing an educational program – determining the objectives of the program, a list of disciplines, their contents, and other components of the educational process.

$$F_1(y) = \begin{pmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \\ z_5 \\ z_6 \\ z_7 \end{pmatrix} \quad (2)$$

there y – learning outcomes, z_1 – program goals, z_2 – list and content of disciplines, z_3 – educational literature, z_4 – learning technology, z_5 – information Technology, z_6 – forms and methods for assessing the development of learning outcomes, z_7 – requirements for the level of applicants.

The third stage of designing the educational process is to solve the inverse problem F2 (y), which arises when: designing teaching technologies s_1 and studying s_2 as an inverse function of $F_3(z_5)$ from learning technologies z_5, assessment technologies s_3, and supporting s_4, and educational environment s_5. The solution of this inverse problem should provide for the achievement of the planned learning outcomes by the largest possible number of students. One of the important components of the solution is the time t required by students to achieve learning outcomes:

$$F_2(y) = \begin{pmatrix} F_3(z_5) = (s_1, s_2), \\ s_3, \\ s_4, \\ s_5, \\ t \end{pmatrix} \quad F_2(y) = \begin{pmatrix} F_3(z_5) = (s_1, s_2), \\ s_3, \\ s_4, \\ s_5, \\ t \end{pmatrix} \quad (3)$$

there y – learning outcomes while fulfilling the condition $\left(\propto_{student} - \propto_{Level\ of\ study}\right) > 0,$ for each student $\left(\propto_{student} - \propto_{Level\ of\ study}\right) > 0,$ for each student, this $\propto_{student} \propto_{student}$ – mastered by student learning outcomes, $\propto_{Level\ of\ study} \propto_{Level\ of\ study}$ – projected learning outcomes appropriate to the level of learning.

The fourth step in solving the problem of designing the educational process is to solve the incorrect inverse problem of designing the individual educational trajectory of the student, considering his capabilities *p* and ability *a*.

$$f\begin{pmatrix} y, \\ p, \\ a \end{pmatrix} = \begin{pmatrix} m_1, \\ m_2, \\ m_3, \\ m_4, \\ m_5, \\ m_6, \\ t \end{pmatrix} \quad f\begin{pmatrix} y, \\ p, \\ a \end{pmatrix} = \begin{pmatrix} m_1, \\ m_2, \\ m_3, \\ m_4, \\ m_5, \\ m_6, \\ t \end{pmatrix} \tag{4}$$

where y – learning outcomes, m_1 is an individual educational trajectory, m_2 is academic mobility, m_3 is an additional educational program, m_4 is certification programs, m_5 is research, m_6 is non-formal learning, t is time.

Let us give the author's model of the sequence of reverse actions in the design of the educational process, which consists in determining:

– learning outcomes;
– a list of academic disciplines;
– their complexity;
– a list of applied teaching methods and technologies;
– a list of students' activities;
– tools for assessing learning outcomes;
– the degree of influence on the level of formation of learning outcomes.

Further, by detailing the model in the further design of learning outcomes, it is possible to identify the following activities carried out in the development of an educational program:

– analysis of the European and national qualifications frameworks, Dublin descriptors and professional standards;
– analysis of labor market needs;
– accounting for the educational program the provisions of the university development strategy;
– determination of the list of professionally significant competencies;
– the formulation of the learning outcomes of the educational program relevant at the time of completion of the educational program;
– determination of criteria for evaluating the completion of an educational program by students;
– determination of the compulsory and elective set of academic disciplines;
– determination of the complexity of academic disciplines;
– the choice of teachers for teaching disciplines;
– determination of the input requirements for students to start mastering the educational program;
– development of the content of academic disciplines;
– development of learning outcomes within the framework of modules and individual academic disciplines;
– development of a system of prerequisites and post requisites to determine the program development order;

– selection and adaptation of teaching methods;

– determination of the types of activities of students, consistent with the learning outcomes;

– determination of forms, methods, and tools for assessing learning outcomes, considering their specifics;

– assessment of the possibility of constructing individual educational paths;

– assessment of the degree of influence of all stages of the educational process on the achievement of learning outcomes;

– assessment of the attainability of learning outcomes in the framework of the developed educational program.

The detailed design of the educational process can be continued to the level of specific classes, as an integral unit of the educational process, which has its own corresponding learning outcomes.

During in-depth interviews and participation in various procedures for evaluating educational programs, a gap was revealed between the generally accepted practice of designing an educational program, which is based on the capabilities and abilities of teachers who offer "convenient" and familiar academic disciplines. The limitation of the possibilities for including disciplines in the program sharply narrows the possibilities of determining the planned learning outcomes in accordance with the needs of the labor market, which naturally leads to a decrease in the quality of education and a decrease in the competitiveness of graduates. This model is the basis for the reengineering of the educational process.

Conclusion

The analysis of the research results made it possible to formulate the following conclusions.

1. Innovations in the field of education and smart technologies have transformed educational reality, which exacerbated the contradiction between traditionally used models in the field of education and the specifics of real processes and systems, which caused the need to apply mathematical modeling methods to build and optimize models of educational systems and processes in conditions of uncertainty.

2. Expansion of academic independence has led to the need to overcome stereotypes in the design of the educational process, relying on the theory of inverse problems, using the understanding of incorrectness and uncertainty.

3. Designing the educational process at a university is inherently an inverse incorrect task. Despite this, the educational process is most often understood as a direct correct, unambiguously defined process, which hinders the quality assurance of education and the achievement of the planned learning outcomes by each graduate of the educational program.

4. Methods of mathematical modeling made it possible to identify the gap between the ideal mathematical model and practice, which demonstrated the need for reengineering of the educational process at the university.

5. The proposed approach will make it possible to effectively organize the educational process in conditions of uncertainty, providing a solution to the problem of designing learning outcomes.

NOTES

1. www.elibrary.ru

REFERENCES

ABASSIAN, A., SAFI, F., BUSH, S., BOSTIC, J., 2020. Five different perspectives on mathematical modeling in mathematics education. *Investigations in Mathematics Learning*, **12**(1), 53 – 65.

BERDROW, I, BIRD, A.W. 2018, Development and Assessment of Intercultural Effectiveness: A Learner-Centered Approach. *Journal of Education,* **198**(2), 136 – 145.

BLAZAR, D., ARCHER, C. 2020. Teaching to Support Students with Diverse Academic Needs. *Educational Researcher,* **49**(5), 297 – 311.

CHIRKOVA, T.I., KOCHNEVA, E.M., 2011. The uncertainty factor in higher education: the contours of the problem. *Bulletin of the Russian Academy of Education*, (2), 114 – 125.

CONAWAY, C., GOLDHABER, D., 2020. Appropriate Standards of Evidence for Education Policy Decision Making. *Education Finance and Policy,* **15**(2), 383 – 396.

ENRÍQUEZ, L., 2017. Fractal: An Educational Model for the Convergence of Formal and Non-Formal Education. *Open Praxis,* **9**(4), 375 – 386.

FISCHER, C., PARDOS, Z. A, BAKER, R. S. ET AL., 2020. Mining Big Data in Education: Affordances and Challenges. *Review of Research in Education*, **44**(1), 130 – 160.

FRUMIN, I. D., 2019. Simple steps on the way to new education. *Practices of development: ideas, technologies, contexts,* 5 – 11.

GOLDHABER, D., KRIEG, J., NAITO N., THEOBALD, R., 2020. Making the Most of Student Teaching: The Importance of Mentors and Scope for Change. *Education Finance and Policy*, **15**(3), 581 – 591.

GONZALEZ-SANMAMED, M., MORER, A.S., SEIJO, A.S., ESTÉVEZ, I., 2020. Learning ecologies in the digital era: challenges for higher education. Publicaciones*: Facultad de Educación y Humanidades del Campus de Melilla*, **50**(1), 83 – 102.

GRINSHKUN, V.V., KRASNOVA, G.A., 2017. Development of education in the era of the fourth industrial revolution. *Informatics and education*, **1**, 42 – 45.

KABANIKHIN, S. I., 2018. *Inverse and ill-posed problems*. Novosibirsk: Publishing house of the SB RAS.

KINCADE, L, COOK, C, GOERDT, A., 2020. Meta-Analysis and Common Practice Elements of Universal Approaches to Improving Student-Teacher Relationships. *Review of Educational Research*, **90**(5), 710 – 748.

KOLESNIKOV, A. K. & LEBEDEVA, I. P., 2011. Complex application of mathematical methods in pedagogical research. *Profile school*, **5**, 49 – 54.

KRIEGER, E. E., 2014. Situations of uncertainty and problematic situations: general and special. *Modern problems of science and education*, **2**, 581 – 586.

MAASS, K., GEIGER, V., ARIZA, M. R. ET AL., 2019. The Role of Mathematics in interdisciplinary STEM education. *ZDM Mathematics Education*, **51**, 869 – 884.

OKE, A. & FERNANDES, F.A.P., 2020. Innovations in Teaching, and Learning: Exploring the Perceptions of the Education Sector on the 4th Industrial Revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity,* **6**(2), 31.

PONOMAREVA, L.A. & GOLOSOV, P.E., 2017. Development of a mathematical model of the educational process in a university to improve the quality of education. *Fundamental research*, **2**, 77 – 81.

RAPANTA, C., BOTTURI, L., GOODYEAR, P., GUÀRDIA, L. & KOOLE, M., 2020. Online university teaching during and after the Covid-19 crisis: Refocusing teacher presence and learning activity. *Postdigital Science and Education*, **2**(3), 923 – 945.

ROBLEK, V., MEŠKO, M., BACH, M.P., THORPE, O. & ŠPRAJC, P., 2020. The interaction between internet, sustainable development, and emergence of society 5.0. *Data*, **5**(3), 80.

SIM, M., CONDUIT, J. & PLEWA, C., 2018. Engagement within a service system: a fuzzy set analysis in a higher education setting. *Journal of Service Management,* **29**(3), 422 – 442.

STALEY, K. & BARRON, D., 2019. Learning as an outcome of involvement in research: what are the implications for practice, reporting and evaluation? *Research involvement and engagement*, **5**(1), 1 – 9.

TATSUOKA, M. M., 1986. Graph Theory and its Applications in Educational Research: A Review and Integration. *Review of Educational Research*, **56**(3), 291 – 329.

YAO, F., 2019. Design and simulation of integrated education information teaching system based on fuzzy logic. *Journal of Intelligent & Fuzzy Systems*, **37**(4), 4687 – 4695.

✉ **Dr. Alma Turganbayeva**
ORCID ID: 0000-0001-9723-4679
Al-Farabi Kazakh National University
Almaty, Republic of Kazakhstan
E-mail: turganbayeva.alma1@kaznu.kz

✉ **Prof. Maktagali Bektemesso, DSc.**
ORCID ID: 0000-0001-8634-853
Abai Kazakh National Pedagogical University
Almaty, Republic of Kazakhstan
E-mail: m.bektemessov@abaiuniversity.edu.kz

✉ **Prof. Dr. Marina Skiba**
ORCID ID: 0000-0002-4155-9957
Financial Academy
Nur-Sultan, Republic of Kazakhstan
E-mail: marina.skiba@fin-academy.edu.kz