DEVELOPMENT OF INTELLIGENT KNOWLEDGE CONTROL SYSTEMS: EVOLUTION, ARCHITECTURE, AND KEY TRENDS IN DIGITAL DIDACTICS

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Abstract

The article analyzes the design and architecture of Intelligent Knowledge Control Systems (IKCS) in digital didactics. The limitations of traditional testing are reviewed, and three core components of IKCS are described: the domain ontology model, the learner's digital profile, and the pedagogical module. The evolution of approaches from Item Response Theory (IRT) to Large Language Models (LLM) and multimodal proctoring systems is systematized. Key trends in IKCS development are outlined, including the shift toward continuous formative assessment and micropersonaliation.

Keywords

Intelligent control systems, artificial intelligence in education, adaptive testing, ontological models, test item generation, large language models (LLM).

The transformation of the global EdTech market and the deep penetration of artificial intelligence (AI) technologies into the academic environment have formed a steady demand for revising the methodology of learning outcomes assessment. [2, 5]

Traditional testing tools integrated into classical learning management systems (LMS) possess a rigidly fixed logic and are incapable of considering the individual cognitive pace of the respondent. [2]

They are focused on stating the fact of mastering isolated fragments of information, losing sight of the consistency and depth of subject understanding. In

contrast, modern digital didactics relies on the design of intelligent knowledge control systems.

These platforms utilize machine learning algorithms, semantic networks, and fuzzy logic to conduct continuous, objective, and flexible diagnostics of competence acquisition levels. The purpose of this article is to systematize scientific and practical experience in the field of designing intelligent knowledge control systems, analyze their base architecture, and explicate dominant technological trends.

The effectiveness of intelligent knowledge control systems as engineering, technical, and pedagogical solution is determined by the isolation and integration of three fundamental domain modules that simulate the expert knowledge of a subject teacher and dialogue interaction. [2]

The first component is the domain model (expert module), which represents a formalized core of the academic discipline, most often implemented as a semantic network or an ontological model of the knowledge base [6].

This module contains not just a flat list of didactic units such as concepts, theorems, or rules, but rigidly fixes hierarchical links between them, including relationships of the "is a part of", "requires preliminary study", and "extends the concept" types. Thanks to this, the system understands that a deficit of knowledge in topic A automatically makes the correct mastering of topic B impossible.

The second component is the learner model (cognitive profile), which is a dynamic digital twin of the student updated in real time based on the trajectory of their answers. [2, 5]

The model incorporates not only an integral academic performance score but also a multidimensional vector of parameters: problem-solving speed, the nature of typical errors, the level of attention stability, and the prevailing style of information perception. [1]

In advanced systems, the apparatus of Bayesian networks or fuzzy set theory is used for this purpose, allowing the evaluation of latent variables of student preparedness.

The third component is the pedagogical module (control-diagnostic block), which acts as an intelligent communication agent. [2]

Based on a comparison of the domain model and the current learner model, the algorithm builds an individual testing strategy, determining the optimal difficulty of the

next question, varying the form of material presentation through text, program code, or graphical schemes, and performing adaptive branching of the testing scenario.

The development of intelligent knowledge control systems has come a long way from simple linear computer tests to multimodal dialogue systems [5].

For a long time, the gold standard of adaptive testing was Item Response Theory (IRT). Algorithms based on IRT recalculate the student's knowledge level after each answer and select the next question so that its complexity corresponds maximally to the current capabilities of the respondent, which reduces testing time by 40–50% without losing measurement accuracy [2].

However, a qualitative leap in the development of intelligent knowledge control systems occurred due to the introduction of large language models (LLM) and neural network architectures [3].

AI agents have transformed knowledge control in three main directions.

First, they enabled natural language dialogue, facilitating the transition from closed-ended multiple-choice questions to an open-ended "question-answer" form [5].

The intelligent knowledge control system is capable of analyzing extended text answers of students, identifying logical lacunae, matching them with a reference semantic graph, and providing reasoned feedback [2].

Second, they allow the dynamic generation of unique content, where AI generates customized case studies, mathematical conditions, and code autotests directly during the exam process, reducing unauthorized copying and cheating to zero [5].

Third, they introduce multimodal intelligent proctoring, where computer vision and image recognition systems control the honesty of passing tests by analyzing gaze direction, behavior patterns, extraneous noise, and biometric parameters of the user in real time.

The integration of intelligent knowledge control systems into the educational ecosystem entails a global paradigm shift—the transition from summative assessment where the exam serves as a final verdict to formative assessment where control acts as a continuous element of learning. Several key trends stand out within this shift [2, 6].

Deep micropersonalization (nanolearning and microlearning) involves fracturing knowledge control into micro-modules lasting from 2 to 10 minutes embedded in the user's daily digital context, which ensures a stable tonic level of motivation [6].

Integration with immersive environments (VR/AR) utilizes intelligent control within virtual reality simulations for the automatic evaluation of practical skills, including surgical and engineering tasks, based on the analysis of movements and decision-making speed.

Finally, objectification and desubjectification completely exclude the human factor and bias when evaluating complex creative or project works through cross-verification by artificial intelligence algorithms [5].

The development and implementation of intelligent knowledge control systems is a major direction in the development of modern educational engineering. The transition from discrete testing to continuous multimodal AI monitoring allows not only obtaining a valid and objective metric of educational achievements but also forming a solid foundation for building adaptive trajectory of lifelong learning.

The main challenge for developers and researchers in this field remains ensuring the ethics of AI use, protecting the personal data of students' cognitive profiles, and harmoniously distributing roles in the "teacher – intelligent platform – student" system [2].

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