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ONTOLOGICAL MODELING OF THE TEACHER TRAINING PROCESS WITH ELEMENTS OF STEM EDUCATION

STEM-БІЛІМ БЕРУ ЭЛЕМЕНТТЕРІ БАР ОҚЫТУШЫЛАРДЫҢ БІЛІКТІЛІГІН АРТТЫРУ ПРОЦЕСІН ОНТОЛОГИЯЛЫҚ МОДЕЛЬДЕУ

ОНТОЛОГИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССА ПОВЫШЕНИЯ КВАЛИФИКАЦИИ ПРЕПОДАВАТЕЛЕЙ С ЭЛЕМЕНТАМИ STEM-ОБРАЗОВАНИЯ

Abstract. *The article discusses the construction of an "Ontological model of the teacher training process with the integration of STEM education." The scope of ontological modeling of the teacher training process with elements of STEM education is determined by several factors.*

Firstly, in recent years, attention to STEM education (science, technology, engineering and mathematics) has been increasing around the world, as these areas of knowledge are key to the development of innovation and economics. Secondly, the development of information and communication technologies leads to the emergence of new teaching methods and educational models. Thirdly, the existence of an ontological model of the teacher training process with elements of STEM education can significantly facilitate the creation and implementation of individual educational programs.

The implementation of the results of the study "Ontological model of the teacher training process with the integration of STEM education" in educational institutions and universities of the Republic of Kazakhstan will provide online support for the educational process, as well as organize collaboration and communication between students and teachers.

The use of ontological engineering and the STEAM approach in the professional development of teachers will help in the development of curricula, assessment of their competencies, improvement of the quality of education and personalization of training.

Keywords: *knowledge, ontology, ontological engineering, knowledge base, ontological model.*

Аңдатпа. *Мақалада «STEM-білім беру интеграциясы бар оқытушылардың біліктілігін арттыру процесінің онтологиялық моделі» құрылысын қарастырады. STEM-білім беру элементтері бар оқытушылардың біліктілігін арттыру процесін онтологиялық модельдеу салалары бірнеше факторларға байланысты.*

Біріншіден, соңғы жылдары бүкіл әлемде STEM біліміне (ғылым, технология, инженерия және математика) назар аударылуда, өйткені бұл білім салалары инновация мен экономиканы дамытудың кілті

болып табылады. Екіншіден, ақпараттық және коммуникациялық технологиялардың дамуы оқытудың жаңа әдістері мен білім беру модельдерінің пайда болуына әкеледі. Үшіншіден, STEM-білім беру элементтері бар оқытушылардың біліктілігін арттыру процесінің онтологиялық моделінің болуы жеке білім беру бағдарламаларын құруды және іске асыруды едәуір жеңілдетеді.

Қазақстан Республикасының Білім беру ұйымдары мен жоғары оқу орындарында «STEM-білім берудің интеграциясы бар оқытушылардың біліктілігін арттыру процесінің онтологиялық моделі» зерттеу нәтижелерін қолдану білім беру процесіне онлайн-қолдауды, оқытушылармен білім алушының бірлескен жұмысы мен қарым-қатынасын ұйымдастыруды қамтамасыз етеді.

Оқытушылардың біліктілігін арттыру процесінде онтологиялық инжиниринг пен STEAM-тәсілді қолдану оқу бағдарламаларын әзірлеуге, оқытушылардың құзыреттерін бағалауға, білім сапасын арттыруға және оқытушылардың біліктілігін арттыру кезінде оқытуды жекелендіруге көмектеседі.

Түйін сөздер: *білім, онтология, онтологиялық инженерия, білім базасы, онтологиялық модель.*

Аннотация. *В статье рассматривается построение «Онтологическая модель процесса повышения квалификации преподавателей с интеграцией STEM-образования». Сферы онтологического моделирования процесса повышения квалификации преподавателей с элементами STEM-образования обусловлена несколькими факторами.*

Во-первых, в последние годы внимание к STEM-образованию (наука, технологии, инженерия и математика) увеличивается по всему миру, так как эти области знаний являются ключевыми для развития инноваций и экономики. Во-вторых, развитие информационных и коммуникационных технологий приводит к появлению новых методов обучения и моделей образования. В-третьих, существование онтологической модели процесса повышения квалификации преподавателей с элементами STEM-образования может значительно облегчить создание и реализацию индивидуальных образовательных программ.

Внедрение результатов исследования «Онтологическая модель процесса повышения квалификации преподавателей с интеграцией STEM-образования» в образовательные учреждения и вузы Республики Казахстан позволит обеспечить онлайн-поддержку учебного процесса, а также организовать совместную работу и общение обучающихся с преподавателями.

Использование онтологического инжиниринга и STEAM-подхода в повышении квалификации преподавателей поможет в разработке учебных программ, оценке их компетенций, улучшении качества образования и персонализации обучения.

Ключевые слова: *знание, онтология, онтологический инжиниринг, база знаний, онтологическая модель.*

Introduction. In the State Program for the Development of Education and Science of the Republic of Kazakhstan for 2020-2025 and in the program “Digital Kazakhstan” President Kassym-Jomart Tokayev focuses on the importance of digitalization of all spheres of life, as well as on the continuous education of students and improving the professional competence of teachers.

The Law on Education in the Republic of Kazakhstan, the national educational standard and the Education Development program for 2022-2025 define new targets for the country's educational system aimed at meeting the challenges of the 21st century, the requirements of international law, innovative economic development and modern needs of society. One of the key areas is the development of human individuality and competitiveness in an ever-changing world. In the modern world, the problem of the formation of a creative personality capable of independently replenishing knowledge, extracting benefits, and realizing their own goals and values in life is very relevant. This can be achieved through the cognitive-research activities of students in various key academic areas such as science, mathematics, technology, and engineering. For this purpose, it is planned to introduce STEAM elements into the educational program, aimed at developing new technologies, scientific innovations, and mathematical modeling.

STEAM education is the bridge that connects learning and careers. The need for innovators in education in the modern world leads to a shift in existing priorities. It is necessary to develop critical thinking skills, digital skills that are important for innovation, and find ways to develop them.

The relevance of research in the field of ontological modeling of the process of teacher training

with elements of STEM education is due to several factors. Firstly, in recent years there has been a worldwide trend towards increasing attention to STEAM education (science, technology, engineering and mathematics), as these disciplines play a key role in the development of innovation and economics. Secondly, the development of information and communication technologies creates new teaching methods and educational models.Third, the existence of an ontological model for the process of teacher professional development with elements of STEM education can significantly facilitate the creation and implementation of individual educational programs.

Object of study is the process of improving the teacher's qualifications. Subject of research are concepts, connections and properties associated with the process of professional development of teachers with elements of STEM education are crucial. It is advisable to put forward a research hypothesis that the use of ontological modeling in the process of advanced training of teachers with elements of STEM education will effectively structure and organize the knowledge and skills necessary for successful teaching of science, technology, engineering and mathematics subjects, which will lead to improved quality of education and increasing the professional competence of teachers.

Objective of the project: creating a formal model that allows you to describe and structure the knowledge, concepts and connections associated with the process of professional development of teachers in the field of STEM education.

Research objectives:

- research of world experience in the field STEAM approach and ontological engineering in the process of advanced training of teachers;
- development of an information model of the ontological knowledge base of the process of advanced training of teachers with elements of STEM education;
- performing a semantic description of knowledge about the subject area using ontological engineering methods;
- building an ontological model of the process of advanced training of teachers with elements of STEM education.

Ontological modeling allows you to create a formal knowledge structure that reflects the connections between concepts and the subject area, which in turn allows you to more effectively organize and standardize the process of training and advanced training for teachers, i.e. process of teacher training.

Scientific novelty: is to use ontological modeling methods for the process of advanced training of teachers with elements of STEM education, providing the opportunity to develop new competencies among teachers, as well as methods of intellectual knowledge processing based on the use of descriptive logic, statistical classification methods, Text Mining and Semantic Web technologies.

Practical significance: lies in the possibility of creating an ontological modeling system for the process of advanced training of teachers with elements of STEM education, providing the opportunity to develop new competencies among teachers, the learning process implementation of the STEAM approach in educational institutions and authorized bodies of education and science of the Republic of Kazakhstan.

Literature review. STEAM education is a mechanism that provides a link between learning and professional careers. In the modern world, there is a need for innovators in education, which leads to a change in priorities. One of the important areas of student activity is scientific and technical creativity, and one of the most innovative areas in this area is educational robotics, including the study of the fundamentals of technology, information modeling, programming and information technology.

Developing critical thinking and digital skills, which are essential for innovation, is a must.

Developments in the application of robotics, artificial intelligence, unmanned vehicles, e-commerce and big data processing technologies are proving important.

STEAM education offers an integrated approach to solving urgent problems, which is based on the interaction of various fields such as natural sciences, engineering, mathematics, digital technologies, as well as the study of networks, blockchain and foresight. The education system is influenced by the digital revolution and the IV technological revolution, which combines several "exponential technologies" such as artificial intelligence, biotechnology and nanomaterials. As a result, significant changes are needed in data science, artificial intelligence, robotics, and nanomaterials curricula.

Future jobs in the technology sectors will be related to artificial intelligence, machine learning, robotics, nanotechnology and 3D printing. New forms of education associated with the IV technological Revolution cover the development of new technologies and emphasize the importance of educational robotics as a means of preparing students for innovative technical activities. Attention is also focused on the formation of students' competencies, such as solving complex problems, critical thinking, creativity, effective teamwork, leadership and emotional intelligence, which is achieved through project activities.

Modern artificial intelligence and programming tools (deep neural networks of artificial intelligence) make it possible to solve complex problems in the field of robotics. Aimed at creating and analyzing algorithms, artificial intelligence tools are computer programs that provide a machine with its own intelligence and behavior. Artificial intelligence provides robots with computer vision capabilities, allowing them to navigate, perceive, and respond appropriately. Machine learning (as a part of programming) is how robots learn to perform tasks from humans.

Although the term "knowledge management" originated in the 90s of the XX century, the issues of developing and implementing knowledge management systems at the basic level of infrastructure are still relevant and extremely important for involving more participants in the knowledge transfer process. One of the ways to solve this problem is to create an ontological model of the teacher training process using the STEAM approach.

Knowledge is a key resource for organizations. Therefore, they need to use and manage their existing knowledge effectively. In this regard, the importance of knowledge management and transfer becomes obvious.

Currently, ontological knowledge bases are gaining the greatest interest, since they have a significant advantage over traditionally used relational databases. The ontological approach to the development of competency models is considered in (Davydenko, 2016; Bova, 2021; Kalimoldaev et al., 2015; Sutaphan et al., 2019; Hassan, et al., 2021). The STEAM approach to the educational process is reflected in works (Shahali et al., 2017; Ritz et al., 2015; Ahmadi et al., 2014).

ApproachThe works of foreign scientists are devoted to ontological engineering (Sharef et al., 2017; Alaa et al., 2021; Reyes-Peña et al., 2019).

Ontological modeling of the process of advanced training of teachers with elements of STEM education is of practical importance in several aspects:

1. Curriculum development: Ontological modeling allows us to understand what competencies teachers need to successfully implement STEM education. Based on this information, appropriate training programs can be developed, where sufficient attention will be paid to the development of the necessary competencies.

2. Assessing teacher competencies: the ontology model can be used to assess teacher competencies. Based on the model, it is possible to determine which competencies the teacher already has and which ones need to be developed. This allows a more informed competency development plan to be made and areas where additional training is needed.

3. Improving the quality of education: ontological modeling helps to identify shortcomings in

the educational system and suggest ways to eliminate them. The analysis of the model makes it possible to determine which competencies of teachers are insufficiently developed, and how this may affect the quality of education. Based on these data, measures can be developed to improve the overall quality of education.

4. Personalization of learning: The ontological model provides an individual assessment of the competencies of each teacher. Based on this information, you can create personalized training programs and recommend special courses to develop the necessary competencies.

Materials and methods. Methods for solving scientific research problems: include analysis of existing approaches to ontological modeling, conducting experiments and research, development and testing of an ontological model, as well as its use in the process of teacher training using elements of STEM education, methods of data collection and analysis, as well as conducting surveys and interviews with teachers and educational specialists.

The methodological and theoretical basis of the project consists of methods and models of discriminatory logics, which logics allow to describe the axioms and facts of the subject area of a distributed knowledge base. The technological basis of the work consists of methods for designing distributed information systems, distributed search algorithms and inference engines. To implement the search, the principles of Text Mining and Semantic Web are used.

The research tasks were solved using the project method and ontological analysis, an object-oriented approach to software development, as well as optimization methods and mathematical and computer modeling.

Now there are professions related to technology at the intersection of natural sciences. Improving the quality of training is possible through the use of the STEAM approach. The introduction of STEAM education will facilitate the adaptation of students to higher education and their future profession, and increasing their STEAM literacy will ensure demand and competitiveness in the labor market.

Ontologies are created using the Protégé 4.3 Ontology Editor, which is a free, open and cross-platform knowledge base development tool. The editor can be accessed at http://protege.stanford.edu. The knowledge base level in the structure of a distributed information system is presented in OWL/XML and RDF/XML formats.

The principles of scientific ethics, including ethical management procedures, will be observed during the implementation of the project. This implies maintaining high standards of intellectual integrity and preventing falsification of scientific data, plagiarism, false co-authorship and the use of data obtained in the course of collective research, without the consent of other participants.The interdisciplinary approach in this project allows us to combine knowledge, methods and tools from different fields to create a comprehensive and effective approach to the development of teacher competencies using elements of STEM education.

Results and discussion. To build an ontological modeling of the process of advanced training for teachers with elements of STEM education, you can use the following software:

1. Protege (https://protege.stanford.edu/) is a powerful and flexible platform for creating ontologies. It allows you to define concepts, connections and attributes that describe the process of professional development of teachers, as well as use various standards and languages to formalize the ontology.

2. RDFox (https://www.oxfordsemantic.tech/rfox) is a high-performance system for working with RDF (Resource Description Framework) and SPARQL (SPARQL Protocol and RDF Query Language), which are standards for representing knowledge in web semantics. Using RDFox, you can store and process data describing teacher competencies and their development.

3. OWLAPI (https://github.com/owlcs/owlapi) is a Java API for working with ontologies formalized in OWL (Web Ontology Language). With this library you can create, modify and analyze ontologies using the functionality of the OWL language.

4. Protégé Graph Editor (https://github.com/ncbo/protege-graph) is an extension for Protege that allows you to visualize ontologies as a graph. This can help in understanding the structure and connections between teacher competencies, as well as in conducting competency network analyses.

5. JENA (https://jena.apache.org/) is a Java framework for working with data related to semantic web technologies. It includes tools for storing, querying and processing data describing teacher competencies, and provides convenient APIs for working with data in RDF and SPARQL format.

These are just some examples of software that can be used in the project "Ontological modeling of the process of advanced training of teachers with elements of STEM education." The choice of specific tools depends on the requirements and preferences of the project team.

Research methods are based on knowledge management, ontological engineering, service-oriented programming, description logic and methods of knowledge inference. They also rely on the theory of sets and graphs, the theory of syntactic analysis and the concept of creating ontologies (Bazarova et al., 2024; Bazarova et al., 2023).

The main goals of ontology development include improving the integration of information for management decision-making, improving the efficiency of data retrieval and providing the possibility of joint knowledge processing based on a single semantic description of the subject area.

When creating information systems, the ontological model serves as an extensible and customizable knowledge system. In the course of the study, an ontological approach was chosen to form a unified educational environment that takes into account the requirements of the labor market both at the national and international levels.

Currently, the most common language for representing ontologies is OWL (Web Ontology Language), which extends the capabilities of XML, RDF and RDF Schema (Glimm et al., 2014; Ghanim et al., 2021; Abdelghany et al., 2019). An ontological model of the process of advanced training of teachers with the integration of STEM education has been constructed. The hierarchy of classes of this ontology is presented in Figure 1.

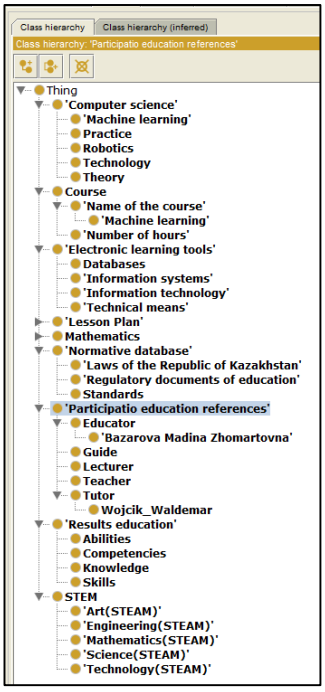

Figure 1. Hierarchy of the ontological model of the teacher training process

Note – compiled by the author (Bazarova, 2024)

As an example, consider the advanced training course “Machine Learning”. Figure 2 shows SubClass - Course_name, Members (individuals) - course topics.

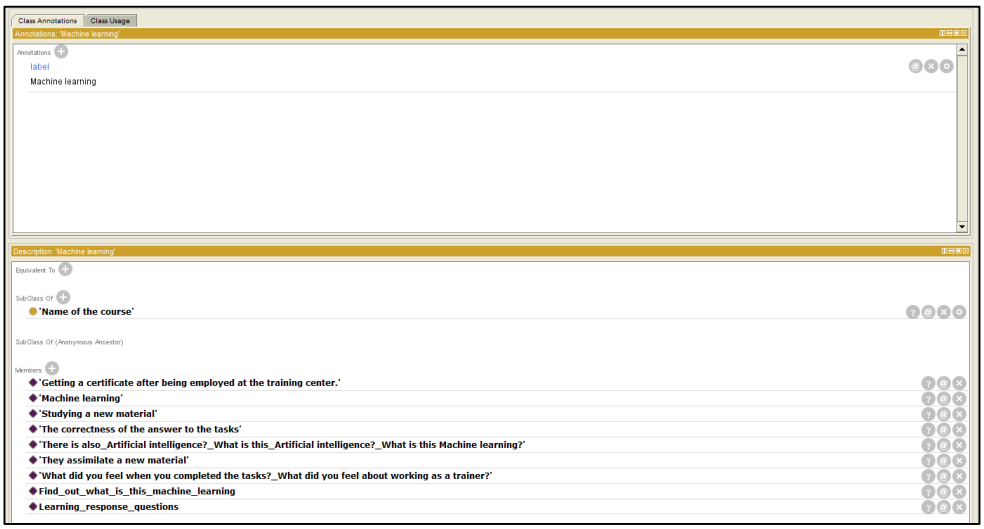

Figure 2. Advanced training course “Machine Learning”

Note – compiled by the author (Bazarova, 2024)

To create a connection between “Tutor” and “Course”, we create a property of the object has_leads_the_course (teaches the course), as shown in Figure 3.

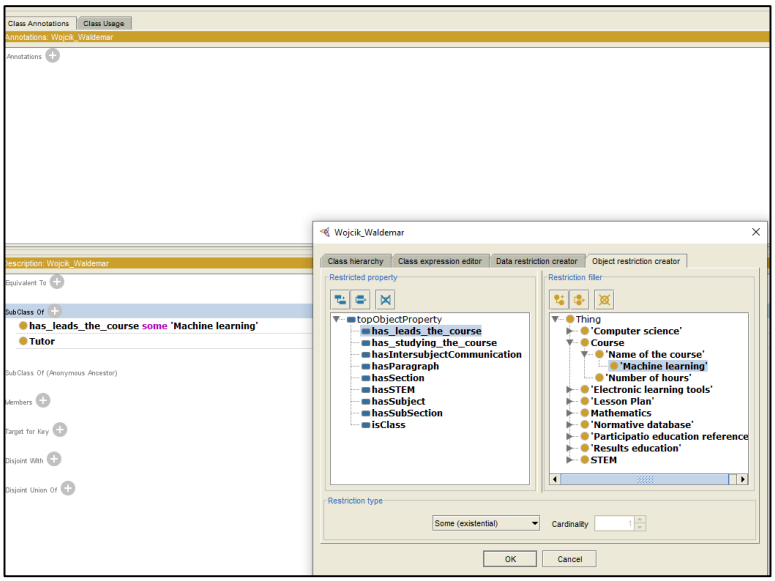

Figure 3. Has_leads_the_course object property

Note – compiled by the author (Bazarova, 2024)

Figure 4 shows the connections and relationships of classes and individuals of the ontology

for the courseadvanced training “Machine learning”. The has_leads_the_course object property is shown in red.

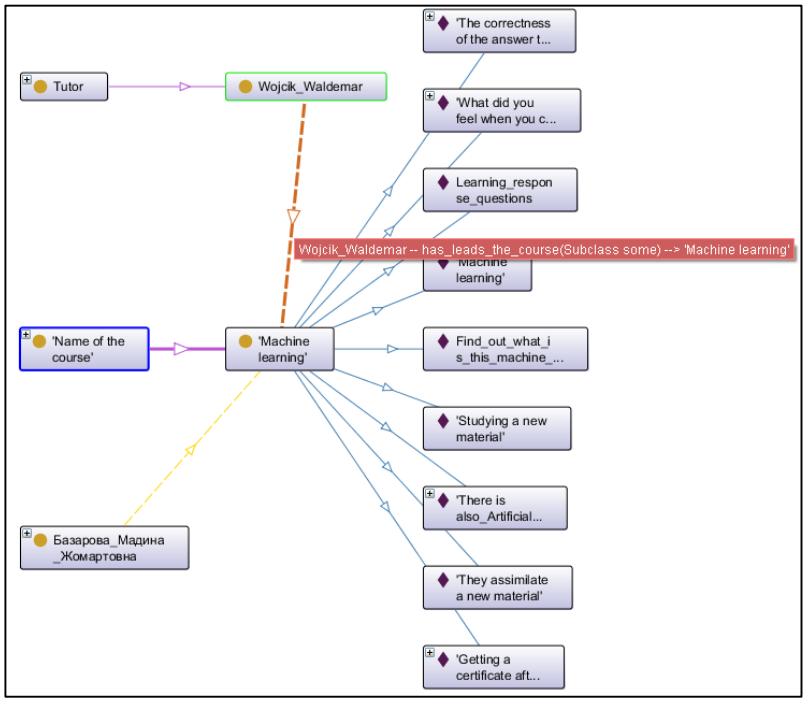

Figure 4. Fragment of the ontology displaying the Tutor-Course relationship

Note – compiled by the author (Bazarova, 2024)

To create a connection between “Teacher”, taking a course and “Course”, we create a property of the object has_studying_the_course (studying the course), as shown in Figure 5.

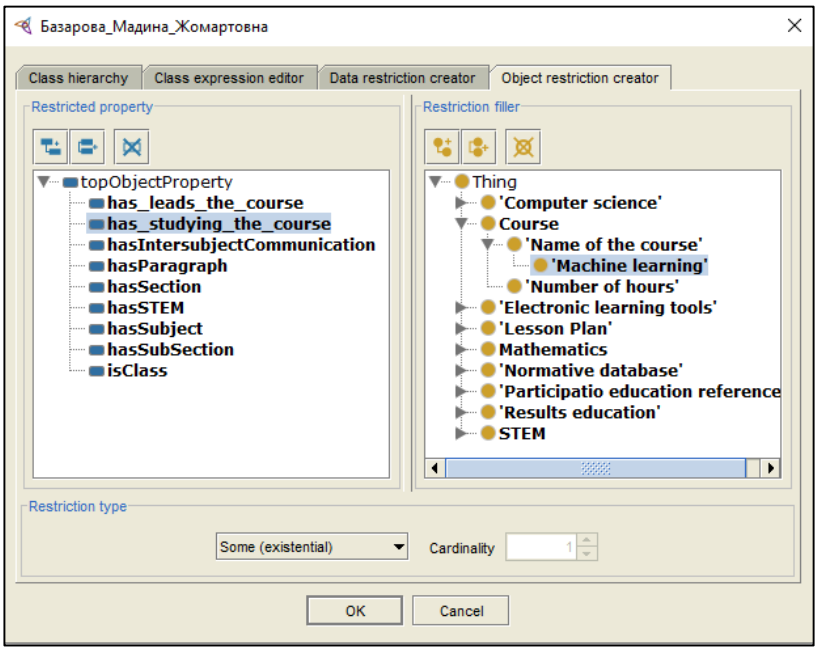

Figure 5. Property of the object has_studying_the_course
Note – compiled by the author (Bazarova, 2024)

Figure 6 shows the connections and relationships of classes and individuals of the ontology for the courseadvanced training "Machine learning". The object property has_studying_the_course is shown in red.

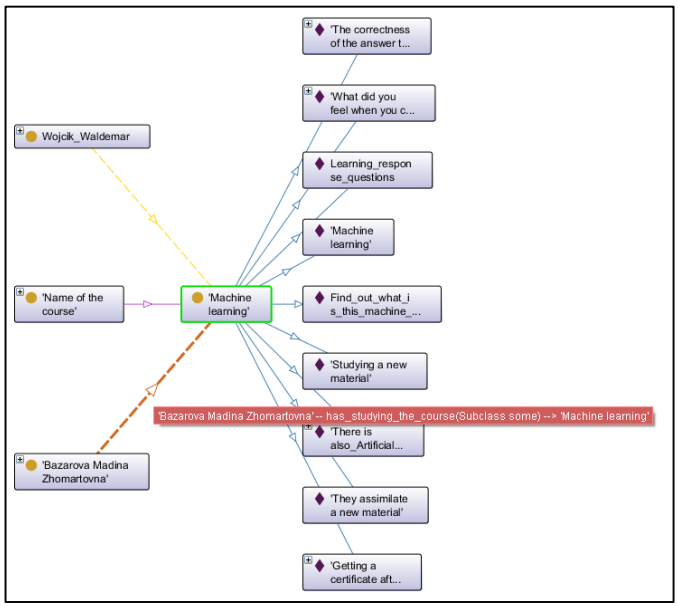

Figure 6. Fragment of the ontology displaying the teacher-course relationship
Note – compiled by the author (Bazarova, 2024)

A fragment of the ontological model of the process of advanced training of teachers with the integration of STEM education, shown using the Ontograf visualization tool is presented in Figure 7.

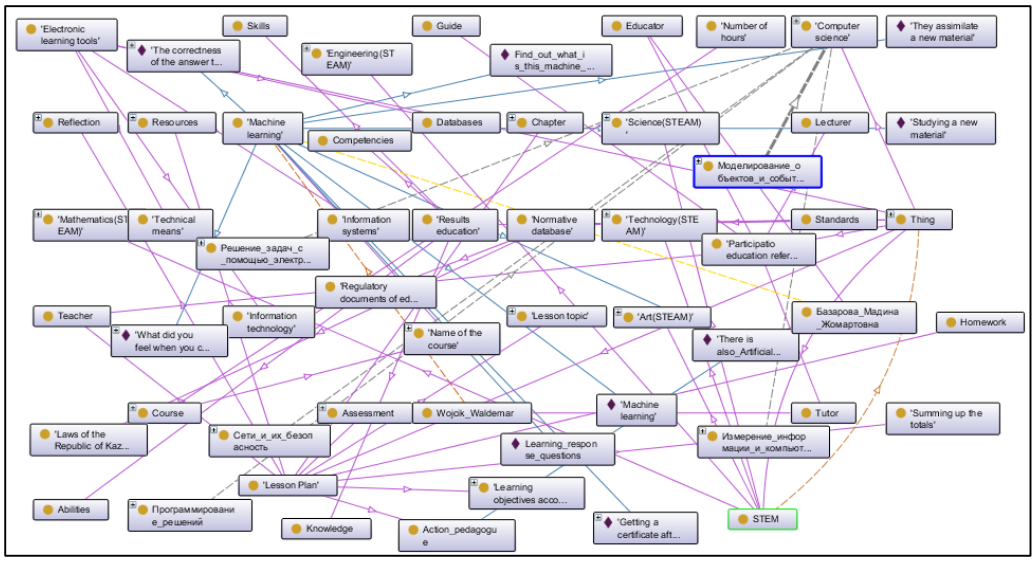

Figure 7. Fragment of the ontological model of the process of advanced training

of teachers with the integration of STEM education

Note – compiled by the author (Bazarova, 2024)

Conclusion. The implementation of the results of the research "Ontological model of the teacher training process with the integration of STEM education" in educational institutions and universities of the Republic of Kazakhstan will provide online support for the educational process and organize collaboration and communication between students and teachers.

The use of ontological engineering and the STEAM approach in the process of teacher training contributes to the development of educational programs, assessment of their competencies, improvement of the quality of education and personalization of learning. This approach will make it possible to refine and apply data from the ontological model in the process of teacher training.

Filling out the knowledge base helps to identify the relationships between professional development programs. The use of ontological engineering methods can improve the quality of pedagogical education through the semantic description of knowledge in the subject area and the introduction of interdisciplinary and STEM approaches into the educational process.

Conflict of interest. The authors declare that there is no conflict of interest.

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