ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ

әл-Фараби атындағы Қазақ ұлттық университетінің

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Казахский национальный
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N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
al-Farabi Kazakh National University

SERIES
PHYSICS AND INFORMATION TECHNOLOGY

2 (346)

APRIL – JUNE 2023

PUBLISHED SINCE JANUARY 1963

PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Физика және информатика сериясы».
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 14.02.2018 ж. берілген **No 16906-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *физика және ақпараттық коммуникациялық технологиялар сериясы.*
Қазіргі уақытта: *«ақпараттық технологиялар»бағыты бойынша ҚР БҒМ БҒСБК ұсынған журналдар тізіміне енді.*
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«Известия НАН РК. Серия физика и информатики».
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

Собственник: *Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).*

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **No 16906-Ж** выданное 14.02.2018 г.

Тематическая направленность: *серия физика и информационные коммуникационные технологии.*

В настоящее время: *вошел в список журналов, рекомендованных ККСОН МОН РК по направлению «информационные коммуникационные технологии».*

Периодичность: *4 раз в год.*

Тираж: *300 экземпляров.*

Адрес редакции: *050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19*
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News of the National Academy of Sciences of the Republic of Kazakhstan.
Series of physics and informatics.
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty). The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. 16906-Ж,** issued 14.02.2018
Thematic scope: *series physics and information technology.*
Currently: *included in the list of journals recommended by the CCSES MES RK in the direction of «information and communication technologies».*
Periodicity: *4 times a year.*
Circulation: *300 copies.*
Editorial address: *28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19*
http://www.physico-mathematical.kz/index.php/en/

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Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS OF THE NATIONAL ACADEMY OF SCIENCESOF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 2. Namber 346 (2023). 108–127
https://doi.org/10.32014/2023.2518-1726.188

UDC 28.23.25

© A.S. Omarbekova, A.E. Nazyrova*, N. Tasbolatuly, B.Sh. Razakhova, 2023
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ONTOLOGICAL MODEL OF AN INTELLIGENT E-LEARNING SYSTEM AND LEARNING OUTCOMES

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Abstract. This paper presents issues related to intelligent learning systems, ontology model, as well as the development of evaluation of the achieved learning outcomes. The purpose of this article is to investigate the ontology of intelligent learning systems, which is one of the important technologies in the semantic network. An analysis of sources on intelligent learning systems has been conducted. Issues related to the construction of intelligent systems, ITSS, e-learning and LMS have been considered. Nowadays, intelligent learning systems (ILS) are one of the most relevant technologies in the field of education. They allow you to create personalized learning materials and training programs that take into account the characteristics of each student and his or her needs. However, for ILSs to be as effective as possible, it is necessary to develop an ontology — a set of terms and concepts that define the relationship between them in a particular area of knowledge. The purpose of this article is to explore the ontology of intelligent learning systems, analyze sources on ILSs, and consider issues related to building intelligent systems, information technology in education (ITSS), e-learning, and LMSs. The article presents a study of the ILS ontology, which is one of the important technologies in the semantic network. The authors of the article describe the methods of developing an ontology for the ILS, which allows to take into account the characteristics of each student and his or her needs. Issues related to the construction of ILS s and assessment of learning outcomes are discussed, including an analysis of various ITSSs and their use in e-learning and LMSs. The article discusses the benefits of using ILSs in education. They allow students to receive individualized instruction and maximize their strengths, which contributes to deeper learning and improved academic performance. ILSs allow teachers to maximize their time and resources by creating personalized learning materials for each student.

Keywords: intelligent systems, ITSs, e-learning, LMS, intelligent assessment system of achieved learning outcomes

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ИНТЕЛЛЕКТУАЛДЫ ELEARNING ЖҮЙЕСІНІҢ ОНТОЛОГИЯЛЫҚ МОДЕЛІ ЖӘНЕ ОҚЫТУ НӘТИЖЕЛЕРІ

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Аннотация. Бұл мақалада интеллектуалды оқыту жүйелеріне, онтология моделіне, сондай-ақ қол жеткізілген оқу нәтижелерін бағалауды әзірлеуге қатысты сұрақтар берілген. Бұл мақаланың мақсаты семантикалық желідегі маңызды технологиялардың бірі болып табылатын интеллектуалды оқыту жүйелерінің онтологиясын зерттеу болып табылады. Зияткерлік оқыту жүйелері бойынша дереккөздерге талдау жүргізілді. Интеллектуалды жүйелерді, ITSS, eLearning және LMS құруға қатысты мәселелер қарастырылды. Қазіргі уақытта интеллектуалдық оқыту жүйелері білім беру саласындағы ең өзекті технологиялардың бірі болып табылады. Олар әр студенттердің ерекшеліктері мен қажеттіліктерін ескеретін жеке Оқу материалдары мен оқу бағдарламаларын жасауға мүмкіндік береді. Алайда, интеллектуалдық оқыту жүйелері мүмкіндігінше тиімді болуы үшін онтологияны – белгілі бір білім саласында олардың арасындағы байланысты анықтайтын терминдер мен ұғымдардың жиынтығын әзірлеу қажет. Бұл мақаланың мақсаты-интеллектуалдық оқыту жүйелерінің онтологиясын зерттеу, интеллектуалдық оқыту жүйелері бойынша дереккөздерге талдау жүргізу, сондай-ақ интеллектуалдық жүйелерді, білім берудегі ақпараттық технологияларды (ITSS),электрондық оқытуды және LMS құруға байланысты мәселелерді қарастыру. Мақалада семантикалық желідегі маңызды технологиялардың бірі болып табылатын интеллектуалдық оқыту жүйелері онтологиясын зерттеу ұсынылған. Мақала авторлары әр студенттердің ерекшеліктері мен қажеттіліктерін ескеруге мүмкіндік беретін интеллектуалдық оқыту жүйелері үшін онтологияны дамыту әдістерін сипаттайды. Интеллектуалдық оқыту жүйелері құруға және оқу нәтижелерін бағалауға байланысты мәселелер қарастырылады, соның ішінде әртүрлі itss-ке талдау және оларды eLearning және LMS-те пайдалану. Мақалада интеллектуалдық оқыту жүйелері білім беруде қолданудың артықшылықтары талқыланады. Олар студенттерге оқуға жеке көзқараспен қарауға және олардың күшті жақтарын барынша тиімді пайдалануға мүмкіндік береді, бұл материалды тереңірек игеруге және оқу үлгерімін арттыруға ықпал етеді. Интеллектуалдық оқыту жүйелері оқытушылардың әр оқушы үшін жеке оқу материалдарын жасау арқылы уақыт пен ресурстарды тиімді пайдалануға мүмкіндік береді.

Түйін сөздер: интеллектуалды жүйелер, ITSs, eLearning, LMS, қол жеткізілген оқу нәтижелерін бағалаудың интеллектуалды жүйесі

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ОНТОЛОГИЧЕСКАЯ МОДЕЛЬ ИНТЕЛЛЕКТУАЛЬНОЙ СИСТЕМЫ ЭЛЕКТРОННОГО ОБУЧЕНИЯ И РЕЗУЛЬТАТЫ ОБУЧЕНИЯ

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Аннотация. В данной статье представлены вопросы, связанные с интеллектуальными системами обучения, моделью онтологии, а также разработкой оценки достигнутых результатов обучения. Целью данной статьи является исследование онтологии интеллектуальных обучающих систем, которая является одной из важных технологий в семантической сети. Был проведен анализ источников по интеллектуальным системам обучения. Были рассмотрены вопросы, связанные с построением интеллектуальных систем, ITSS, электронного обучения и LMS. В настоящее время интеллектуальные системы обучения (ИСО) являются одной из самых актуальных технологий в сфере образования. Они позволяют создавать персонализированные учебные материалы и обучающие программы, учитывающие особенности каждого ученика и его потребности. Однако, для того чтобы ИСО были максимально эффективны, необходимо разрабатывать онтологию – совокупность терминов и понятий, которая определяет взаимосвязь между ними в конкретной области знаний. Цель данной статьи – исследовать онтологию интеллектуальных обучающих систем, провести анализ источников по ИСО, а также рассмотреть вопросы, связанные с построением интеллектуальных систем, информационных технологий в образовании (ITSS), электронного обучения и LMS. В статье представлено исследование онтологии ИСО, которая является одной из важных технологий в семантической сети. Авторы статьи описывают методы разработки онтологии для ИСО, которые позволяют учитывать особенности каждого ученика и его потребности. Рассматриваются вопросы, связанные с построением ИСО и оценкой результатов обучения, в том числе проводится анализ различных ITSS и их использование в электронном обучении и LMS. В статье обсуждаются преимущества использования ИСО в образовании. Они позволяют студентам получать индивидуальный подход к обучению и максимально эффективно использовать свои сильные стороны, что способствует более глубокому усвоению материала и повышению успеваемости. ИСО позволяют учителям максимально эффективно использовать свое время и ресурсы, создавая персонализированные учебные материалы для каждого ученика.

Ключевые слова: интеллектуальные системы, ITSs, электронное обучение, LMS, интеллектуальная система оценки достигнутых результатов обучения

Introduction

Digitalization of education involves the use of modern digital educational technologies that differ from the previous e-learning system and LMS content management system in the presence of flexible functions not only for management, but also for analyzing and evaluating student achievements. The development of intelligent assessment system of achieved learning outcomes is urgent. The implementation of the technology of the intelligent assessment system of achieved learning outcomes in general, specifically with the content in the Kazakh language as well, is not sufficiently disclosed both in the world of science and in the Republic of Kazakhstan. In this regard, the disclosure of the essence and method of implementation of such technology is an urgent task.

The demand for intelligent systems is growing at a record pace during the pandemic. In educational system of the Republic of Kazakhstan various educational learning systems, in which the assessment function is partially implemented and is often limited to automatic verification of test and interactive tasks or in the form of manual verification by a teacher.

The crucial aim of the article is to conduct a literature review, analyse methods for assessing and predicting knowledge, skills and competencies of students in the intelligent technologies.

"Intelligent training system is the system with the elements of artificial intelligence. The intelligent training system allows you to adapt the learning process to the each individual student characteristics working with the system. Learning management is defined by the learning system itself based on learning outcomes. Implementation is carried out on the ground of knowledge about the subject area, the learning process and the learner".

Related works. The literature review of different authors from 2017–2022 has been conducted and analysed.

The analysis of the article Intelligent Tutoring Systems: a systematic review of characteristics, applications, and evaluation methods (Mousavinasab et al., 2018) has been carried out in accordance with the artificial intelligence methods for creating more personalized educational system. Such systems are called Intelligent Tutoring Systems (ITSs). The authors of the article focus on the characteristics of ITSs developed in various fields of education. The authors conducted research from 2007 to 2017, and 53 articles were included in the study on the basis of inclusion criteria. The educational areas in ITSs were mainly computer science (37.73 %). The most frequent artificial intelligence methods used in rule-based reasoning, data mining, and Bayesian networking with frequencies of 33.96 %, 22.64 %, and 20.75 %, respectively. These methods allow ITSs to provide adaptive guidance and learning, evaluate students, determine and update the student model, and classify or group students. The system performance indicators, student performance and experience were used to evaluate ITSs in particular.

Further the Smart Learning (García-Peñalvo et al., 2020) has been considered. In the consequence of pandemic due to COVID-19 artificial intelligence has a huge potential, applied in the educational sphere. Therefore, educational systems claim to use more intelligent learning technologies that do not claim to replace the teaching staff, but facilitate their teaching activities. This special issue is focused on introducing a collection of articles about original advancements in educational applications and services driven by AI, big data, machine and deep learning.

In article An intelligent tutoring system for supporting active learning: A case study on predictive parsing learning (Castro-Schez et al., 2021) authors designed and developed an intelligent mentoring system to allow students to learn through experience, working at the top cognitive level of Bloom's Taxonomy, encouraging them to actively learn and be self-sufficient. Thus, the developed tool called Proletool 3.0 (Figure 1) includes modules that are commonly encountered in systems of this type (domain module, mentor module, student module, interface module, and evaluation module). In addition, the system provides a web interface that allows you to use it as a learning object on the e-learning platform.

Authors (Grivokostopoulou et al., 2016) have utilised the app for interactive examples and exercises related to search algorithms. The research area is the artificial intelligence curriculum. The issue of using Bsearch algorithms has been considered to offer theoretical descriptions, interactive examples and exercises related to search algorithms in the artificial intelligence training system. The results show that visualized animation and interactivity are two of the most important factors contributing to better learning.

A methodology for assessing the student intelligence level based on the theory of multiple intelligences. The research area is computer engineering. The system is based on a hybrid approach with artificial intelligence generated by an artificial neural network and an optimization algorithm called the Vortex Optimization Algorithm (VOA). It was tried and tested on students and gave positive results for improving self-learning (Kose et al., 2017).

In the article Application intelligent search and recommendation system based on speech recognition technology (Jiang et al., 2020) was considered the speech recognition technology to create smart search and app recommendation. The authors designed a system of extraction levels, speech information analysis and finalized the recommendations. Experimental results show that the proposed method is more efficient and intelligent.

In the article Early segmentation of students according to their academic performance: A predictive modelling approach (Jiang et al., 2020) were considered the the methods Random Forests, decision trees, support vector machines and naive Bayes. The authors propose a two-stage model supported by data mining methods that uses information available at the end of the first year of students ' academic career (path) to predict their overall academic performance. Unlike most educational data mining literature, academic success is measured by both the average score achieved and the time taken to complete the degree. In addition, this study suggests segmenting students based on the dichotomy between evidence of failure or high performance at the beginning of the degree program and student performance levels predicted by the model.

Investigates the relationship of two aspects to objective and subjective academic achievements, as well as their incremental validity and interaction with the two aspects of conscientiousness diligence and orderliness. Cross-sectional data from 424 students showed that a) intellectual openness is a strong positive predictor of academic achievement, while sensory-aesthetic openness is a moderate negative predictor, b) aspects of openness showed significantly greater incremental confidence in aspects of conscientiousness than vice versa, and c) intellectual openness and order interacted in predicting objective academic achievement (Thomas Gatzka, 2021).

Therefore, in the article Improving the expressiveness of black-box models for predicting student performance (Carlos et al., 2017) has been proposed a black box method that allows us to take advantage of the power and versatility of these methods in making some decisions about the input data and the design of the classifier, providing a rich set of output data. A set of graphical tools has also been offered to use the output information and provide meaningful guidance for teachers and students.

Authors of the article A new methodology for early warning of critical academic performance, based on discrete predictive models (Meca et al., 2019) have presented a methodology based on the hypothesis that the method of sampling the performance variable will significantly affect the generated predictive models. The authors have emphasized the relationship between the factorization criteria and the most relevant attributes selected for instance classification. In addition, the relationship between the obtained predictive model and the criteria for factorization of the target variable has been presented.

Three studies (Mousavinasab et al., 2018), (Garcia-Penalvo et al., 2020), (Castro-Schez et al., 2021) conducted a comparative analysis of the effectiveness of intelligent systems used in the educational sphere.

The analysis showed that there is a large amount of research on assessment and prediction methods in e-learning, students' skills competencies, and academic achievements (Zulfiya et al., 2019).

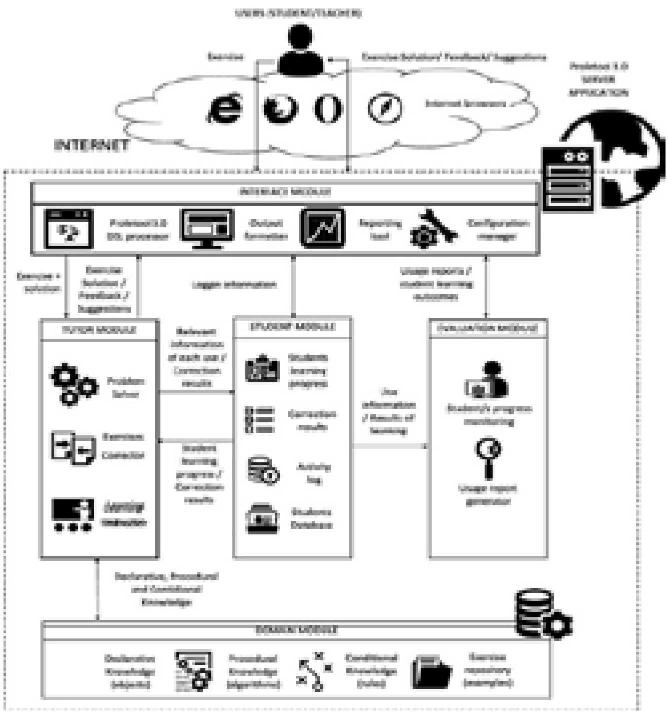

Fig. 1. Architecture of the web interface system software according to Bloom's Taxonomy (Castro-Schez et al.:2021)

In this paper, the authors discussed (Quezada et al., 2021) about using NEON (ontology methodology), Scrum (agile methodology), and web scraping to develop an application of the ontology model of knowledge representation for knowledge arrays as an additional tool to improve the curriculum in the context of software development. The benefits of this paper are as follows: First, it combines and applies ontology methodologies and agile development; second, a Java application using the Jsoup library has been developed to extract and visualize information about a bachelor's degree in software engineering.

One can see the design of a competence ontology for educational program analysis. It is shown as an analytical review of the works on this topic. The methodology of the process of collecting and analyzing professional and personal qualities is proposed. Created data on programmer diploma requirements. The ontology of required competencies for this specialty is created. For example, the ontology of key skills for the profession "Programmer" is given. It is possible to see variants of compositions of all collected qualities. The practical implementation of the transition and the combination of research related to market analysis and research related to the dynamic changes in education is explained. The resulting lists of professional qualities and personality traits will then be classified into generalized groups (Aksenov et al., 2020).

The need to ensure compliance of professional training with both formal and informal requirements of the education system and the labor market of this work is confirmed by the relevance. The reason for the employment of university graduates in the labor market, is the lack of methods and technologies that are able to align the results of the information technology curriculum with the requirements of the labor market. This article (Kurzaeva et al., 2020) describes methods for developing an ontological model that would be capable of shaping the content of IT competencies and assessing them in university students. Firstly, the boundaries of the subject area of awareness must be defined, and secondly, a method for taking into account individual characteristics and needs must be considered and developed in advance to create an individual training and self-study plan, these two theses are our basis. On the example of the subject area of business solutions platform "1C:Enterprise" presented ontological model, developed by the stated method for the formation of the content of IT competencies and their evaluation. Knowledge base, created with the help of ontological model, can be integrated into the intellectual information systems of decision-making, designed for education, corporate training and human resource management. For professionals developing new tools and methods of distance education and distance learning management this article will be useful.

The professor is known as the mentor who guides and guides students throughout their professional learning, this is provided in the competency-based model. Consequently, the professor must determine which courses students have approved and which courses they should take during the next period so that their academic learning does not fall behind. Curricula should be modeled to indicate a complex structure consisting of courses (which are represented as nodes), links (denoted as edges) between course prerequisites, and semester number (represented by a node weight). The paper (Galvez et al., 2020) provides a bi-directional weighted graph that will represent internal and wire constraints in the flow of courses that students must take and pass, creating an organized context (which is governed by each course weight) in which they can be guided and directed by the instructor. A system is proposed for monitoring student progress and enabling student-teacher interaction that integrates a weighted bi-directional schedule. Developments that are based on an ontology model is a collaborative application, such systems. So, this work integrates graphs with artificial intelligence.

The article (Mandić et al., 2018) also describes a semi-automated software platform developed to harmonize computer science curricula at all levels of education. The algorithms used for ontology matching are described in detail, as well as the principle of matching computer science curricula with ontology models. For computer science teachers from the Republic of Serbia, the model of the selected curriculum was created and compared with the model of the reference curriculum for computer science teachers using the software platform. According to the analyses of the results, which include a comparison with the data obtained for other possible pairs of created input ontology models (ACM K12 high school model and the reference model, high school model and the model of the selected curriculum). The experiments presented in this article indicate that consideration should be given to improving the curriculum for teachers, as well as the use of new matching methods.

In the field of education, the semantic network and the development of ontologies can play a significant role. In this (Katis et al., 2020) discussion, the authors focus on conceptualizing educational knowledge structures in an academic setting. More specifically, we present the methodology and process of developing an educational ontology. The methodology could be reused and applied to any type of course at various institutions and contribute to several objectives of the curriculum and course activities.

In education, ontologies have been used with great success because they allow us to formulate a representation of the subject domain by identifying all the concepts involved, the relations between the concepts, and all the existing properties and conditions. The purpose of this paper (Stancin et al., 2020) is to present the field of ontologies and provide an overview of recent research in the field in the context of education. As this paper presents a literature review, articles from the past five years, have been collected from the IEEE Xplore database, analyzed and classified based on the use of ontologies for: curriculum modeling and management, description of learning domains, learning data and e-learning services. From the resulting work, one can observe a somewhat growing trend in the contribution of ontologies to educational systems. Many analyses used ontologies to describe learning domains, and some of the 95 papers collected could not fit into just one category because the system used more than one ontology. Throughout the work, the following contributions were made: the term "ontology" was defined, the most common types of ontologies and commonly used methodologies for building ontologies were identified, and an overview of existing systems that use ontologies in education was provided.

With the emergence of data-driven technologies, the importance of education and training in data science is increasing, and of an organizational culture that aims to gain practical value for improving the research process or enterprise business by using a variety of enterprise data and widely available open data and social media data. By today's research and data-driven industries require new types of professionals capable of supporting all phases of the data lifecycle, from production, input, to data processing and delivery of actionable results, visualization and reporting, which can be collectively defined as a family of data science professions. An interdisciplinary approach is required for education and for professional training of data scientists, combining a broad view of the fundamentals of data science and analytics with in-depth practical knowledge of specific subject areas. In current situations with rapidly changing technologies and high demand for professional skills, data science education and training must be customizable and provided in a variety of forms, as well as provide sufficient opportunities for data processing labs for hands-on learning. Article (Demchenko et al., 2020) discusses an approach to creating a customizable data science curriculum for different types of learners based on the EDISON Data Science Framework (EDSF) ontology, developed through the EU-funded EDISON project and widely used by universities and professional learning organizations.

The art and expertise of data management are critical to the widespread adoption of open science and the effective use of data in research, industry, business, and other sectors of the economy. Unbiased data management views (searchable - accessible - compatible - reusable) and data management provide the foundation for effective research data management. The paper (Demchenko et al., 2021) "Turning YARMARKS into Reality" and others recommend that data skills be more widely integrated into university curricula and that a concerted effort be made to coordinate and accelerate the teaching of professional roles in data processing. Reliable Data Skills for Learning is being worked on by many projects and initiatives, across Europe and beyond. Here is the ongoing work of the FAIRsFAIR project to develop a data management competency framework and provide guidance on how to implement this framework into university curricula by defining model data management curricula. In the labor market analysis, the proposed method and identified competencies and knowledge themes are validated. The material presented uses the EDISON Data Science Framework as a framework for defining data management competencies and a methodology for linking competencies, skills, knowledge, and intended learning outcomes in curriculum development.

As a result of the formation of e-learning systems, personalization and adaptability have now become important characteristics of educational technology. By design, the authors describe (Aeiad et al., 2019) the development of an architecture for a personalized and adaptable e-learning system (APELS) that attempts to contribute to advances in this area. A personalized and adaptable learning environment APELS seeks to provide users from freely available resources on the Internet. Modeling a specific learning subject and extracting relevant learning resources has been used an ontology from the Internet based on the learner model (learners' experiences, needs and learning styles). The APELS processing methods is to use natural language to evaluate content extracted from relevant resources according to a set of learning outcomes defined by standard curricula to ensure appropriate learning of the subject matter. A computer science primer is used to illustrate the working mechanisms of APELS and its assessment based on the ACM / IEEE computing curriculum. Experimental opinions were conducted with subject matter experts to assess whether APELS can create the right instructional content to meet the learning needs of the student. The scores show that the content created by APELS is of good quality and satisfies the learning outcomes for teaching purposes.

Ontologies are one of the pillars of the semantic network. The semantic network tangibly relies on formal ontologies that structure subordinate data and information in a machine-readable way so that this knowledge can be automatically read and processed by machines. In this process, the authors (Piedra et al., 2018) present an ontology approach to the foundations required for the IEEE and ACM computer science curricula (CS2013). The goal of this process is to improve the usability of the curriculum through the development and implementation of a computer science ontology. Through ontology definitions of concepts, data properties, and data objects can be useful to overlay and maintain a logical structure for new types of curriculum concepts that may emerge from autonomous higher education institutions (HEIs). Users gain a resource from obtaining information in open portable data formats. As a result, the developed ontology is a powerful tool that can change the way curriculum knowledge is defined, managed, negotiated, analyzed, and shared. The Semantic Curriculum Viewpoint can be used in a variety of learning modes, facilitate academic mobility, accelerate the recognition of academic credits earned at different institutions, and integrate and interact with different computer science faculty curricula or provide convergence and interoperability of other disciplines.

A course of teaching and learning is a curriculum because it contains an important promise between faculty and students in higher education and in the university. But at the moment, most curriculum management systems provide simple functionality, including the creation, modification and retrieval of unstructured curriculum. The approach of the authors (Chung et al., 2014) consists of defining the ontological structure of the curriculum and the semantic relationships of the curriculum, classifying and integrating the curriculum based on ACM/IEEE computing curriculum, and formalizing the learning goals, learning activities, and learning assessment in the curriculum using Bloom's taxonomy to improve the usability of the curriculum. Among other things, we propose an effective method for enhancing student learning effects through the construction of a subject ontology that is used in discussion, visual presentation, and knowledge sharing between instructor and students. The authors assure the correctness of the search and classification of our proposed methods according to experiments and performance evaluations.

Although model-based software engineering (MBE) is a widely recognized discipline in the field of software engineering (SE), no agreed basic set of concepts and practices (i.e., body of knowledge) has yet been defined for it (Burgueño et al., 2019). In order to property the content of the MBE discipline, promote a global, consistent view of it, clarify its scope with respect to other SE disciplines, and define a framework for MBE curriculum development, this paper proposes content for the body of knowledge for MBE. In doing so, the authors outline the methodology they used to compile the proposed list of content, as well as the results of a survey we conducted to solicit community opinion on the importance of the proposed topics and their level of coverage in existing SE curricula.

Theoretical analysis of the literature shows that this problem has been widely considered. At the same time, education implies the use of such forms and methods of learning, which allow to include in the educational process. The most important role in this process can be played by the ontological model, to which additional requirements are imposed in the conditions of higher education.

Materials and methods

In the materials and methods section of the e-learning system, two key aspects are outlined: the definition of the main components of the system and the development of an ontological model to establish the semantic structure and relationships between these components. Here's a breakdown of each aspect:

Definition of Main Components:

The main components of the e-learning system are defined, including:

Courses: These are the overarching units of instruction that cover specific topics or subject areas. Courses typically consist of a series of lessons, activities, and assessments designed to facilitate learning.

Modules: Courses can be divided into smaller units called modules. Modules focus on specific subtopics or learning objectives within a course. They provide a structured approach to organizing the content and activities for effective learning.

Assignments: These are tasks or projects given to students as part of their learning process. Assignments can include essays, research papers, group projects, or any other form of work that assesses the students' understanding and application of the course material.

Tests: Tests are assessments designed to evaluate students' knowledge and understanding of the course material. They can take various forms, such as multiple-choice questions, open-ended questions, or practical exercises.

Other Elements: This refers to any additional components or features that are part of the educational process in the e-learning system. It could include discussion forums, virtual labs, interactive simulations, or any other tools or resources used to enhance the learning experience.

Development of Ontological Model:

An ontological model is created to define the semantic structure and relationships between the components of the e-learning system. An ontology is a formal representation of knowledge that describes entities, their attributes, and the relationships between them.

In this context, the ontological model would define the relationships between courses, modules, assignments, tests, and other elements of the e-learning system. It establishes how these components are interconnected and how they relate to each other within the overall educational framework.

The ontological model can provide a structured and organized representation of the e-learning system, facilitating effective content management, navigation, and retrieval. It helps ensure coherence, consistency, and interoperability of the system components, enabling seamless integration and interaction between different elements.

Stages of creating an intelligent e-learning system.

1. Learning outcome formulation

The formulation of discipline learning outcomes is carried out taking into account the form of training, as the achievement of learning outcomes may differ in distance, mixed and traditional training. However, the results must be formalized as achievable for any type of training. Each learning result corresponds to (at least does not contradict) the purpose of the educational program.

2. Ontological model of the discipline

The structure and content. The ontological model of the discipline is being built on Protégé. tool (Center:2019). https://protege.stanford.edu/ It was developed at Stanford University in collaboration with the University of Manchester.

The model includes topics of the discipline and a glossary, each topic of the discipline includes basic concepts from the glossary, control questions on the topic with links to the glossary are being developed, as well as tasks to check the achievement of results on each topic, questions to check knowledge and their answers on ontology in natural language is created, the system can be self-studiable within a given discipline (Fig.2) (Zulfiya et al., 2019).

3. Assessment system development

Assume test question assignments and create a knowledge base with reference answers on the subject of databases:

1 What is a relational data model?

Reference answer: A relational data model is a structured approach to organising data in a database based on representing data as tables consisting of rows (tuples) and columns (attributes) and defining relationships between tables.

2 What is a primary key?

Reference answer: A primary key is a unique identifier that uniquely identifies each record (row) in a database table. It ensures uniqueness and integrity of the data in the table.

3 What is a foreign key?

Reference answer: A foreign key is an attribute (column) in a table that establishes a relationship between two tables in a database. It refers to the primary key of the other table and is used to determine the relationship between the data in the different tables.

4 What is database normalisation?

Reference answer: Database normalisation is the process of organising data in tables to eliminate redundancy and ensure data integrity. It involves dividing tables into smaller and related tables using certain normal forms.

5 What is SQL?

Reference answer: SQL (Structured Query Language) is a programming language used to manipulate relational databases. It allows you to perform data creation, modification and retrieval operations as well as manage the structure of the database.

By creating a knowledge base with benchmark answers to the test questions, we can compare students' answers with the benchmark answers to assess their understanding and knowledge of databases.

An example of student entries for test questions in a database subject:

Question: What is a relational data model?

Student Answer: A relational data model is a way of organising data in a database.

Question: What is a primary key?

Student's Answer: A primary key is a unique identifier that helps identify records in a table.

Question: What is a foreign key?

Student Answer: A foreign key is an attribute that links two tables in a database.

Question: What is database normalization?

Student's Answer: Database normalization is the process of improving the structure of data in tables.

Question: What is SQL?

Student answer: SQL is a programming language used to work with databases.

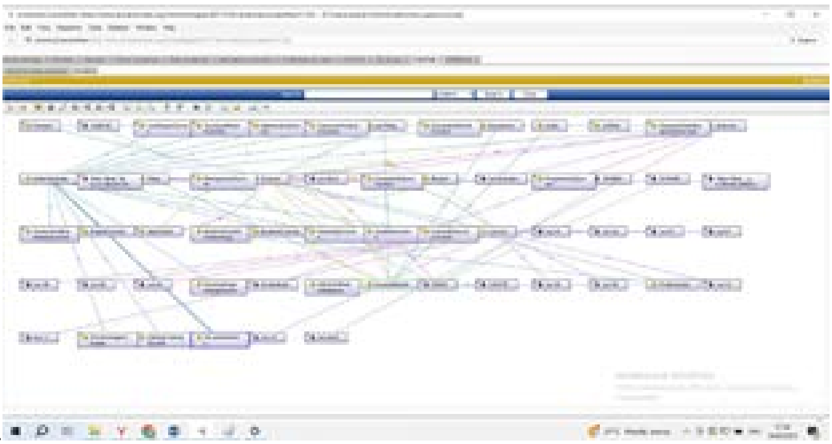

Fig. 2. Ontological model of the discipline

Student's record of answers can be assessed by comparing it to benchmark answers from a knowledge base. For each question, the degree of similarity between the student's answer and the benchmark answer can be determined to calculate the student's score for each question and the overall test score. This will assess the student's understanding and knowledge of the databases.

To calculate the degree of similarity between a student response and a reference response based on a fuzzy binary relationship, a similarity measure, such as cosine similarity, can be used. Cosine similarity measures the angle between the vectors of the student's response and the reference response, and the closer the angle is to 0, the higher the degree of similarity.

An example of calculating the degree of similarity between a student's answer and a reference answer using cosine similarity:

Suppose that the reference answer to the question "What is a relational data model?" is "A relational data model is a way of organizing data in a database."

And the student's answer to this question is "A relational data model is a way of storing information in tables."

We can represent each answer as a vector, where each word is a component of a vector, and then calculate the cosine of the angle between these vectors:

Reference answer: [relational, data, model, is, a, way, of, organising, a, database]

Student answer: [relational, data, model, is, a, way of, storing, information, tables]

Now, let's calculate the Cosine Similarity between these vectors:

$$\textit{Cosine Similarity} = (A - B) / (||A||| * ||B||)$$

Where A and B are vectors of student and benchmark answers respectively, and ||A|| and ||B|| are their norms (lengths).

After calculating the cosine similarity, we obtain a value that reflects the degree of similarity between the student's answer and the reference answer. The closer the value is to 1, the higher the degree of similarity.

Applying this approach to other questions will calculate the degree of similarity and evaluate student responses based on the fuzzy binary relationship.

To determine scores based on the degree of similarity between the student's answer and the benchmark answer, a similarity threshold value can be used and scores can be assigned depending on how close the answers are.

An example of calculating scores based on a similarity threshold:

Question: What is a relational data model?

Reference answer: "A relational data model is a way of organizing data in a database."

Student response: "A relational data model is a way of storing information in tables."

Let the similarity threshold be 0.8.

We calculate the cosine similarity between the answer vectors and get a value of, for example, 0.85.

Since the similarity value (0.85) is higher than the threshold value (0.8), the student receives a full grade for this question.

Question: What is a primary key?

Reference answer: "A primary key is a unique identifier that helps identify records in a table."

Student answer: "A primary key is an identifier for records in a table."

Let the similarity threshold be 0.7.

We calculate the cosine similarity between the response vectors and obtain a value of, for example, 0.65.

Since the similarity value (0.65) is below the threshold value (0.7), the student receives a partial score for this question, such as 0.5.

Scores for the remaining questions can be calculated using the similarity threshold value and setting appropriate scores based on the proximity of the student's answers to the benchmark answers.

To calculate the competence score based on the discipline scores for each module, a weighted sum of scores can be used, where each discipline contributes to the overall competence score.

An example of calculating competence scores based on discipline scores:

Suppose we have two competencies, Competency 1 and Competency 2.

Module 1:

- Discipline 1: Databases
- Discipline 2: Database Management Systems
- Discipline 3: SQL Language

The student received the following marks for the disciplines in Module 1:

- Databases: 85 points
- Database Management Systems: 90 points
- SQL Language: 80 points

Now, to calculate competency scores, assign weights to each discipline according to their importance for each competency.

Let us assume that the weights for the competences are as follows:

- Competency 1: Databases - 0.4, Database Management Systems - 0.3, SQL Language - 0.3
- Competence 2: Databases - 0.2, Database Management Systems - 0.5, SQL Language - 0.3

Now let's calculate competency scores:

Competency 1 scores = (Database scores * Database weight) + (DBMS scores * DBMS weight) + (SQL Language scores * SQL Language weight) = (85 * 0.4) + (90 * 0.3) + (80 * 0.3) = 34 + 27 + 24 = 85 points

Competency 2 Scores = (Database Scores * Database Weight) + (RDBMS Scores * RDBMS Weight) + (SQL Language Scores * SQL Language Weight) = (85 * 0.2) + (90 * 0.5) + (80 * 0.3) = 17 + 45 + 24 = 86 points

Thus, the student received 85 points on competency 1 and 86 points on competency 2 based on the points received on the disciplines included in module 1.

It is possible to calculate competence scores for other modules by applying weights of disciplines depending on their importance for each competence.

To calculate the average achievement of the compulsory learning outcomes of an educational programme, the sum of the points for each discipline can be used and divided by the total number of disciplines. This will provide an overall assessment of the achievement of the learning outcomes throughout the programme.

An example of calculating the average achievement of compulsory learning outcomes:

Suppose we have the following subjects in an educational programme:

1. databases - 85 points
2. Database management systems - 90 points
3. SQL Language - 80 points

To calculate the average of the required learning outcomes, we add up the scores for each discipline and divide them by the total number of disciplines:

Sum of points = 85 + 90 + 80 = 255

Total number of disciplines = 3

Average Achievement = Sum of Scores / Total Number of Disciplines = 255 / 3 = 85

Thus, the average achievement of the compulsory learning outcomes of the disciplines in the educational programme is 85. This makes it possible to assess the overall level of achievement of the learning outcomes throughout the programme.

It is important to note that thresholds and scores can be adjusted according to the requirements and preferences of the assessor or the educational institution.

It is proposed to use an assessment system on the basis of open tests in a specific discipline. The student writes his answer, which is compared with the reference answer based on a fuzzy binary relation set between the student's answers and the reference answers synthesized from the knowledge base of the given discipline in accordance with the test questions. Competence scores can then be calculated for all modules based on the scores obtained in the disciplines included in those modules. As a result, it is possible to assess the achievement of learning outcomes throughout the educational program, which is calculated as the average value of the achievement of compulsory learning outcomes in the disciplines of the educational program.

Results and discussion

The proposed assessment system based on open tests in a specific discipline appears to be designed to evaluate student performance and measure the achievement of learning outcomes. Here's a breakdown of the process and its potential implications:

Open Tests: The assessment system utilizes open tests, where students provide their answers in written form. This format allows for more flexibility and diverse responses compared to multiple-choice questions.

Fuzzy Binary Relation: The student's answers are compared with reference answers using a fuzzy binary relation set. This approach suggests that the evaluation is not limited to strict correctness or incorrectness but considers the degree of similarity or dissimilarity between the student's response and the reference answer.

Knowledge Base: The reference answers are synthesized from the knowledge base of the specific discipline. This knowledge base likely contains a comprehensive collection of information and expertise related to the discipline, which serves as a basis for determining the correctness or quality of the answers.

Competence Scores: Competence scores can be calculated for all modules based on the scores obtained in the disciplines included in those modules. This allows for assessing the overall performance and competence level of students across different areas of knowledge covered in the educational program.

Achievement of Learning Outcomes: The proposed system aims to assess the achievement of learning outcomes throughout the educational program. This involves calculating the average value of the achievement of compulsory learning outcomes in the disciplines of the program. It provides a comprehensive overview of students' progress and proficiency in meeting the defined learning goals.

The strengths of this approach lie in its potential objectivity, scalability, and adaptability. By employing a fuzzy binary relation set and referencing a knowledge base, the system can provide a more nuanced assessment that goes beyond simple right or wrong answers. Additionally, the calculation of competence scores and the assessment of learning outcomes can offer valuable insights into students' overall performance and program effectiveness.

Conclusion

The proposed approach you mentioned seems to focus on creating a teaching system that doesn't require a human teacher. Instead, it relies on some other mechanism or process to facilitate learning. Additionally, it suggests using a large knowledge base to verify the attainment of learning outcomes.

This type of approach aligns with the concept of machine learning and artificial intelligence, where systems can learn and improve from data without explicit programming. By leveraging a large knowledge base, the system can access a vast amount of information to enhance the learning process and verify the achievement of learning goals.

Using a teaching system without a human teacher can have several advantages. It can provide scalability, as the system can potentially handle a large number of learners simultaneously. It can also offer personalized learning experiences, tailoring the content and pace of instruction to individual learners' needs. Furthermore, such a system can adapt and improve over time based on feedback and data analysis.

However, it's important to note that while a teaching system without a human teacher can be valuable in certain contexts, it may not completely replace the role of human educators. Human interaction, guidance, and support are often crucial for fostering deeper understanding, critical thinking, and socio-emotional development in learners.

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ISSN2518-1726 (Online),
ISSN 1991-346X (Print)

Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 12.06.2023.
Формат 60x881/8. Бумага офсетная. Печать –ризограф.
19,0 п.л. Тираж 300. Заказ 2.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19