Ontological Approach in Modern Educational Processes

Kostiantyn Tkachenko[1, 2], Olha Tkachenko[2, 3], Oleksandr Tkachenko[2], Nataliia Mazur[3], and Iryna Mashkina[3]

[1] *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute," 37 Beresteyskyi ave., Kyiv, 03056, Ukraine*
[2] *State University of Infrastructure and Technologies, 9 Kirillivska str., Kyiv, 04071, Ukraine*
[3] *Borys Grinchenko Kyiv Metropolitan University, 18/2 Bulvarno-Kudryavska str., Kyiv, 04053, Ukraine*

Abstract

It is proposed to use ontological modeling in modern learning processes (directly providing educational content to students, organizing educational processes, managing student knowledge control processes, etc.). The proposed ontological approach determines the recording and structuring of knowledge common to the subject area under consideration. This allows you to reuse ontological models built for individual academic disciplines, and individual educational processes as the basis of a unified knowledge model, which ensures logical consistency between individual ontologies when combined to organize and manage educational processes (including when developing a training course with a wide range of topics and tasks). Using an ontological approach is a very effective way to design intelligent learning systems. The constructed individual ontological models (by topic, training course, etc.) contribute to the design of a unified information learning environment in which the efficiency of all educational processes is increased. The proposed approach allows us to develop an infological model of any learning system (informational or intellectual), which fully reflects the pragmatics of the subject area being studied.

Keywords

Ontology, ontological modeling, ontological approach, educational process, educational content.

1. Introduction

Modern management processes are associated with the processing of large information flows. Widespread and comprehensive computerization and digitalization in various subject areas, for example, such as:

- Society.
- Public administration.
- Economy.
- Production.
- Science.
- Education system.

Expands the information space of life in these subject areas and complicates the processes of making relevant decisions [1–2].

As a result, a situation arises when:

- On the one hand, there is a lack of necessary knowledge for the full functioning and management of processes in the subject area under consideration.
- On the other hand, there is a huge amount of information available.

All this makes information processing a big problem for generating management decisions in all areas of management, including in the management of educational processes [3–7].

Ontology is linked by the names of entities and formal axioms that limit the understanding and correct use of these terms [8, 9].

Ontologies can be represented by the following formula [8–10]:

$$O = <X, R, F>,$$

CPITS-2024: Cybersecurity Providing in Information and Telecommunication Systems, February 28, 2024, Kyiv, Ukraine
EMAIL tkachenko.kostyantyn@gmail.com (K. Tkachenko); oitkachen@gmail.com (O. Tkachenko); aatokg@gmail.com (O. Tkachenko); n.mazur@kubg.edu.ua (N. Mazur); i.mashkina@ kubg.edu.ua (I. Mashkina)
ORCID: 0000-0003-0549-3396 (K. Tkachenko); 0000-0003-1800-618X (O. Tkachenko); 0000-0001-6911-2770 (O. Tkachenko); 0000-0001-7671-8287 (N. Mazur); 0000-0003-0667-5749 (I. Mashkina)

where *X* is a set of concepts (elements, terms) of the subject area, which is represented by the ontology *O*.

R is the set between the concepts of the subject area under consideration.

F is a set of interpretation (axiomatization) functions defined on concepts and/or relations of the ontology *O*.

Thus, ontology can be considered as a certain philosophical concept of a digital representation of the reality of the corresponding subject area (in our case, this is the education system in general and/or the State University of Infrastructure and Technology (SUIT) in particular) or knowledge [11].

Among the most common definitions, ontology is understood as a specification of the conceptualization of a representation of a subject area or some artifact consisting of a specific vocabulary for describing the specific reality of a particular subject area [12, 13].

To build ontologies, it is necessary to represent the knowledge of the selected subject area in such a way that it is, in particular [11, 14, 15]:

- Easy to read/process/use/modify with an appropriate computer program.
- Internally consistent.
- Complete.
- Capable of repeated use in different contexts of one or more related subject areas.
- Capable of using existing representations (models, dictionaries, thesauri, etc.) in describing the selected subject area.

That is why it is advisable to use ontologies to reduce terminological and conceptual ambiguity, for example:

- When in different subject areas different names correspond to the same concepts.
- When in different subject areas different concepts are understood under the same name (or these concepts have different semantics).
- When one concept has several synonyms).

Such ambiguity, arising in the education system, can lead, for example, to such negative consequences as:

- Incorrect interpretation of documentation (in particular, in university document management systems).
- Incorrect interpretation of documentation by individual organizations of the country's education system.
- Misinterpretation of documentation by individuals (for example, when using different terminology for the same subject area).
- Misinterpretation of training content (in particular, in information training systems).
- Incorrect interpretation by teachers of trainees' (students') answers.
- Incorrect interpretation of the responses of trainees (students) provided for control in the corresponding information training system that supports this or that online course.

The ontological approach is a basic means of adapting the education system to the growth in volumes of knowledge (data and information) and the urgent need for their formalization and structuring.

Ontologies have long been used in informational learning systems [16–18].

In particular, the following uses can be distinguished:

Modeling of specialty curricula (annual), suggesting, in particular:

- Presentation of the curriculum with a list of academic disciplines for each course of the specialty, the number of hours in each discipline, indicating the control point of the discipline (exam or test, course work, calculation, graphic work, modular test, etc.).
- Curriculum development.
- Analysis of the prospects for implementing the curriculum.
- Assessment of the implementation of the curriculum (by the university administration, teachers, and students).
- Determining the presence of mandatory core elements of the curriculum.
- Determining the compliance of the curriculum with the training schedule (for full-time and part-time forms of study).
- Connection of the elements of the curriculum with the educational program specialty (its goals, objectives, results of studying the academic disciplines of the curriculum, with the achieved competencies and other elements).

Modeling of the academic discipline program, which involves, in particular:

- Presentation of the training program (work program and corresponding training program).
- Development of a program plan (both the work program and the corresponding curriculum).
- Analysis of the prospects for its implementation (determination of the necessary competencies of the teaching staff providing the teaching of this academic discipline, determination of the necessary material, technical, and software necessary for high-quality teaching of this academic discipline).
- Assessment of the implementation of the academic discipline program.
- Determining the presence of mandatory basic elements of the academic discipline program (working with stakeholders, attracting representatives of science, business, production, education, etc. as experts).
- Connection of these elements with the objectives and results of teaching the academic discipline and with other elements of the system of training specialists at the university.

Management of the academic discipline program, providing, in particular:

- Implementation of management at the stages of the educational process (intermediate control and/or final control).
- Reporting activities (preparation and implementation of these activities).
- Issuing grades (intermediate and final).
- Monitoring compliance with the process of assessing students' knowledge during intermediate and/or final control).
- Receiving feedback (both from teachers and students).

Description of the subject area of the academic discipline, providing, in particular:

- Ontology of a certain subject area (the discipline being studied and related disciplines to provide a holistic view of the place of the discipline being studied in the educational program of the specialty).
- Construction of an ontology of tasks and learning goals by the curriculum of the discipline.

Assessment of students' mastery of data, including, in particular:

- Analysis of individual and group progress of students.
- Analysis of the obtained learning results (for example, competency-based).

The use of ontologies is advisable, in particular, for:

- Personalization of learning aspects, such as learning processes (organization, management, control, etc.).
- Personalization of the learning process itself (providing educational content).
- Personalization of the training courses.
- Overcoming the heterogeneity and difficulty of processing large amounts of data (including information taken from the Internet).

The relevance of using the ontological approach both directly in the learning process and in learning management processes is determined, in particular, by:

- The need to transform tacit knowledge into explicit knowledge (for example, in such subject areas as "education," "education system," "educational process," "participants in the educational process," "the subject of a separate course," etc.).
- Improvement of educational processes (including methodological, and technological).
- Digitalization and intellectualization of educational processes (using, for example, artificial intelligence systems, ontological approach, neural networks, etc.).
- Growth in the volume of information and the need to ensure its cybersecurity and protection (using, for example, modern methods of encoding and protecting information).
- The need to store large volumes of information, ensuring its preliminary compression.
- Increasing the importance of the quality content of academic disciplines.

The problem of preserving and accumulating intellectual capital (personnel, software, etc.).

2. Ontological Modeling of Modern Learning

The use of ontologies in education assumes as, in particular, already discussed in [13, 19, 20]:

- Defining the boundaries, types, and structures of ontologies.
- Development of a methodology for creating ontologies of subject areas of training courses, and learning management processes.
- Development of a methodology for managing domain ontologies.
- Principles of using formal ontology and ontological engineering [16, 20, 21] for knowledge engineering in the real world of education.

When developing domain ontologies [22], it is advisable to use the Protege system [15, 23], which allows you to create an ontological model and visualize it in the form of a corresponding ontograph of the model [24, 25].

In our case, the subject area is the sphere of education, and educational processes, supported, in particular, by appropriate information learning systems with elements of intellectualization).

Ontograph G is specified

$G = <V, C, K, L, A_l>$,

where:

V is a set of nodes (primary elements, terms).

C is a set of connecting elements of the ontograph, each of which defines certain fragments of the ontograph.

K is the set of key vertices of the ontograph, each of which defines a certain class of equivalent elements of the ontograph ($K \subset V$).

L is the set of labels of elements of the ontograph, each of which specifies the certain base class of equivalent elements of the ontograph.

A_l is the set of incidence relations that are defined on the set of ontograph elements.

All incidence relationships are binary-oriented relationships.

The application of the ontological approach in education involves, in particular, research and development [26]:

- General methodology for the formation of an ontology of a certain subject area.
- General methodology for the formation of an ontology of a certain subject area using already existing ontologies of other subject areas.
- General methodology for using the ontology of a certain subject area in the formation of ontologies of other subject areas.
- Means of adapting the education system to the growth of knowledge.
- Structuring and formalization of subject areas.
- Languages for formal description of ontologies (similar to OWL language (Ontology Web Language) [27] and others [22, 28]).
- General knowledge base, using the language of ontologies, understandable to specialists in various related fields (for example, management, economics, art, etc., even when studying academic disciplines of specialties:
  - 121 “Software Engineering”
  - 122 “Computer Science”
  - 125 “Cybersecurity”
  - 124 “System analysis”.

The construction of ontological models is used in each of these types of learning.

However, the most appropriate need to introduce an ontological approach is manifested in problem-based, team-oriented, and competency-oriented types of training.

The use of such elements of teaching as control, feedback, and the application of new knowledge in the study of an academic discipline explains to some extent the complexity of managing both the teaching processes themselves and the processes of improving the teacher’s skills.

These types of training are most often implemented in the format of classes in which:

- There is an instant exchange of knowledge (between a teacher and a student, between students, or in the case of online learning—between an information learning system and students).
- Updating of the general knowledge base of training courses occurs constantly (for example, some educational content is updated daily, some—weekly, and some—when moving to a new topic (subtopic).

- The period (frequency) of updating the general knowledge base depends on the goals, and objectives of training, as well as on the level of knowledge acquired by students.
- There is an influence of the information context (due to both the subject area under consideration and related subject areas).
- The educational process is adapted and improved to the goals, and objectives of learning, as well as to the needs and interests of students.

When implementing a modern ontological approach to learning and learning management, events of different directions are combined, in particular:

- Differentiated learning events (based on differences in methods, techniques, technologies, levels, and volume of educational (training) content provided, the degree of influence of management influences on learning processes, etc.).
- Undifferentiated (homogeneous in structure) learning events (based on the commonality of methods, techniques, technologies, levels and volume of educational content provided, the degree of influence of management influences on learning processes, etc.).

The learning events discussed above are divided between the following main groups of participants in the learning process:

- Students.
- Lecturers.
- Developers of online courses.
- Administrator of the information training system.
- Employees of the dean's office and university administration.

The tasks set for students are differentiated. Such tasks include, in particular:

- Search and analysis of information from various sources.
- Checking the accuracy of the information received.
- Creation of new knowledge based on one's assumptions, supported by knowledge from existing reliable sources.
- Combination of research methods, etc.

The use of traditional methods and technologies of knowledge management in training, such as, for example:

- Lecturing.
- Providing students with educational material without taking into account their level of interest, goals for studying the material, etc.
- Giving examples without analyzing them in depth (for example, giving analogous examples and examples demonstrating the opposite results).
- Conducting tests (especially without analyzing the results).

These teaching methods (related to undifferentiated learning events and having a relatively homogeneous structure) are not focused on achieving learning goals (or are not fully focused on achieving such goals).

Such teaching methods have long ceased to be the only source of knowledge transfer in the modern information environment of the national education system.

Taking into account the growing volume of information, new modern (mostly differentiated) tools and ways of transmitting, applying, and creating knowledge should be used when interacting with students.

2.1. Creating an Ontological Model

Interaction with students involves, in particular:

- Their direct participation in the educational process:
  - attending lectures, and practical/laboratory/seminar classes.
  - completing practical/laboratory assignments.
  - preparation for discussion and/or presentation of one's position on the issues discussed at seminar classes.
  - performing individual/independent tasks.
- Preparation for the reporting event (exam, test, module test, defense of course work, etc.).
- Participation in the scientific activities of the university, which involves:
  - work in student scientific circles.
  - work on research topics of the faculty, and department.
  - participation in Olympiads (university, all-Ukrainian and international).

- publication of scientific articles.
- speaking at conferences.

When constructing an ontology of the university educational process, it is necessary to take into account the connection of this process with the field of science, which can be expressed in the form of the following chain:

<observation—experiment—measurement—description—classification—systematization>.

When building an ontological model, several requirements must be met:

- Formalization by uniform strictly defined principles.
- Use of a limited number of basic entities (concepts, terms, keywords, etc.).
- Completeness of the model representation of the subject area under consideration.
- Logical consistency of the entities of the subject area and the connections (relationships) between them.

In this case, the created ontological model can be distributed for use (in part or in full) for a wide range of educational disciplines of the above specialties.

This article discusses the use of the ontological method within the framework of constructing the "Preparation for the reporting event" stage in the discipline "Fundamentals of Software Engineering", which is:

- Compulsory for study in the specialty program 121 "Software Engineering" (bachelor's degree) SUIT (Kyiv).
- Selective program for study in the specialty 122 "Computer Science" (bachelor's degree) SUIT (Kyiv).

Within the framework of this discipline it is provided:

- Lecturing.
- Conducting practical classes.
- Intermediate activities for monitoring students' knowledge (defense of practical work, module tests, oral questioning, etc.).
- Execution and protection of individual assignments.
- Final knowledge monitoring activities (test and exam) to assess student performance.

Monitoring students' knowledge when performing practical and/or individual assignments includes:

- Obtaining information about the upcoming reporting event, basic requirements for work, methods of presenting results, and advice on completing the task.
- Completing the task.
- Preparation for defense and presentation of the results of the assignment.
- Open discussion of the presented work.
- Analysis of the advantages and disadvantages of the presented work.
- Evaluation of work by students and teachers.
- Concluding the presented work.

Experience in teaching this academic discipline has shown that students have difficulty perceiving knowledge that is abstract and not individualized (general recommendations, description of formal requirements, etc.).

In the process of completing assignments, many questions arise from students, which relate to the detailed elaboration of the presentation of the results of the assignment (its presentation).

The quality of work was assessed according to the following criteria:

- Originality of the idea (method, approach, algorithm, interface organization, etc.).
- Quality of practical (individual) assignment:
  - for theoretical tasks.
  - the depth of elaboration of the selected topic, and the quality and quantity of analyzed sources.
  - for practical tasks.
  - the quality of the model and/or developed software product).
- Logic in the presentation of the description of the completed practical (individual) task.

The application of knowledge in the learning process involves, in particular:

- Work with the best results in completing practical tasks:
  - sorting, selection, and analysis of the best results of practical tasks.
  - discussion and formation of templates for performing practical tasks.
  - sorting, selection, and analysis of the best results of individual tasks.

- discussion and formation of templates for completing individual tasks.

- Analysis of the advantages, inaccuracies, disadvantages, and typical errors of both the results of performing practical (individual) tasks and their presentation and defense.

The creation of new knowledge in the learning process involves, in particular:

- Analysis and discussion of the reasons that determined the advantages, inaccuracies, disadvantages, and typical errors of completed practical (individual) tasks.
- Discussion of group projects of students and the formation of new knowledge.

2.2. Building and Improving the Ontological Model

The developed ontological model for studying the discipline "Fundamentals of Software Engineering" has the form:

Lecturer
>Teaching tools
>>Knowledge transfer
Theory
Examples
>>Application of knowledge
Best practices
Lessons Learned
Examples of typical errors
>>Knowledge Creation
Analysis
Comparison
Discussion
Group discussions
>Skills
>>Competence
Education
Profile suitability
Practical experience
>>Expertise
Own experience
Colleagues' experience
>>Engagement
Low
Average
High
>Evaluation of teaching
>>Student Feedback
Teaching evaluation
Evaluation of educational content
Assessment of academic discipline
Free form
>>Student progress
Low
Average
High

Item
>Preparation
>>Regulations
Presentation duration
Presentation format
Required components
>>Theoretical recommendations
Presentation Format
Typical errors
>>Practical recommendations
Work examples
Presentation examples
Advice
>>Assessment
>>Evaluation criteria
Regulated
Unspoken
>>Reporting events
Intermediate control
Final control

Students
>Individuality
>>Cognition
>>Skills and abilities
Performance
>>Academic performance
Low
Average
High
>>Engagement
Low
Average
High

This shows the result of ontological modeling of the educational process at the level of the university faculty [11].

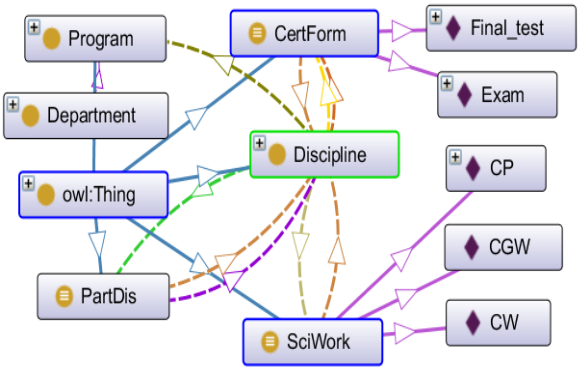

Figure 1: Part of the ontology graph is constructed by Protégé OntoGraf

Modeling student knowledge control. In addition to theoretical educational material, each academic course contains diagnostic material to control students' knowledge.

Operational control of knowledge is often performed using tests that are made up of a set of test items (questions).

Test items are clear and precise items from specific subject areas. It requires an unambiguous answer or the implementation of an appropriate algorithm of action.

The ontological model of teaching and monitoring students' knowledge provides for the use of prompts (information, help) either from the teacher or from the corresponding information-intellectual learning system [11, 26].

Within the framework of the conducted research, it can be noted that knowledge management is important for the implementation of an effective and optimal educational process.

This is because such management shows the positive dynamics in students' presentation of the results of completing their practical (individual) assignments.

In addition, analysis and discussion by students of the results of practical (individual) assignments contributes, in particular, to:

- Highlighting typical errors and omissions.
- Searching for solutions to problems that have arisen.
- Determining the advantages and disadvantages of the work submitted for defense.
- Comparing results with the best works.

The university focuses on knowledge (students, teachers, administration).

For this purpose, information is used (sometimes specially generated) that can be used by all participants in the learning processes.

The process of working with knowledge is managed by people who make appropriate decisions on the organization and management of the educational process at the university.

3. Conclusions

The ontological model was built for shared use and improvement by specialists in the subject area under consideration—the field of education (teachers, guarantors of educational programs, heads of departments, dean's offices, and institutes of SUIT, etc.).

The ontological model can be used when designing academic discipline programs, planning the structure of teaching sessions by a teacher, assessing teaching skills, and other similar tasks.

The use of an ontological approach can help eliminate the shortcomings of traditional teaching (for example, limited dialogue between students; stereotyped delivery of educational content, monotony and lack of opportunities for critical thinking on the part of students; and weak feedback).

The ontological approach can be used as a tool for improving teaching methods in the direction of systematicity and integration using the practical experience of the teacher.

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