

Multi-criteria Assessment of a Student's Individual Profile

Assel Bektenova *, Natalya Denisova, Irina Doymina, and Oryngul Sadykanova

School of Information Technology and Intelligent Systems, East Kazakhstan Technical University, Kazakhstan

Email: bektenova_a@ukk.nis.edu.kz (A.B.); ndenisova@edu.ektu.kz (N.D.); irdyomina@mail.ru (I.D.);

sadykanova_o@ukk.nis.edu.kz (O.S.)

*Corresponding author

Abstract—At the junction of modern social processes, the problem of forming an individual with a high sense of social responsibility, adequate creative activity, morality, and a well-rounded personality has arisen. As well as the use of individual capabilities and intellectual abilities in their activities. One of the main tasks of intellectual schools is the formation of a creative, competent personality through the best examples of world civilization, the development of the intellectual and creative potential of students. To solve such global problems, scientists around the world use various methods; in our research we will try to use fuzzy logic. The article uses a fuzzy model for assessing the quality of education based on the theory of fuzzy sets, which will provide a clearer visualization of individual trajectories of students. To form a model for assessing students' competencies, a matrix of paired comparisons is used as a defuzzification method. During the research, it was possible to conduct a detailed quantitative and qualitative survey of groups of students. Thus, based on expert assessments, we found that there are significant factors that impede the implementation of the new teaching format, and this contributes to the development of an algorithm for identifying giftedness (student profile) and teaching the student taking into account individual needs.

Keywords—giftedness, individual trajectory, methods for determining giftedness fuzzy sets, pairwise comparison matrix, decision making

I. INTRODUCTION

The proposed research was conducted at the Nazarbayev Intellectual School of Chemical and Biological Studies in Ust-Kamenogorsk, Kazakhstan. Making strides towards an innovative economy stands as a key focus of Kazakhstan's industrial strategy, necessitating the thorough preparation of adept young professionals across diverse fields. Consequently, the overhaul of the educational system, particularly at the school level, becomes paramount as it serves as the bedrock for fostering innovative growth and steering the national economy towards digital transformation. In the country at this stage of development of the education system, it works in accordance with the State Program for the Development of Science and Education for 2020–2025.

The education system of Kazakhstan is striving to transform the old format of education towards a differentiated approach. There are such pressing issues as the development of a digital educational environment in schools, modeling students' digital competencies, building personal learning trajectories in the digital environment of a school, as well as the development of information technologies, models and algorithms that allow adaptation. course of the lesson taking into account the individual characteristics of students. The combined use of fuzzy logic and methods of decision theory and statistical information processing is the basis for the study of these issues [1]. Therefore, the significance of this endeavor lies in addressing the challenge of advancing information technologies to discern individual paths for students, enabling tailored support for both individual and small-group learning. Emphasizing the cultivation of digital skills, this approach enhances the quality and effectiveness of the educational process within Kazakhstan's schools.

The object of the study is the process of introducing differentiated learning with the support of information technology. The subject of the study is the models and architecture of information technologies for identifying and supporting individual trajectories. The purpose of the study is to develop a model of multi-criteria formation of an individual trajectory for the development of giftedness in students, which will improve the quality and efficiency of the educational process in schools of the Republic of Kazakhstan. Research methods are based on fuzzy logic [2]. The scientific novelty of the study lies in the fact that for the first time an assessment of the quality of knowledge was used based on the theory of fuzzy sets using a matrix of paired comparisons, and an algorithm was proposed for the formation of individual trajectories for the development of giftedness of students and taking into account the individual characteristics of the student, which is the basis of information technologies for supporting a differentiated format of education.

II. LITERATURE REVIEW

Let's consider a group of publications by authors exploring new approaches to creating expert systems themselves for education (including those based on fuzzy logic). An analysis of the literature in this area led to the

conclusion that one of the discussed approaches to the creation of expert systems is attempts to propose the use of fuzzy logic methods based on the theory of fuzzy sets [3–5]. Below we review the work between the proposed research and existing work in this area.

Let us consider studies that present similar methods of fuzzy set theories. In this article, Krasilnikov and Toiskin [6] presents the application of fuzzy logic methods. His identifies several reasons based on which preference is given to the use of systems with fuzzy logic: they are conceptually easier to understand; it is a flexible system that is resistant to inaccurate input data; can model nonlinear functions of arbitrary complexity. The following authors Solodovnikov *et al.* [7] uses the method of constructing fuzzy rules. They consider the general principles of constructing a software system capable of ensuring comprehensive student performance over the course of a semester using an expert system that uses elements of fuzzy logic. Let's consider a study in which AI is used, one of such authors is Melikhova [8] considers the possibility of designing and implementing an expert system for monitoring the educational process of a university based on a fuzzy approach to modeling intelligent systems. This approach uses "linguistic" variables, the relationships between which are described using fuzzy statements and fuzzy algorithms. It is assumed that the construction of a system for monitoring the educational process may include the following stages: formulating learning goals, determining the level of requirements of each teacher (higher, middle, lower); building a monitoring system that determines the degree of training in each discipline. Indicators: discrimination, memorization, understanding, basic skills, knowledge transfer; determination of the actual effectiveness of the teacher's activities based on indicators of the degree of preparedness of students. The main indicators of a teacher's effectiveness are the strength, depth and awareness of students' knowledge. These same indicators determine the quality of education. Kureichik *et al.* [9] in their work explore an approach to the design of intelligent distance learning systems based on rules and precedent-based inference technologies. Noordin *et al.* [10] consider teaching effectiveness assessment in which expert systems should model the expert's decision-making process as a deductive process using rule-based inference. Yusu *et al.* [11] demonstrate a systematic overview of sequential learning using neural network and its models, where a set of rules can be built into the system that based on input data. A conclusion is drawn about the adequacy of the proposed model. This method can be effective in situations where the main source of knowledge about a problem or situation is experience rather than theory, solutions are not unique to a particular situation and can be used in others to solve similar problems, the purpose of the conclusion is not guaranteed to be the correct solution, but the best of possible. It is assumed that the implementation of this inference technology can be carried out using neural network algorithms.

Having considered many works where fuzzy logic and artificial intelligence were used in the education system,

one cannot help but note their use in a very wide range, both in industry, medicine and education. Jang and Lee [12] in their study showed a method for distinguishing normal people from patients with Parkinson's disease based on their single pressure sensor data using Neural Network with Weighted Fuzzy Membership Functions (NEWFM). Fuzzy logic has proven to be a wonderful tool for building intelligent decision-making systems based on the knowledge and observations of medical professionals. Aamir *et al.* [13] propose a fuzzy logic-based home healthcare system for patients with chronic heart disease (in stable condition) for out-of-hospital surveillance and monitoring. The proposed system helps medical practitioners effectively treat patients with cardiovascular diseases who live alone in their homes. Moreover, this model is expected to be cost-effective, smarter and result-oriented compared to other prevailing traditional methods. The authors present an analysis of the structure and evaluation of the system's performance, as well as potential applicability in the development of real systems.

In our research, we use an assessment of the quality of knowledge based on the theory of fuzzy sets using a matrix of paired comparisons, which will help determine the multi-criteria profile of a gifted student.

III. MATERIALS AND METHODS

Expert assessments of alternative options according to the criteria can be represented as fuzzy sets or numbers expressed using membership functions. To order fuzzy numbers, there are many methods that differ from each other in the way of convolution and construction of fuzzy relations. One of them is evaluation of the quality of education based on the theory of fuzzy sets. The latter can be defined as preference relations between objects. Let's consider one of the mathematical formulations of decision-making problems based on the theory of fuzzy sets [14–17].

In this case, the criteria determine some concepts, and the estimates of alternatives represent the degree of compliance with these concepts. Let there be many alternatives $A = \{a_1, a_2, \dots, a_m\}$ and a lot of criteria $C = \{c_1, c_2, \dots, c_n\}$, at the same time, estimates of alternatives for each i -th criterion are represented by fuzzy sets:

$$C_i = \{a_1, a_2, \dots, a_m\}$$

$$C_1 = \left\{ \frac{M_{C_1}(a_1)}{a_1}, \frac{M_{C_1}(a_2)}{a_2}, \dots, \frac{M_{C_1}(a_m)}{a_m} \right\} \quad (1)$$

The rule for choosing the best alternative can be represented as the intersection of fuzzy sets that meet the criteria:

$$D = \{C_1 \cap C_2 \cap \dots \cap C_m\} \quad (2)$$

The fuzzy set intersection operation can be implemented in different ways. Sometimes the intersection is performed as a multiplication, but usually this operation corresponds to taking the minimum:

$$M_D(a_j) = \min_{i=1, \dots, n} M_{C_i}(a_j), j = 1, \dots, m \quad (3)$$

If the criteria C_i are of different importance, then their contribution to the overall solution can be represented as a weighted intersection:

$$D = C_1^{b_1} \cap C_2^{b_2} \cap \dots \cap C_n^{b_n} \quad (4)$$

where b_i are the weighting coefficients of the corresponding criteria, which must satisfy the following conditions:

$$b_i \geq 0; i = 1, \dots, n; \left(\frac{1}{n}\right) \sum_{i=1}^n a_i = 1 \quad (5)$$

The coefficients of relative importance b_i can be determined using the procedure of pairwise comparison of criteria.

Fuzzy multi-criteria analysis for the formation of individual student trajectories.

As an example of decision making in fuzzy conditions according to the Bellman-Zade scheme, let's consider a comparison of indicators according to three criteria (x_1, x_2, x_3) participating in the rating for providing quality education.

To evaluate groups of students, we will use the following criteria:

- G_1 —language competencies;
- G_2 —participation in the Olympiads;
- G_3 —logistics;
- G_4 —quality of education;
- G_5 —availability of e-learning;
- G_6 —results of students in international comparative studies: the international program for the assessment of educational achievements of students (PISA).

In an expert comparison of groups of students x_1, x_2, x_3 according to the criteria G_1, G_2, \dots, G_6 , linguistic statements were obtained, shown in Table I.

TABLE I. PAIRED COMPARISONS OF PROJECTS ON THE SAATY SCALE

Criterion	Paired Comparisons
G_1	Lack of x_1 advantage over x_2 , Significant x_3 advantage over x_1
G_2	Almost significant advantage of x_1 over x_3 Weak advantage x_2 over x_3
G_3	Significant x_1 advantage over x_2 Clear x_1 advantage over x_3
G_4	Weak x_2 advantage over x_1 Almost weak x_3 advantage over x_1
G_5	Significant x_1 advantage over x_2 Almost clear advantage of x_1 over x_3
G_6	Almost significant advantage of x_1 over x_2 Almost weak x_3 advantage over x_1

These expert statements correspond to the following matrices of paired comparisons:

$$A(G_1) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 0.2 & 0.2 \\ x_2 & & 1 & 0.2 \\ x_3 & & & 1 \end{matrix} \quad (6)$$

$$A(G_2) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 1.35 & 4 \\ x_2 & & 0.75 & 1 \\ x_3 & & & 0.25 & 0.33 & 1 \end{matrix} \quad (7)$$

$$A(G_3) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 5 & 7 \\ x_2 & & 0.2 & 1 \\ x_3 & & & 0.14 & 0.71 & 1 \end{matrix} \quad (8)$$

$$A(G_4) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 0.33 & 0.5 \\ x_2 & & 3 & 1 \\ x_3 & & & 2 & 0.67 & 1 \end{matrix} \quad (9)$$

$$A(G_5) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 5 & 6 \\ x_2 & & 0.2 & 1 \\ x_3 & & & 0.17 & 0.83 & 1 \end{matrix} \quad (10)$$

$$A(G_6) = \begin{matrix} & x_1 & x_2 & x_3 \\ x_1 & 1 & 4 & 0.5 \\ x_2 & & 0.25 & 1 \\ x_3 & & & 2 & 8 & 1 \end{matrix} \quad (11)$$

Matrix elements correspond to pairwise comparisons from Table I. The rest of the elements are found under the assumption that pairwise comparisons are consistent, i.e. taking into account the fact that the matrix of pairwise comparisons is diagonal and has the properties of transitivity and inverse symmetry.

Applying transformations to the matrices of pairwise comparisons, we obtain the following fuzzy sets:

$$G_1 = \left\{ \frac{0.14}{x_1}, \frac{0.14}{x_2}, \frac{0.72}{x_3} \right\} \quad (12)$$

$$G_2 = \left\{ \frac{0.5}{x_1}, \frac{0.38}{x_2}, \frac{0.12}{x_3} \right\} \quad (13)$$

$$G_3 = \left\{ \frac{0.74}{x_1}, \frac{0.15}{x_2}, \frac{0.11}{x_3} \right\} \quad (14)$$

$$G_4 = \left\{ \frac{0.17}{x_1}, \frac{0.5}{x_2}, \frac{0.33}{x_3} \right\} \quad (15)$$

$$G_5 = \left\{ \frac{0.73}{x_1}, \frac{0.15}{x_2}, \frac{0.12}{x_3} \right\} \quad (16)$$

$$G_6 = \left\{ \frac{0.31}{x_1}, \frac{0.08}{x_2}, \frac{0.61}{x_3} \right\} \quad (17)$$

And then we obtain: $D = \left\{ \frac{0.14}{x_1}, \frac{0.08}{x_2}, \frac{0.11}{x_3} \right\}$, which indicates a significant advantage of groups of students x_1 over groups of students x_2 , as well as a weak advantage of groups of students x_2 over groups of students x_3 .

Let us assume that criteria G_1, G_2, \dots, G_6 , are non-equilibrium. To determine the ranks of the criteria, we use the method of paired comparisons. Let the following linguistic statements about the importance of criteria be given:

- almost significant advantage of G_2 over G_1 ;
- clear advantage of G_3 over G_1 ;
- weak advantage of G_3 over G_5 ;
- almost weak G_3 advantage of G_4 over G_6 ;
- no advantage of G_5 over G_6 .

These expert statements correspond to the following matrix of paired comparisons:

	G_1	G_2	G_3	G_4	G_5	G_6
G_1	1	0.25	0.14	0.21	0.43	0.43
G_2	4	1	0.57	0.86	1.71	1.71
$A=G_3$	7	1.75	1	1.5	3	3
G_4	4.67	1.17	0.67	1	2	2
G_5	2.33	0.58	0.33	0.5	1	1
G_6	2.33	0.58	0.33	0.5	1	1

Let us determine the ranks of the criteria G_1, G_2, \dots, G_6 : $\alpha_1 = 0.04$; $\alpha_2 = 0.19$; $\alpha_3 = 0.33$; $\alpha_4 = 0.22$; $\alpha_5 = 0.11$; $\alpha_6 = 0.11$, which means that the G_3 direction priority and the G_4 degree of development are of the greatest importance. We get such fuzzy sets:

$$G_1 = \left\{ \frac{0.14^{0.04}}{x_1}, \frac{0.14^{0.04}}{x_2}, \frac{0.72^{0.04}}{x_3} \right\} = \left\{ \frac{0.91}{x_1}, \frac{0.91}{x_2}, \frac{0.98}{x_3} \right\} \quad (19)$$

$$G_2 = \left\{ \frac{0.5^{0.19}}{x_1}, \frac{0.38^{0.19}}{x_2}, \frac{0.12^{0.19}}{x_3} \right\} = \left\{ \frac{0.88}{x_1}, \frac{0.83}{x_2}, \frac{0.68}{x_3} \right\} \quad (20)$$

$$G_3 = \left\{ \frac{0.74^{0.33}}{x_1}, \frac{0.15^{0.33}}{x_2}, \frac{0.11^{0.33}}{x_3} \right\} = \left\{ \frac{0.91}{x_1}, \frac{0.53}{x_2}, \frac{0.48}{x_3} \right\} \quad (21)$$

$$G_4 = \left\{ \frac{0.17^{0.22}}{x_1}, \frac{0.5^{0.22}}{x_2}, \frac{0.33^{0.22}}{x_3} \right\} = \left\{ \frac{0.68}{x_1}, \frac{0.86}{x_2}, \frac{0.79}{x_3} \right\} \quad (22)$$

$$G_5 = \left\{ \frac{0.73^{0.11}}{x_1}, \frac{0.15^{0.11}}{x_2}, \frac{0.12^{0.11}}{x_3} \right\} = \left\{ \frac{0.97}{x_1}, \frac{0.81}{x_2}, \frac{0.79}{x_3} \right\} \quad (23)$$

$$G_6 = \left\{ \frac{0.31^{0.11}}{x_1}, \frac{0.08^{0.11}}{x_2}, \frac{0.61^{0.11}}{x_3} \right\} = \left\{ \frac{0.88}{x_1}, \frac{0.76}{x_2}, \frac{0.95}{x_3} \right\} \quad (24)$$

As a result of the intersection of fuzzy sets $G_1 \cap G_6$, we obtain: $D = \left\{ \frac{0.68}{x_1}, \frac{0.53}{x_2}, \frac{0.48}{x_3} \right\}$ which indicates a significant advantage of groups of students x_1 over groups of students x_2 and x_3 , as well as a weak advantage of groups of students x_2 over groups of students x_3 .

During the implementation of the method, it was concluded that some of the presented groups are at a higher level than others. Using other criteria, it is possible to conduct a more detailed analysis of the rating of the quality of education in classes with small groups. This conclusion can be adjusted taking into account the results of other indicators that are involved in the system. The study's findings, evaluated by experts, indicate prominent barriers to implementing a new educational format: namely, the absence of comprehensive individualized pathways within the educational platform, inadequate resource availability, insufficient attention given to students' individual needs and interests during the learning process due to inadequate motivation, and a deficiency in future-oriented professional training. What contributes to the development of a new architecture for determining multi-criteria

trajectories of students and their further implementation in the educational process.

IV. RESULT AND DISCUSSION

In this study, stakeholders these are the parties, whether individuals, collectives, or organizations, whose interests are influenced or impacted by a project that leads to a transition to differentiated instruction, which is primarily of interest to high school students and their parents, administrators and teachers who teach in high schools. Throughout the project execution, the concerns of secondary schools and the Autonomous Educational Organization "NIS" are affected. During the 2020-2021 academic year, the authors conducted surveys aimed at pinpointing challenges related to the shift towards personalized learning within Intellectual Schools. These surveys encompassed students, parents, and teachers across the entirety of Kazakhstan's Intellectual Schools network, spanning all regions. The decision to focus on Nazarbayev Intellectual Schools as the primary study subject was influenced by several factors:

- NIS serves as a pivotal center for pioneering innovative teaching methodologies in Kazakhstan, particularly in their approach to educating talented youth.
- The technical infrastructure of NIS schools is notably advanced.
- Students attending Intellectual Schools exhibit significant motivation to excel in competencies and actively engage with modern information and communication technologies.
- Educational institutions within the NIS network possess experience in successfully executing substantial collaborative innovative projects.
- The positive outcomes and experiences derived from the NIS network are being disseminated and implemented in secondary schools across Kazakhstan.

Thus, the results of the study, based on expert assessments, show that significant factors hindering the introduction of a new format of education are: the lack of multi-criteria individual trajectories of students. To visually present the results of the expert assessment, a problem tree was built, allowing one to visualize the identified key problems and their cause-and-effect relationships (Fig. 1).

Based on the problem tree, a thorough analysis was carried out and strategies for achieving goals were identified, which made it possible to determine strategic directions that ensure the possibility of introducing differentiated education in schools of the Republic of Kazakhstan with the support of information technology and to develop a conceptual model. The developed conceptual model (Fig. 2) presents a holistic picture of solving the problem of introducing differentiated learning and takes into account all the factors influencing the effectiveness of achieving the goal. Effective implementation of differentiated learning is possible with a comprehensive consideration of four tasks: development

of personalized training programs as the main condition for the introduction of information technologies to support differentiated learning, improvement of the regulatory framework, technical and resource support for the process of differentiated learning, retraining of teachers in this direction.

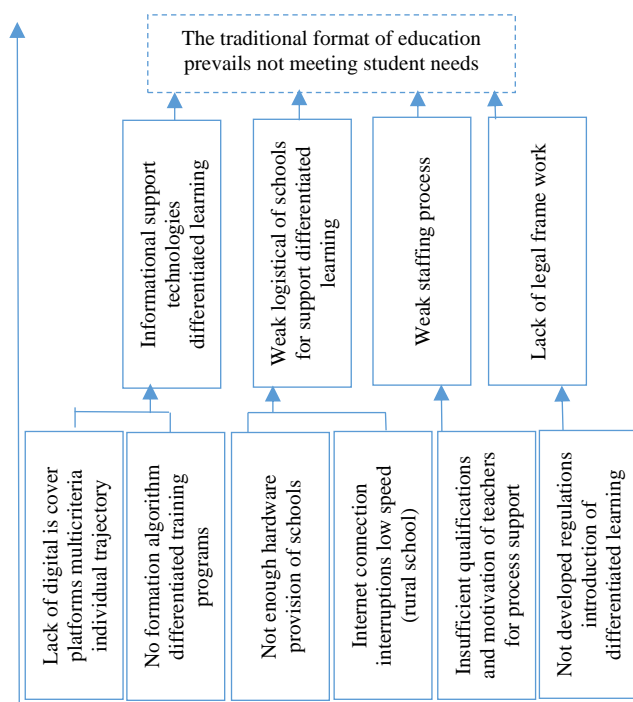


Fig. 1. Tree of problems of implementing differentiated learning.

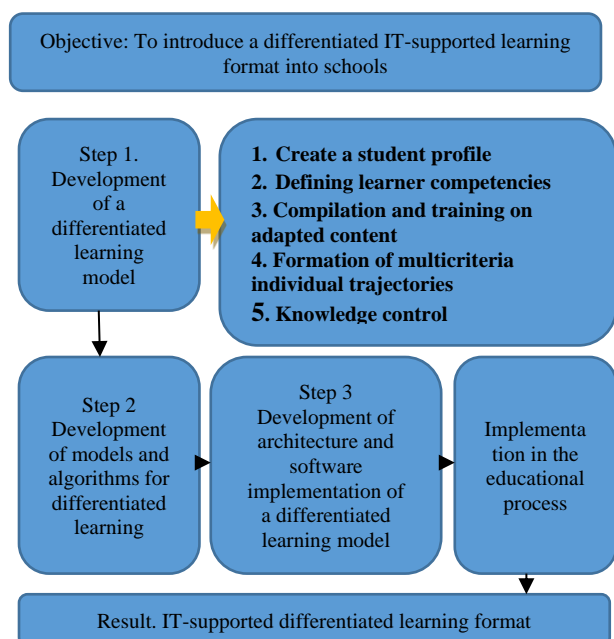


Fig. 2. Conceptual model for introducing differentiated training.

In the course of studying the relevance of the problem, a number of actions, experiments and various analyzes were carried out, the results of which were published in various international and republican journals that are part

of the Committee for Supervision in Education and Science [18–24].

The result of all research leads to the development of an electronic platform for supporting gifted children (identification of giftedness, formation of individual trajectories, further development of a training program, lesson adaptation). Let's discuss the conceptual model.

The first step in implementing task No. 1 is to develop a model of differentiated learning, consisting of two interconnected environments: a differentiated digital environment and an active school environment. The classroom-lesson form remains the main form of training in Kazakhstan, therefore, the integration of a digital and active learning environment is proposed, which will allow this training format to be fully implemented. The digital environment covers such components as "creating a learner profile", "defining competencies", "creating programs and training using adapted content". This block of components requires information technology support with an automated system for selecting content, taking into account the personal characteristics of students.

Based on fuzzy sets for assessing the quality of knowledge of students in groups, we define one of the criteria—a multi-criteria student profile, which will be used in the implementation when creating a student profile. To create a student profile, not only the quality of knowledge in groups will be used, but also the current academic performance, choice of subjects (in depth), language competencies, participation in competitions and projects of each student.

In the proposed information technology, the student profile contains 2 blocks of data: a basic profile and a special profile. The special profile data is changeable, and after completing the selected course, it is adjusted for the subsequent formation of a package of courses based on the changed input data. The determination of competencies for the formation of training programs is carried out on the basis of a comparative analysis of world models of competencies, identifying the correspondence of a set of competencies to the current educational programs of schools and mathematical processing of expert assessments. Drawing up adapted training content involves developing a system for adapting program content, which consists of 4 stages: the preparatory stage, the stage of automatic selection of courses, the training stage, the evaluation and adjustment stage. Based on the automated selection of a course package, the learning process transforms from a static and linear process into a dynamically adaptable process. In an active school environment, "development of competencies" and "control of knowledge" are directly carried out, which involves conducting practical and laboratory work, active forms of activity, and formative and summative assessment of students' knowledge. Such integration will make it possible to complete training along an individual path and will not contradict the current forms of organization of training in Kazakhstan. The next stage: the development of appropriate models and algorithms that will be taken as the basis for the architecture of the software implementation of the educational platform for

differentiated learning. The final stage is the introduction of the software product into the educational process of schools, monitoring and evaluating effectiveness through testing in an experimental mode. And, as a result, there is a systematic transition to a differentiated learning format with the support of information technology.

V. CONCLUSION

Several ongoing challenges, including establishing a digital learning setting in schools, shaping students' digital skills, crafting personalized learning paths within the digital school landscape, and advancing information technologies, models, and algorithms for tailoring lessons to individual student characteristics, have spurred a series of initiatives and actions. The use of fuzzy logic and methods of decision theory and statistical information processing together formed the basis for the study of these issues. Addressing the challenge of creating information technologies to identify personalized student paths, supporting individual and small-group learning, with a specific emphasis on enhancing digital competencies, aims to elevate the quality and effectiveness of the educational system in schools within the Republic of Kazakhstan. The article also presents a conceptual model for the implementation of differentiated learning and a methodology for using fuzzy set theory to assess quality. This approach is different in that it allows you to deeply analyze the problem. In our study, this method was used to develop a conceptual model (for assessing the quality of small group education) of the implementation of differentiated instruction based on the results of the analysis phase. Results of the stakeholder survey; The construction of a "problem tree" study made it possible to identify the main factors contributing to the implementation of differentiated learning and to build a conceptual model of its implementation with the support of information technology. The information technology being developed contains a system for automated selection of content based on student profile data.

During the study, it was determined that the organization of a differentiated learning process that meets the needs and capabilities of the student and the demands of modern society can be effective with the support of information technology. These technologies make it possible to develop the necessary competencies through the construction of automated individual learning paths. According to the method of assessing the quality of knowledge, based on the theory of fuzzy sets, one of the criteria for multi-criteria trajectories of students is identified on the basis of paired comparison matrices. Which made it possible to build a conceptual model for the implementation of differentiated learning, a structural model of the student's profile was built, including basic and special profiles. The developed model can be scaled, which will increase the number of criteria for assessing the chair profile. The complex of the listed models will allow us to develop a universal algorithm for creating a program that allows you to master existing competencies and takes into account the personal characteristics of the student. The above models and algorithms are taken as the basis for the

software architecture of the educational platform for differentiated learning. Information technologies will make it possible to implement a new model of differentiated education aimed at improving the quality of the educational process in schools of the Republic of Kazakhstan.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

A.M. Bektenova conducted the research, analyzed the data, and wrote the article. A.M. Bektenova and O. Sadykanova collected and pre-processed the data. N. Denisova and I. A. Demina analyzed and improved proposed an approach and reviewed the document. All authors approved the final version.

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