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PECA LUDMILA

E-LEARNING STRATEGIES IN THE STUDY OF COMPUTER SCIENCE DISCIPLINES IN THE UNIVERSITY CURRICULUM

532.02 –SCHOOL DIDACTICS ACROSS LEVELS AND EDUCATIONAL DISCIPLINES (COMPUTER SCIENCE)

Summary of the doctoral thesis in educational sciences

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The thesis was developed at the Doctoral School of „Educational Sciences" of the „Ion Creangă" State Pedagogical University of Chișinău.

The Public Defense Committee for the PhD thesis is composed as follows:

1. **PAVEL Maria**, PhD in educational sciences, associate professor at „Ion Creangă" State Pedagogical University of Chișinău – **chair of the committee.**
2. **DUMBRAVEANU Roza**, PhD in physical and mathematical sciences, associate professor at „Ion Creangă" State Pedagogical University of Chișinău – **scientific supervisor.**
3. **GORAȘ-POSTICĂ Viorica**, PhD hab. in pedagogy, University Professor at Moldova State University – **official reviewer.**
4. **SUDACEVSCHI Viorica**, doctor in technical sciences, associate professor at Technical University of Moldova – **official reviewer**.
5. **CABAC Valeriu**, doctor in physical and mathematical sciences, University Professor at „Alecu Russo" State University of Bălți – **official reviewer**.

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The PhD thesis and the summary can be consulted at the National Library of the Republic of Moldova, the Library of Ion Creangă State Pedagogical University of Chișinău, and on the website of ANACEC (https://www.anacec.md/ro/technical-staff/evaluations).

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Chair of the Public Defense Committee for the PhD Thesis:
PAVEL Maria, PhD in Educational Sciences,
Associate professor

Scientific supervisor:
DUMBRAVEANU Roza, PhD in Physical and Mathematical Sciences
Associate professor

Author: **PECA Ludmila**

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CONCEPTUAL FRAMEWORKS OF RESEARCH

Relevance and importance of the addressed issue. Over the past two decades, higher education has undergone profound transformations, largely driven by advancements in digital technologies. Traditional strategies of teaching, learning, and assessment, once the cornerstone of higher education, are increasingly being supplemented and, in some cases, replaced by e-learning strategies. This shift is not merely a reaction to technological innovation but a necessary evolution to meet the demands of a globalized, knowledge-based economy. The need for flexible, innovative, and accessible learning experiences has never been greater in a world where the boundaries of time and space are being redefined by the Internet.

Research highlights the advantages of e-learning and addresses a fundamental question: how can universities optimize e-learning strategies to enhance the quality of instruction and develop students' professional skills, particularly in computer science disciplines? This question serves as the starting point for developing a model and an e-learning strategy aimed at streamlining the teaching process and improving student performance.

Description of the research context and identification of the research problem. In the e-learning approach, digital environments play a fundamental role in the development of modern didactic theory, marking a significant difference from traditional education. The teacher becomes a designer of learning environments, where didactic methods and planning decisions are transformed into concrete objectives and measurable outcomes.

At the same time, curricula in e-learning represent an essential strategic framework regarding the use of digital technologies and resources. Studies show that effective integration of digital technologies requires not just the mere adoption of ICT tools, but also a reconfiguration of teaching strategies to genuinely support the educational process.

The thesis emphasizes the need to implement e-learning strategies in higher education at the course level, investigating their impact on the teaching process and student outcomes. By understanding the determining factors of adopting e-learning strategies, as well as the challenges and opportunities they present, higher education institutions can be better prepared to meet the needs of 21st – century students.

Globally, a number of researchers have played an essential role in the development and promotion of e-learning strategies and the integration of digital technologies in university education. For instance, Mitra S. [1], Khan S. [2], Laurillard D. [3], Mazur E. [4], Bates T. [5], Hattie J. [6], November A. [7], Martin F. and Bolliger D. [8], Whittle C. [9], Gautam S. and Kumar Tiwari M. [10] have demonstrated that effective integration of digital technologies requires not only the adoption of ICT tools but also a paradigm shift in teaching strategies. Several related

topics in the field of e-learning have been addressed by researchers from Russia, such as Bespalko V. [11], Larionova V., Bystrova T., Sinitsyn E., as well as from Romania, including Holotescu C. [12], Vlada M., Adăscăliței A., Jugureanu R. [13], Vasilache S. [14], among others. The implementation and development of ICT in the Republic of Moldova, including within computer science disciplines, have been supported by valuable contributions from researchers such as Gremalschi A. et al. [15], Cabac V. [16, 17], Braicov A. [18, 19], Dumbraveanu R. [20-22], Pavel M. [23], Goraș-Postică V. [24], Sudacevschi V. [25], Globa A. [26, 27], Gasnaș A. [28], Chiriac T. [29], Gîncu S. [30], Botnariuc P. et al. [31], Tudos P. [32], Hera C.G. [33], and others. The research conducted by the mentioned authors has been essential in shaping education through ICT, promoting innovative methods of teaching, learning, and assessment. Furthermore, through various international projects, these researchers have contributed to the adoption of the Moodle platform by several universities in the country, starting in 2004. Training sessions were conducted for university teaching staff on the development of digital resources, focusing primarily on technological aspects and less on the didactic ones.

In the academic literature of the Republic of Moldova, the topic of e-learning and related strategies is represented by only a few works. Discussions about the effectiveness of e-learning are lacking, and this term is often confused with distance education, online learning, or ICT-assisted learning. Although there are contributions in the fields of e-didactics and educational innovations, specific approaches to e-learning are insufficiently explored and disseminated. Identifying effective strategies for implementing e-learning, clarifying the meaning of the e-learning concept, raising awareness of the transformative role of ICT in the teaching process, designing and evaluating electronic courses in higher education, and developing relevant digital educational content are pressing issues that require in-depth study in the academic environment of Moldova.

The evaluation of electronic courses at a global level is a major concern in educational research, where both the effectiveness of these courses and their impact on academic performance and student satisfaction are analyzed. Special attention in evaluation is given to instructional design, interactivity, accessibility, and content quality. In the Republic of Moldova, there are no national-level documents guiding the development and evaluation of electronic courses. Additionally, there are no studies analyzing the specific impact of e-learning implementation on academic performance in technical fields or assessing the effectiveness of various platforms and digital tools used in universities.

The existing situation can be described by the following **contradictions** between: (1) the conservatism of teaching staff and the imperative need to adopt e-learning strategies; (2) the

growing demands of the labor market for professionals skilled in the context of accelerated digitalization across all professional fields and the current level of competence development among students; (3) the integration of e-learning into the university curriculum and the complexity of managing this change; (4) the technology used to replicate traditional methods versus its transformative potential in education.

Based on the analysis of the existing situation and the mentioned contradictions, the research problem is identified as follows: *determining the theoretical and praxeological foundations for the effective use of e-learning strategies in the study of computer science disciplines in higher education, aimed at improving the quality of training for future specialists in the field.*

Object of the research is the process of integrating e-learning strategies into university IT courses.

Research aim is to develop a pedagogical model and an implementation methodology, theoretically and praxiologically grounded, for the effective use of e-learning strategies in studying computer science disciplines in higher education.

Research objectives focus on analysing theoretical concepts related to e-learning, e-learning strategies, and the current state of the field; (2) to develop a pedagogical model for implementing e-learning strategies in the study of computer science disciplines; (3) to elaborate a methodology for implementing the designed model; (4) to experimentally evaluate the effectiveness of the developed model and methodology.

Hypothesis of the research. *If* the pedagogical model integrating e-learning strategies in the study of computer science subjects is implemented and the methodology developed for integrating e-learning strategies in the study of computer science subjects at the university level is validated, *then* the learning outcomes for students in these courses in higher education will improve.

Research methodology: *theoretical methods*: scientific documentation, literature review, synthesis, comparison, interpretation, generalization, systematization, pedagogical modeling, task analysis, and the formulation of conclusions and recommendations. p*raxiological methods*: observation, questioning, expert analysis method, testing, analysis of academic results, and evaluation of the didactic impact of e-learning strategies on the quality of the educational process and student performance. e*xperimental methods*: pedagogical experimentation for verification, formation, and control. s*tatistical methods*: statistical processing of experimental data.

Scientific novelty and originality are theoretical and practical foundation for enhancing the study of computer science subjects through the development of a pedagogical model focused

on e-learning; the development of a methodology for implementing the pedagogical model through the design of an e-learning adapted curriculum; the integration of e-learning strategies into the teaching, learning, and assessment processes for computer science subjects to improve efficiency and quality.

Scientific problem solved. Development and validation of a pedagogical model based on e-learning strategies, which integrates curriculum design and digital platforms to optimize the professional training of engineering students by adapting instruction to labor market demands.

Theoretical significance of research of the **c**ontextual updating of theories on e-learning approaches, analysis and systematization of e-learning concepts and strategies, and theoretical foundation of the pedagogical model for implementing e-learning strategies in the study of computer science disciplines.

Practical value of research. Applicability of the developed model and methodology, successfully implemented in the course on Computer Networks, and the e-learning platform, tested and validated in the Computer Networks course, for enhancing the study of computer science subjects**.**

Main scientific results of the research submitted for defense focus on: a pedagogical model for implementing e-learning strategies in the study of computer science disciplines (MPISe-lSDI); the methodology for implementing e-learning strategies; an e-learning course developed according to the MPISe-lSDI model; course support materials for Computer Networks (within the category of computer science disciplines).

The implementation of scientific results was carried out within a pedagogical experiment conducted in the „Computer Networks" course, which involved 331 students from the Faculty of Computers, Informatics, and Microelectronics at the Technical University of Moldova.

Approval of research results. The research was conducted in accordance with the fundamental stages, throughout the activities of achieving the thesis objectives. The dissertation results were subject to discussions and were approved during the meeting of the Department of Software Engineering and Automation (DISA) of FCIM, as well as by the doctoral thesis advisory committee.

Research results have been published in 4 articles in scientific journals listed in the National Register, 12 articles in the proceedings of international and national conferences, and 2 specialized guides for the field of CN, with ISBN.

Keywords: e-learning, pedagogical model, learning management system, e-learning strategies, digital tools, computer networks, computer science disciplines.

THE CONTENT OF THE THESIS

The *Introduction* outlines the relevance and timeliness of the research, describing the current state of the research field. It formulates the problem, object, purpose, objectives, and hypothesis of the research, as well as the experimental basis, scientific novelty, and originality, and the value of the research. The stages of the research are presented, along with the structure of the thesis and the methods of validating the research results.

In **chapter 1**, titled „Analysis of E-Learning Concepts and E-Learning Strategies" the theoretical foundations of the e-learning approach are examined from the perspective of the evolution of the e-learning concept and e-learning strategies. A series of studies are presented, analyzing either directly or indirectly the concept of e-learning. The adoption of a unified definition of e-learning in this thesis is based on two significant studies in the field [34, 35].

The paper [34] contains a comprehensive analysis of the concept of e-learning and provides an argument for a definition that integrates all the examined definitions: "*E-learning is **an approach** to teaching and learning, representing components of an educational model that relies on the use of electronic means and devices as tools to enhance access to studies, communication, and interaction, and which facilitates the adoption of new ways of understanding the learning process*".

The definition in reference [35] is broadly similar to the definition in [34]: *„e-learning represents an approach to learning and development: a collection of learning methods combined with the use of digital technologies that facilitate, distribute, and enhance learning".*

These definitions provide a common framework for the academic community engaged in theoretical and empirical research in the field of e-learning and serve as a reference for educators and decision-makers who are less familiar with this concept. The definition adopted in the thesis from the paper [34] is highlighted because it explicitly outlines four components of this complex concept and emphasizes their interdependence: ***learning design, learning content, technology, and communication.*** These fundamental aspects constitute the core structure of the e-learning approach. As an educational paradigm, e-learning encompasses a broad range of methods and digital technologies used for instruction.

Research published subsequently has not contributed new insights to this definition; they have only specified certain components in various contexts.

The implementation of e-learning requires the existence of a strategy. A strategy is a coherent set of planned actions designed to achieve the long-term objectives of an educational system, institution, or department. Accordingly, strategies exist at the national, institutional, and departmental levels (fig. 1). Chapter 1 briefly describes the characteristics of these strategies, while

the research presented in this thesis focuses on the strategy at the departmental level.

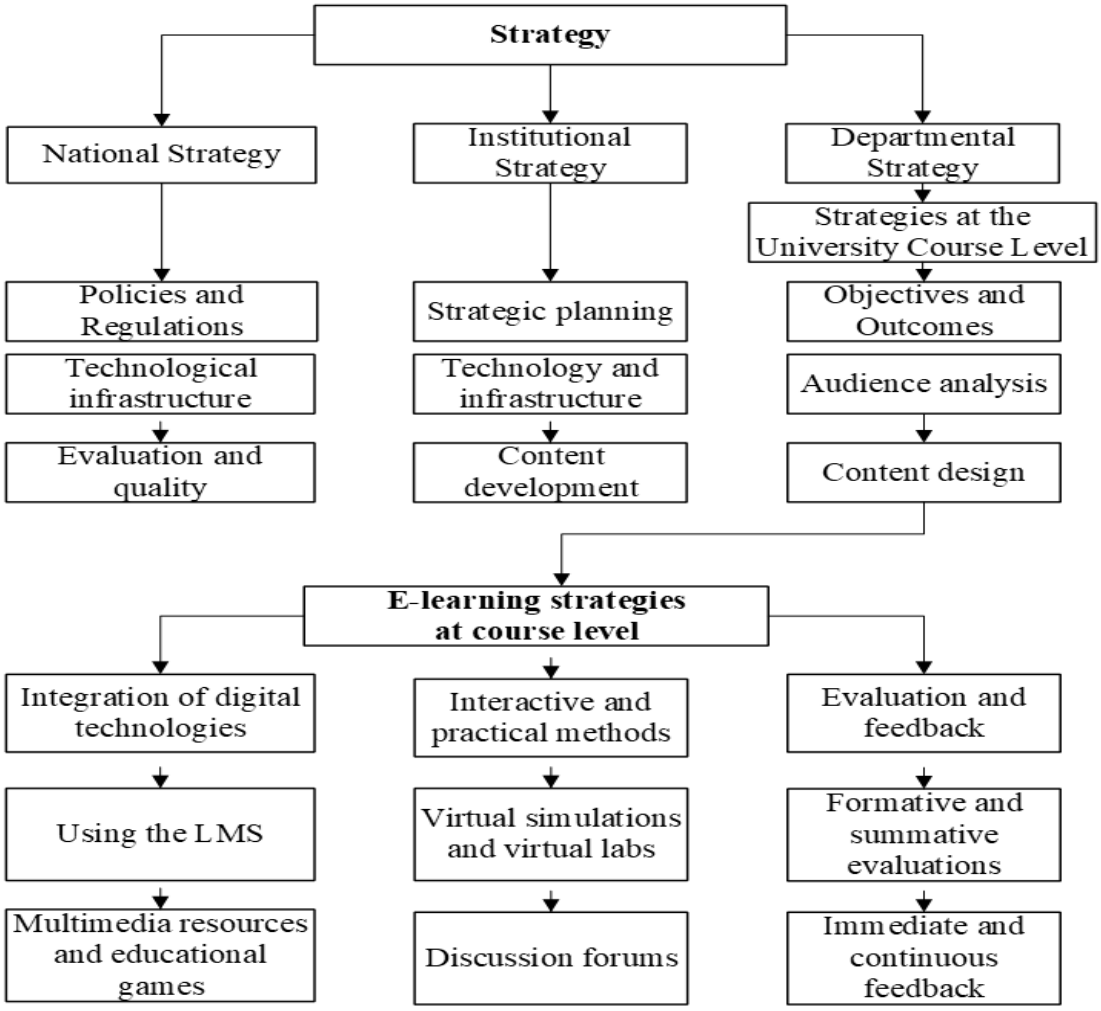

Fig. 1. E-learning strategies by levels

As an evolution of departmental strategy, the strategy of a successful university in this field is presented: Hong Kong University of Science and Technology (HKUST) [36]. This example can be regarded as a best practice model for other educational institutions seeking to develop and implement effective e-learning strategies. The HKUST strategy emphasizes the importance of a phased and well-structured approach that includes regular updates, support for faculty, and the integration of emerging technologies to address the changing needs of students.

The concept of e-learning strategy at the departmental level materializes into several definitions from various studies and authors. The work lists a series of definitions of e-learning strategy. In essence, all these definitions refer to a strategic plan aimed at improving the teaching process through the design, implementation of learning activities, evaluation of learning outcomes, and selection of appropriate technological solutions.

The development and implementation of e-learning strategies at the departmental level in

higher education involve creating electronic courses, using learning platforms, implementing appropriate teaching strategies, developing high-quality digital educational resources, and evaluating them. These strategies enable universities to provide students with flexible and innovative learning experiences in line with labor market demands.

The COVID-19 pandemic had a significant impact on education systems worldwide, prompting a rapid transition to e-learning and other forms of remote learning. The implementation of e-learning during the pandemic highlighted two distinct consequences: a negative impact in the form of regression and a positive impact in the form of development.

The thesis analyses the challenges associated with the transition to e-learning during the pandemic period, including the decline in student interest and engagement in e-learning activities, motivation, psychological issues, technological problems, preparedness for e-learning implementation, and the interaction between students and teachers, as well as among students themselves. At the same time, several factors catalysed the implementation of the e-learning approach: the rapid development of digital infrastructure, support from governments and institutions, the recognition of the need for a more flexible teaching approach supported by technologies, the accelerated development of digital competencies, and the adoption of an innovative instructional design paradigm. This innovative paradigm involves a deep understanding and application of learning theories (briefly described in Chapter 1) to create effective e-learning strategies.

In **chapter 2** „The Pedagogical Model and Implementation Methodology Based on E-learning Strategies", the following were accomplished: (1) the analysis and description of models for designing e-learning strategies; (2) the development and theoretical foundation of the pedagogical model, as well as the methodology for its implementation; (3) the constructive alignment of the model's components, ensuring their efficient and coherent integration to support the effectiveness of the learning process.

The design model serves as the foundation for developing the educational strategy, providing a clear and coherent framework for implementing digital technologies in the learning process. The model represents a structure where all educational components—ranging from the content taught to the methods of assessment—are integrated to optimize the efficiency and effectiveness of instruction.

In this context, the model proposed by Kenneth Fee [35], discussed in Chapter 2, outlines a comprehensive and strategic approach to the design, implementation, and evaluation of e-learning initiatives. The essence of Fee's model lies in the holistic consideration of various components that contribute to the success of e-learning initiatives, focusing on a balanced

integration of pedagogical principles, ICT tools, and the organizational context. Table 1 presents the key stages in the e-learning strategy.

Table 1. Key Stages in the E-learning Strategy

Key stages	Description
Strategic planning	Aligning e-learning initiatives with institutional objectives, understanding student needs, and determining how e-learning supports overall goals.
Design and development	Student-centered design, the application of instructional design principles, and the creation of engaging and effective content, including multimedia and interactivity.
Implementation	Ensuring the necessary infrastructure and support, including technical implementation and providing training and assistance for both students and instructors.
Evaluation and monitoring	Continuous evaluation of e-learning programs, utilizing feedback to enhance the program, and conducting formative and summative assessments.
Sustainability and continuous improvement	E-learning as a continuous process, evolving in alignment with technological advancements and organizational needs, with regular reviews and updates.
Target group	Clear identification of beneficiary groups (students, teaching staff, administrators) and adaptation of content according to their needs and learning styles.
Choosing technology	Selection of appropriate technological platforms and tools, assessment of infrastructure, compatibility, and resources necessary for the effective use of e-learning.

These key stages constitute the fundamental pillars, ensuring not only alignment with institutional objectives but also continuous adaptability to the evolving needs of students and technological advancements. This strategic approach represents significant value in the design and implementation of modern study programs, oriented towards the long-term success of educational initiatives

Table 2. E-learning models according to Kenneth Fee

Model 1	Traditionally enriched with digital resources and tools	Face-to-face teaching supplemented with digital resources (online platforms, multimedia), providing students with additional access to online content without eliminating the traditional teaching method.
Model 2	Blended learning	Learning programs that integrate online learning with complementary offline activities.
Model 3	Self-directed e-learning	Students have significant control over their learning process, setting their own learning objectives, selecting resources and instructional materials they deem appropriate, and managing their own study pace. They can learn remotely using online resources, learning modules, or other digitally available materials.
Model 4	Live E-learning	Synchronous online learning events, involving students from multiple locations who participate together in a pre-scheduled session.
Model 5	Online learning to support specific tasks	Online learning in the workplace supports specific tasks, systems, or operational procedures.
Model 6	Online courses	Content is delivered to students through online tools. Initially, this type of e-learning was implemented via the web, but it has evolved with the advent of new technologies and web services. Content may also be delivered via an intranet, utilizing a Learning Management System (LMS).

The models presented in table 2 underscore the flexibility in e-learning, demonstrating how these structures can be adapted to meet both academic and practical requirements, thereby ensuring effective and relevant learning across a variety of educational contexts. These models reflect not only technological evolution but also the necessity for an adaptable educational system capable of supporting the continuous development of competencies in the digital age.

The models applied in e-learning represent an essential framework for designing and implementing instruction in computer science disciplines at the university level. These models facilitate the development of systematic strategies that integrate educational theories, interaction methods, and assessment modalities, thereby contributing to the creation of an interactive, tailored, and effective learning experience within higher education.

Computer science disciplines are branches of knowledge focused on the study of computer science and information technology. They concern themselves with how information systems are developed, designed, implemented, and utilized to address various problems and human needs. Computer science disciplines may include, but are not limited to, programming, databases, networking and cybersecurity, artificial intelligence and machine learning, software development and web design, operating systems, and information technology. Studies in computer science provide the knowledge and skills necessary to contribute to advancement and innovation in a constantly evolving digital world.

Just as there is a lack of research identifying the most effective approaches for collaborating with labor market representatives, there are also gaps in studies determining the approaches that work best for specific groups across different types of institutions or educational cycles. As partnerships evolve at various levels and between diverse institutions, the needs of these groups may change, highlighting the necessity for ongoing adaptability and flexibility within the e-learning model to address these evolving requirements.

Alignment with labor market demands is analysed through actions taken at the program, department, institutional, and system levels to address the needs for job quantities and required competencies [37]. Many stakeholders are involved in activities related to funding and policy to promote this interest. Depending on the institutional level, these stakeholders may include higher education system leaders, rectors, department and program heads, faculty members, students, and employers. The engagement of these stakeholders is crucial for the successful implementation of the e-learning model, as it helps align educational strategies with institutional goals and labor market needs, and their support facilitates the provision of necessary resources and adequate infrastructure.

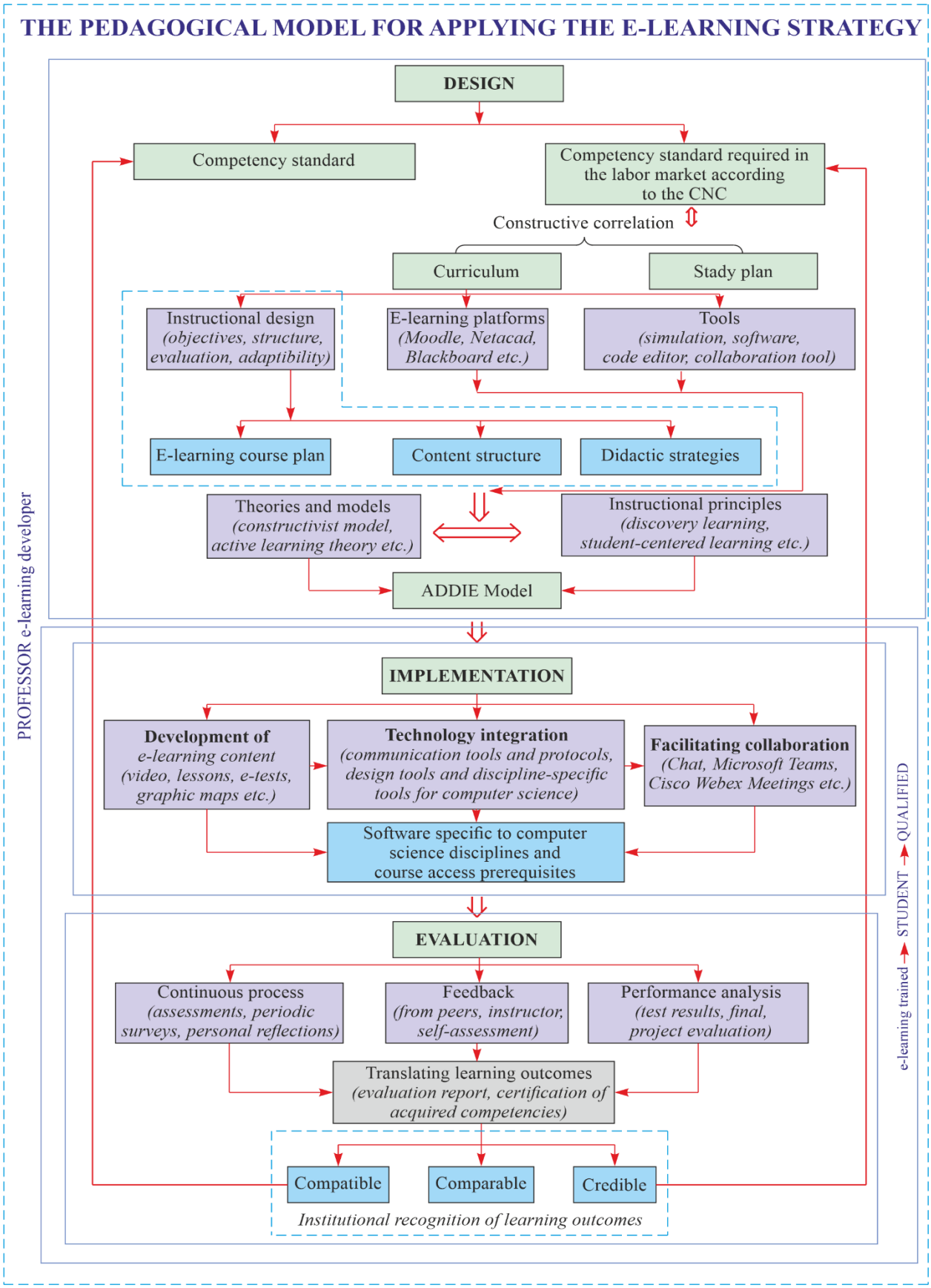

Fig. 2. The pedagogical model for implementing e-learning strategies in the study of computer science disciplines (MPISe-lSDI)

The core elements of the model encompass specific aspects of the design and implementation of e-learning strategies [38]. These include: 1. *Instructional design;* 2. E-learning platforms and tools; 3 *E-learning content development*; 4. *Technology integration*; 5. *Teaching strategies*.

It is important to distinguish between e-learning models integrated into the designed pedagogical model that are fundamentally reliant on technology and those that can operate both with and without it. Within the model, certain components, such as the use of e-learning platforms and online collaboration tools, are essential for facilitating real-time interaction and collaboration between instructors and students, making these models feasible and effective primarily due to technology. On the other hand, the designed model also includes teaching strategies and content structures that, although enhanced by the use of technology, can function in the absence of online technologies. Thus, the model ensures flexibility and adaptability, allowing for the effective implementation of e-learning in various environments and contexts.

This distinction highlights the flexibility of e-learning models to specific contexts and the learning needs of students. The use of technology must be justified and contribute to enhancing the quality of the learning process, and the choice of a particular e-learning model should consider the objectives and available resources.

The MPISe-lSDI model has been translated into educational practice through the presentation of a methodology for applying e-learning strategies, thereby ensuring an efficient and contextually relevant integration of technology into the study process.

In the CN course at UTM, the learning content focuses on the theoretical and practical aspects of designing, managing, and securing computer networks. This course is an integral part of the undergraduate programs and aims to deepen students' knowledge in the field of computer networking.

The e-learning strategy adopted for CN represents a combination of three models: traditional instruction enriched with digital resources and tools (Model 1), blended learning (Model 2), and online courses (Model 6). This strategy is designed not only to address the diverse needs of students but also to facilitate an effective transition between traditional and electronically mediated learning.

Model 1 is based on the course was delivered in a traditional face-to-face format but was enhanced through the use of digital resources, such as supplementary materials, video tutorials, and online simulations. Students had access to multimedia resources and collaboration platforms, which complemented the traditional lectures and facilitated a deeper understanding of the subject matter.

Model 2 has integrated online elements with offline activities, providing students with the opportunity to combine face-to-face lessons with online modules. Students participated in online sessions for discussions, interactive exercises, and assessments, thereby complementing what they learned in the classroom. This approach facilitated an effective transition from traditional to digital instruction.

Model 6 involves a fully online course delivery entirely online using a Learning Management System (LMS). Students accessed course materials, tests, and practical activities through the platform, allowing them to manage their own learning pace. This model facilitated access to distance learning and supported students in adapting to their individual needs.

The e-learning strategy adopted for the course combined these three models to address the diverse needs of students and facilitate an effective transition between traditional and electronically mediated learning.

The course implemented a traditional mix of teaching methods, including pre- and post-class activities available online. The course is initiated on an online platform rich in digital resources, such as recorded videos and topic-structured materials. These resources are accessible through a Learning Management System (MOODLE), managed by the UTM platform.

In addition to this digital environment, the course also included face-to-face components, where students have the opportunity to work either in groups or individually on essential activities. These in-person meetings significantly contribute to achieving the course objectives and facilitate interaction between students and instructors.

To ensure the proper development of students' knowledge and skills, various learning activities are included for each course topic. These activities range from self-assessment quizzes and questions to mini-research tasks and group discussions, focusing on problem-solving and identifying solutions to practical challenges related to computer networks.

The developed pedagogical model is structured into three main blocks: ***design, implementation,*** and ***evaluation.*** Design involves developing the curriculum, selecting instructional content, and identifying necessary resources, while implementation encompasses the processes of teaching, learning, and assessment. The evaluation component focuses on measuring student progress and providing the necessary feedback to enhance the learning process. Each of these blocks is interdependent and impacts the effectiveness of the teaching, learning, and assessment processes.

To ensure a coherent and effective structure of the instructional process, the implementation of the pedagogical model requires a well-defined horizontal alignment (fig. 2), also referred to as the horizontal alignment map. This alignment focuses on correlating learning

outcomes, teaching-learning methods, and specific assessment methodologies for each module. This approach ensures a coherent and structured framework for the development of competencies that need to be cultivated in each course.

The MPISe-lSDI pedagogical model pertains to the design, implementation, and evaluation of a digital course developed through e-learning strategies. The course design process is included in the *„Design"* block. This process begins with identifying domain-specific competencies and aims to develop a modular course that employs modern instructional strategies, tailored to the training needs of students and the demands of the labor market.

The **DESIGN** block is the initial phase in creating a modern environment focused on developing competencies necessary for the labor market. The applied description begins with how competency standards are integrated into the course:

1. The competency standard is closely linked to the professional profile, with each element of the curriculum contributing to the development of competencies within that profile.
2. The MPISe-lSDI model emphasizes aligning the university curriculum with labor market requirements through collaboration with employers and identifying relevant competencies.
3. Constructive alignment involves selecting appropriate instructional strategies to develop the declared competencies.
4. The curriculum is structured to build a solid foundation of knowledge and to allow for a logical progression to more advanced topics.

In the **IMPLEMENTATION** block of the MPISe-lSDI model, the designed strategies are put into practice. This phase is critical, as it transforms the concepts from the design stage into concrete learning experiences.

During the course content development phase, course materials are drafted and digital educational resources are selected or created. This process requires rigorous selection and careful structuring of the content to ensure it aligns with and develops the competencies established in the design phase.

The learning tasks and activities are designed to reflect the real-world requirements of the engineering field and to promote the application of knowledge in practical scenarios. These tasks must be diverse and tailored to cover a broad spectrum of skills, ranging from technical abilities specific to computer network engineering to transversal competencies such as critical thinking and problem-solving.

Continuous assessment and feedback are integrated into the course structure to monitor students' progress and adjust teaching methods as needed. Evaluations can take various forms, including tests, projects, presentations, and research papers, each contributing to the assessment

of competencies. Structured feedback is crucial for guiding the ongoing development of students' skills and ensuring that they can meet the demands of the job market.

The **EVALUATION** block within the MPISe-lSDI pedagogical model represents the final, crucial stage for ensuring the quality and effectiveness of the e-learning strategy. This ongoing process measures the extent to which learning objectives are achieved, collecting data for subsequent improvements. Evaluation begins from the initial interactions and continues throughout the entire course, utilizing formative and summative assessments, real-time activities, and electronic portfolios.

Continuous feedback between students and instructors fosters a student-centered learning culture, contributing to the dynamic adaptation of courses and long-term revisions of the curriculum to maintain relevance and alignment with academic and professional standards.

The MPISe-lSDI model, a dynamic mechanism grounded in the ADDIE framework, is designed to enhance the efficiency of the instructional process and interactivity, while fostering students' creative thinking. In this model, the instructor assumes the role of a facilitator, guiding students through the learning process. The instructor creates an interactive and collaborative learning environment, encourages critical thinking, promotes student autonomy, and directs students in strengthening their self-reflection and problem-solving abilities. Their role involves facilitating access to resources and supporting discussions and activities that help students deeply explore and understand the study materials.

In **chapter 3**, titled "The Praxiological Framework for Implementing the Pedagogical Model in the Study of Computer Science Subjects within the University Curriculum," the stages of the pedagogical experiment are detailed, and a statistical analysis of the obtained results is conducted using IBM SPSS Statistics 27. This software provides a comprehensive array of functionalities and tools for managing, analysing, and interpreting data. To test the research hypotheses, both the parametric Student’s t-test and the non-parametric Mann-Whitney U test were applied. The effect of implementing the pedagogical model and the developed methodology was assessed by calculating the effect size, a crucial statistical measure for quantifying the impact of the intervention and highlighting the practical relevance of the obtained results.

The objectives of the pedagogical experiment conducted in the research are as follows: (1) determining the initial level of competencies possessed by students relevant to the CN course; (2) establishing methodological benchmarks for the development of professional competencies; (3) updating and expanding teaching materials and educational resources; (4) organizing interactive and collaborative educational activities; (5) creating an integrated and flexible digital educational environment; (6) ensuring continuous access to educational materials: course materials

https://else.fcim.utm.md/course/view.php?id=569, Computer Networks lectures https://lectii.utm.md/courses/retele-de-calculatoare-computer-networks/ and network technician career path https://www.netacad.com/career-paths/network-technician; (7) developing and validating an assessment tool for professional competencies in the field of CN; (8) assessing the level of professional competencies in the field of CN; (9) collecting, statistically processing, and interpreting experimental data; (10) formulating conclusions.

The pedagogical experiment was conducted at UTM, FCIM, Department of Software Engineering and Automation (DISA) over the academic years 2019-2022. It involved 64 students in the observation phase, 77 students in the training phase, and 190 students in the assessment phase, which included 92 students from the control group and 98 students from the experimental group.

The observation phase aimed to identify the current state of knowledge and the initial level of expertise in the field of computer networks at that time. An analysis was conducted to assess the existing situation concerning the e-learning components of the initially proposed MPISe-lSDI pedagogical model in the context of the CN course.

The analysis of the model components was conducted by the author in collaboration with department members. This analysis encompassed: evaluating the course design strategy, assessing the relevance and currency of the study materials used, evaluating the available technological infrastructure and the use of specific software, and analysing the effectiveness of communication methods between students and instructors, including the use of online platforms.

The observations encompassed several aspects, including: curricular design, content materials, course delivery methods, communication between instructors and students, and evaluation methods. The course curriculum included a brief overview with objectives and study topics, a list of laboratory assignments, and bibliographic references. Course materials comprised excerpts from various monographs, teaching resources, and some internet resources, along with methodological instructions for conducting laboratory work in printed format. Additionally, at this stage, it was ensured that there were no significant differences between the groups involved in the experiment, as students from both samples had approximately the same level of preparedness.

During the **training phase of the experiment,** the curricula for all academic programs, including those with information technology courses, were reviewed. The curriculum for these disciplines was revised according to a competency-based approach, and the graduate profile was developed to encompass the set of competencies that graduates are expected to possess. The curriculum for the course „Computer Networks" was updated, and the course syllabus was revised to reflect these competencies. The course content was expanded to incorporate the latest

technologies and methods, adding new modules such as network security, network management, emerging technologies, as well as practical laboratories and simulation scenarios.

Teaching strategies were reconfigured to be student-centred, incorporating active learning methods such as group discussions, case studies, and projects. Periodic assessments and continuous feedback were integrated to monitor student progress and adjust teaching methods as necessary. Laboratory work was redesigned to provide students with relevant practical experiences, using modern equipment and real-world scenarios. Theoretical examples were combined with practical applications to ensure a deep understanding of the concepts.

The **control phase** was crucial for the final configuration of the MPISe-lSDI model implementation, as it allowed for the identification and resolution of potential issues and challenges before broad deployment within the faculty. This ensured that the pedagogical model was well-defined and that the necessary resources and tools were available to support its effective operation in both online and offline environments. Additionally, this phase provided the opportunity to train students for the paradigm shift in teaching, learning, and assessment methodologies.

In this context, the **null hypothesis (H_0)** was formulated as follows: the use of e-learning does not significantly affect student performance compared to traditional learning environments. The alternative **hypothesis (H_1)**: posits that the use of e-learning significantly enhances student performance compared to traditional learning environments.

To test these hypotheses and assess the significance of the mean differences between the experimental groups, an independent-samples t-test was conducted using SPSS. This statistical test was deemed appropriate due to the numeric nature of the research variable (final grade achieved in the course) and the evident independence of the groups. Table 3 presents the descriptive statistics for the experimental and control groups, including mean values, standard deviations, and standard errors for the overall grades achieved by the students.

Table 3. Statistical analysis by experimental groups, final evaluation

Group	N	Average result	Standard deviation	Average standard error
control	92	8,1359	,75609	,07883
experimental	98	8,5418	,99405	,10041

Table 4. Results of the independent samples t-Test for final assessment

	Levene's Test for Equality of Variances		t-test for Equality of the average results						
	F	Sig.	t	df	Sig. (2-tailed)	Difference between the average results	Standard error of the difference	95% Confidence Interval for the Difference	
								Bottom limit	Top limit
Assumed Equality of Variances	13,313	,000	-3,153	188	,002	-,40597	,12875	-,65994	-,15200
Assumption of unequal variances			-3,180	180,37	,002	-,40597	,12766	-,65786	-,15407

From Table 4, which presents the primary results of the independent samples t-test, it can be observed that, according to Levene's test, there is a significant difference between the variances of the means ($F = 13{,}313$, with $p = 0{,}000 < 0{,}05$). This indicates that the assumption of equal variances is not met, and the results of the t-test should be interpreted from the second row of the table. Therefore, $t(180{,}37) = 3{,}180$ with a significance level of $p = 0{,}002 < 0{,}05$, indicating significant differences between the means of the groups involved in the experiment. Specifically, the mean of the control group is 0.40 points lower than that of the experimental group ($8{,}14 < 8{,}54$), as detailed in Table 2.

Table 5. Normality tests, final evaluation

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Final evaluation	,104	190	,000	,963	190	,000
a. Lilliefors Significance Correction						

The Kolmogorov-Smirnov and Shapiro-Wilk tests indicate that the quantitative variable Final Evaluation does not follow a normal distribution: $K - S(190) = 0{,}104$ and $S - W(190) = 0{,}963$, with $p = 0{,}000 < 0{,}005$ (see Table 5). Consequently, the results of the t-test will be further examined using the Mann-Whitney test, which is appropriate for quantitative variables that are not normally distributed.

Table 6. Rank statistics, final assessment

	Experimental group	N	Rank average	Sum of ranks
Final evaluation	control	92	84,28	7754,00
	experimental	98	106,03	10391,00
	Total	190		

Table 6 presents the ranks of the overall grades obtained by students in the control group and the experimental group, highlighting a significant difference in the mean ranks. This suggests a positive impact of using e-learning strategies on the academic performance of students in the CN course.

Table 7. Mann-Whitney test statistics, final evaluation

	General grade
Mann-Whitney U	3476,000
Wilcoxon W	7754,000
Z	-2,727
Asymp. Sig. (2-tailed)	,006
a. Grouping Variable: Grup experimental	

According to the Mann-Whitney test statistics, $U = 3476{,}000$ and $Z = 2{,}727$, with $p = 0{,}006 < 0{,}05$, which confirms significant differences between the sample means, favoring the experimental sample, as the mean ranks are $84{,}28 < 106{,}03$.

In conclusion, the experiment results demonstrate that integrating e-learning strategies into the teaching, learning, and assessment process of computer science courses significantly improves the quality of the study process, thereby confirming the alternative hypothesis (H_1). This demonstrates the effectiveness of e-learning strategies in the context of university education and supports their integration into the curriculum to enhance students' learning experiences.

An essential criterion for testing the research hypothesis is the effect size of the independent variable (traditional learning environment versus electronically mediated learning environment) on the dependent variable (learning outcomes).

From table 8, it is observed that $d = 0{,}458 < 0{,}50$, which, according to Cohen's criteria, represents a medium effect of the independent variable on the dependent variable.

Table 8. Effect size for independent samples

		Estimated value	Confidence Interval 95%	
			Lower bound	Upper bound
Final evaluation	Cohen's d	-,458	-,745	-,169
	Hedges' correction	-,456	-,742	-,168
	Glass's delta	-,408	-,698	-,117

The graphical illustration of the means across samples is shown in fig. 3.

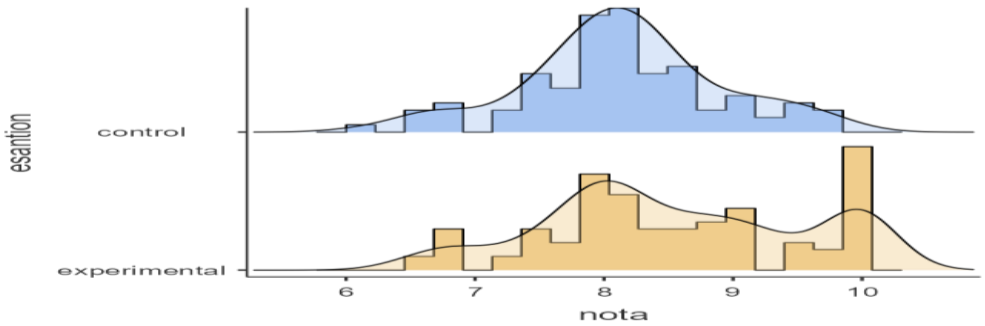

Fig. 3. Distribution of results for control and experimental group students

For the evaluation of the course ***Computer Networks***, a questionnaire was administered to the experimental group. The 8 categories of items in the questionnaire were classified into ***Content*** (A1, A6, A7, A8), ***Technology*** (A2, A4, A5), and ***Interaction*** (A3, A7). After quantifying each

category and summing the compatible items within each category at each level, three quantitative variables corresponding to the levels of ***Content, Technology***, and ***Interaction*** were constructed. To test the hypothesis of successfully implementing e-learning through the interrelation of its essential components—content, technology, and interaction—the Pearson correlation coefficient was calculated between the three levels (the variables are quantitative)

The results of the bivariate Pearson correlation test demonstrated a significant interaction (Sig. (2-tailed) = 0.000 < 0.01) among all three e-learning components and a direct proportional relationship (correlation coefficients r are greater than 0). Specifically, there is a strong link between content and technology, with $r = 0{,}638 > 0{,}50$, and between technology and interaction, with $r = 0{,}508 > 0{,}50$. The relationship between content and interaction is moderately strong, very close to strong, with $0{,}30 < r = 0{,}483 < 0{,}50$.

The correlation analysis of these components within the e-learning strategy demonstrates the successful implementation of e-learning in the context of the experiment, providing effective support for the teaching, learning, and assessment processes, and adapting to the specific needs of students.

The research results confirm the hypothesis formulated in the introduction, showing that the implementation of e-learning strategies significantly improved the learning outcomes and practical skills of students in the Computer Networks course. This underscores the added value of e-learning in higher education and its relevance for preparing future specialists in computer science disciplines.

CONCLUSIONS AND RECOMMENDATIONS

The research provides arguments in favor of adopting e-learning strategies in higher education institutions. Developing and implementing programs aligned with the e-learning approach is essential for ensuring the quality of the teaching process. The main findings of the research are summarized in the following **general conclusions**:

1. The need for a clear definition accepted by the academic community for the e-learning concept was highlighted. The analysis of specialized literature showed that the lack of a single definition generated varied and sometimes confusing interpretations. Reference studies have significantly contributed to solving these problems. Conceptual clarifications are essential for future research and effective implementation of the e-learning approach in higher education (ch. 1, § 1.1).

2. It has been shown that e-learning strategies are dynamic according to technological progress and educational paradigms. The MPISe-lSDI model developed and implemented in the thesis highlights the transition from using the traditional classroom enriched with digital resources to the fully online model. The model reveals the importance of a flexible and innovative approach, which takes into account new trends and requirements in the educational field, to ensure the relevance and effectiveness of e-learning strategies in the long term (chap. 1, § 1.2, § 1.3, ch. 2).

3. It was highlighted that the integration of digital technologies requires a rigorous and well-planned pedagogical approach. It is not enough just to adopt ICT tools, but it is essential to reconfigure teaching strategies to really ensure the learning process. The analyzes presented have shown that a well-structured design significantly improves study programs and leads to student satisfaction. The COVID-19 pandemic was a catalyst for the widespread adoption of the e-learning approach (chap. 1, § 1.3).

4. Through the implementation of the MPISe-lSDI model, the increase in the efficiency of the didactic process, the level of student involvement in learning, and their academic performance was demonstrated. The integration of e-learning strategies facilitated their access to diverse educational resources and promoted interactive, adaptive, and engaging learning. This model highlights the importance and potential of e-learning in improving the quality of the modern teaching process (chap. 2, § 2.1, § 2.2).

5. The complex role of collaboration and interaction was highlighted through the implementation of e-learning strategies, which encouraged and facilitated effective collaboration and constructive interaction between student – student, student – teacher. The use of discussion forums, chats and other online communication tools has helped to maintain an active, dynamic,

engaged learning environment, supporting continuous and engaged dialogue, vital to the modern educational process (ch. 2, § 2.3).

6. It was confirmed that MPISe-lSDI requires the planning, organization and monitoring of resources and infrastructure, the use of specific tools to deliver content and interaction, knowledge of e-learning platforms and active participation in courses. The MPISe-lSDI model integrates technological, pedagogical and management aspects to ensure an effective learning experience (ch. 2, § 2.4).

7. The statistical analysis of the experimental data demonstrated the effectiveness of the MPISe-lSDI model and the developed methodology, by improving the learning outcomes of the students in the RC course. The proposed model was adopted as a model for implementing e-learning strategies at the FCIM faculty level (chap. 3, § 3.1, § 3.2).

8. . The results obtained contributed to the solution of an important scientific problem which consists in the theoretical and praxeological substantiation of the pedagogical model for implementing e-learning strategies in the study of IT subjects in higher education, a fact that led to the improvement of the quality of the training of future specialists in the field and to achieve the research objectives: analysis of theoretical concepts regarding e-learning, e-learning strategies and the situation in the field; elaboration of the pedagogical model for the implementation of e-learning strategies in the study of IT subjects (MPISe-lSDI); developing the methodology for implementing the designed model; the experimental evaluation of the efficiency of the model and the developed methodology, regarding the implementation of e-learning in the teaching of IT courses in engineering specialties in higher education, through the statistical analysis of the data (ch. 1, 2, 3).

Although the data from the pedagogical experiment confirm the initial research hypothesis, certain **limits** were identified: given the rapid pace of changes in information technologies, predicting future requirements for the effective implementation of e-learning in computer science disciplines at the university level is challenging; the impact of traditional instructional practices on the development of computer skills was not assessed in detail compared to e-learning practices, with a primary focus on analysing and evaluating the effectiveness of the MPISe-lSDI pedagogical model.

In light of the results obtained, the following **recommendations** for e-learning strategies in future research are proposed:

1. The development of a legislative and educational policy framework for the integration of e-learning strategies is essential. It is recommended to establish a normative framework at institutional and departmental level, which effectively regulates e-learning strategies in curricula.

Quality standards are essential to ensure widespread recognition and validation of computer science education programs.

2. Adaptation and expansion of the MPISe-lSDI pedagogical model. It is proposed to adapt and expand the MPISe-lSDI pedagogical model within other university disciplines, considering the demonstrated effectiveness of this model and the advantages provided by the integration of e-learning strategies in the teaching, learning and evaluation process. The MPISe-lSDI model has demonstrated improvement in student learning outcomes and can be adapted for other disciplines.

3. Capitalizing on the components of the model in other educational dimensions. Leveraging components of the model in developing other dimensions of educational design, such as creating educational content, developing open resources, problem solving, and systems security. Integrating components of the MPISe-lSDI model into various aspects of instructional design can enhance the quality and effectiveness of instruction.

4. Encouraging collaboration and exchange of best practices in e-learning. Higher education institutions must encourage collaboration and exchange of best practices in e-learning, both nationally and internationally. Partnerships with the private sector and the IT sector can contribute to the harmonization of efforts and the development of innovative and effective educational solutions. Cross-sector partnerships facilitate the adoption and development of innovative e-learning strategies by providing access to resources and expertise.

Research perspectives: Based on the results, future research could explore the integration of Artificial Intelligence (AI) to personalize and optimize the learning experience by adapting content in real-time to the specific needs of students. The development of the MPISe-lSDI model could be extended by incorporating machine learning technologies, allowing for the dynamic adjustment of pedagogical strategies based on academic performance. Exploring virtual and augmented reality could create immersive and interactive learning environments, significantly enhancing the practical component of instruction. International collaborations within global research networks could facilitate the exchange of best practices and the development of innovative e-learning solutions, contributing to the ongoing evolution of university-level instruction.

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ADNOTARE

PECA Ludmila

STRATEGII E-LEARNING ÎN STUDIEREA DISCIPLINELOR INFORMATICE DIN CURRICULA UNIVERSITARĂ

Teza de doctor în științe ale educației, Chișinău, 2024

Structura tezei: teza cuprinde introducere, trei capitole, concluzii și recomandări, bibliografie din 244 de surse, adnotare (română, engleză, rusă), cuvinte-cheie, lista abrevierilor. Teza este expusă pe 141 pagini text de bază, 15 figuri, 25 tabele și 18 anexe. Rezultatele obținute sunt publicate în 16 lucrări științifice.

Cuvinte-cheie: e-learning, model pedagogic, sistem de management al învățării, strategii e-learning, instrumente digitale, rețele de calculatoare, discipline informatice.

Scopul cercetării: elaborarea modelului pedagogic și a metodologiei de implementare, fundamentate teoretic și praxiologic, de utilizare eficientă a strategiilor e-learning în studierea disciplinelor informatice în învățământul superior.

Obiectivele cercetării: (1) analiza conceptelor teoretice cu privire la e-learning, strategii e-learning și a situației în domeniu; (2) elaborarea modelului pedagogic de implementare a strategiilor e-learning în studierea disciplinelor informatice; (3) elaborarea metodologiei de implementare a modelului proiectat; (4) evaluarea experimentală a eficienței modelului și a metodologiei elaborate.

Noutatea și originalitatea științifică a cercetării: a) fundamentarea teoretică și practică a eficientizării studierea disciplinelor informatice prin elaborarea unui model pedagogic axat pe e-learning; b) elaborarea metodologiei de implementare a modelului pedagogic prin proiectarea unui curriculum e-learning; c) integrarea strategiilor e-learning în procesul de predare, învățare și evaluare la disciplinele informatice, pentru a spori eficiența și calitatea instruirii.

Rezultatul obținut care contribuie la soluționarea unei probleme științifice importante: fundamentarea teoretică și praxiologică a modelului pedagogic de implementare a strategiilor e-learning în studiul disciplinelor informatice în învățământul superior, fapt ce a condus la îmbunătățirea calității formării viitorilor specialiști în domeniu.

Semnificația teoretică a lucrării: actualizarea contextuală a teoriilor cu privire la abordarea e-learning, analiza și sistematizarea conceptelor e-learning și strategie e-learning, fundamentarea teoretică a modelului pedagogic de implementare a strategiilor e-learning în studiul disciplinelor informatice.

Valoarea aplicativă a lucrării: aplicabilitatea modelului și metodologiei elaborate, care au fost implementate cu succes la cursul Rețele de calculatoare, dar și a platformei, care a fost testată și validată în cadrul cursului RC, pentru eficientizarea disciplinelor informatice.

Implementarea rezultatelor științifice: a fost realizată în cadrul experimentului pedagogic, desfășurat la cursul Rețele de Calculatoare, în care au fost implicați 331 de studenți ai Facultății de Calculatoare, Informatică și Microelectronică, Universitatea Tehnică din Moldova.

ANNOTATION

PECA Ludmila

E-LEARNING STRATEGIES IN THE STUDY OF COMPUTER SCIENCE DISCIPLINES IN THE UNIVERSITY CURRICULUM

Doctoral thesis in educational sciences, Chisinau, 2024

Thesis structure: introduction, three chapters, conclusions and recommendations, bibliography with 244 sources, annotations (Romanian, English, Russian), keywords, and abbreviations. The thesis consists in 141 basic text pages, 15 figures, 25 tables, and 18 appendices. The results are published in 16 scientific papers.

Keywords: e-learning, pedagogical model, learning management system, e-learning strategies, digital tools, computer networks, computer science disciplines.

Aim of the research: development of a pedagogical model and an implementation methodology, theoretically and praxeologically grounded, for the effective use of e-learning strategies in the study of computer science disciplines in higher education.

Objectives of the research: (1) analysis of theoretical concepts regarding e-learning, e-learning strategies and the situation in the field; (2) elaboration of the pedagogical model for the implementation of e-learning strategies in the study of computer science subjects; (3) development of the implementation methodology for the designed model; (4) experimental evaluation of the efficiency of the developed model and methodology.

Scientific novelty and originality of the research: a) the theoretical and practical substantiation of the efficiency of the study of computer science subjects by developing a pedagogical model focused on e-learning; b) development of the methodology for implementing the pedagogical model by designing an adapted e-learning curriculum; c) the integration of e-learning strategies in the teaching, learning and assessment process in computer science subjects, in order to increase efficiency and quality.

The obtained result that contributes to the solution of an important scientific problem: theoretical and praxeological grounding of the pedagogical model for the implementation of e-learning strategies in the study of computer science subjects in higher education, which led to the improvement of the quality of training for future specialists in the field.

Theoretical significance of the study: contextual updating of theories regarding the e-learning approach, analysis and systematization of e-learning and e-learning strategy concepts, theoretical grounding of the pedagogical model for the implementation of e-learning strategies in the study of computer science subjects.

Practical value of the study: the applicability of the developed model and methodology, which were successfully implemented in the Computer Networks course, but also of the online and blended learning platform, which was tested and validated in the CN course, to improve the study of computer science subjects.

Implementation of scientific results: The implementation occurred within the pedagogical experiment, carried out in the CN course, in which 331 students of the Faculty of Computers, Informatics and Microelectronics, Technical University of Moldova were involved.

АННОТАЦИЯ

ПЕКА Людмила

СТРАТЕГИИ ЭЛЕКТРОННОГО ОБУЧЕНИЯ В ИЗУЧЕНИИ КОМПЬЮТЕРНЫХ ДИСЦИПЛИН В УНИВЕРСИТЕТСКОЙ ПРОГРАММЕ

Докторская диссертация по педагогическим наукам, Кишинёв, 2024 год

Структура диссертации: введение, три главы, выводы и рекомендации, библиография из 244 источников, аннотации (румынский, английский, русский), ключевые слова, список аббревиатур. Диссертация изложена на 141 страницах основного текста, 15 рисунках, 25 таблицах и 18 приложениях. Полученные результаты опубликованы в 16 научных статьях.

Ключевые слова: электронное обучения, педагогическая модель, система управления обучением, стратегии электронного обучения, цифровые инструменты, компьютерные сети, компьютерные дисциплины.

Цель диссертации: разработка педагогической модели и методологии её внедрения, теоретически и праксиологически обоснованных, для эффективного использования стратегий электронного обучения в изучении компьютерных дисциплин в высшем образовании.

Задачи исследования: (1) анализ теоретических концепций, касающихся электронного обучения, стратегий электронного обучения и ситуации в данной области; (2) разработка педагогической модели внедрения стратегий электронного обучения в изучение компьютерных дисциплин; (3) разработка методологии внедрения разработанной модели; (4) экспериментальная оценка эффективности разработанной модели и методологии.

Научная новизна и оригинальность исследования: а) теоретическое и практическое обоснование повышения эффективности изучения компьютерных дисциплин путём разработки педагогической модели, ориентированной на электронное обучение; б) разработка методологии внедрения педагогической модели через проектирование адаптированного к электронному обучению учебного плана; в) внедрение стратегий электронного обучения в процессе преподавания, обучения и оценки по компьютерным дисциплинам с целью повышения их эффективности и качества.

Полученный результат, способствующий решению важной научной проблемы: теоретическое и праксиологическое обоснование педагогической модели внедрения стратегий электронного обучения в изучение компьютерных дисциплин в высшем образовании, что привело к улучшению качества подготовки будущих специалистов в данной области.

Теоретическая значимость исследовании: контекстуальное обновление теорий, связанных с электронным обучением, анализ и систематизация концепций электронного обучения и стратегии электронного обучения, теоретическое обоснование педагогической модели внедрения стратегий электронного обучения в изучение компьютерных дисциплин.

Практическая ценность исследования: применимость разработанной модели и методологии, которые были успешно внедрены в курсе „Компьютерные сети”, а также платформы онлайн и смешанного обучения, которая была протестирована и проверена в рамках курса КС, для повышения эффективности изучения компьютерных дисциплин.

Внедрение научных результатов: осуществлялось в ходе педагогического эксперимента, проведенного в рамках курса „Компьютерные сети”, в котором были задействованы 331 студентов факультета Компьютеров, Информатики и Микроэлектроники Технического Университета Молдовы.

PECA LUDMILA

E-LEARNING STRATEGIES IN THE STUDY OF COMPUTER SCIENCE DISCIPLINES IN THE UNIVERSITY CURRICULUM

532.02 –SCHOOL DIDACTICS ACROSS LEVELS AND EDUCATIONAL DISCIPLINES (COMPUTER SCIENCE)

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