



Ministry of Education
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SUMMARY THESIS
CONTRIBUTIONS ON ADAPTIVE LEARNING
SYSTEMS IN E-LEARNING TECHNOLOGIES

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The development trend and popularity of the e-learning sector around the world has not only brought advantages in information and communication technology (ICT), but has also brought a recognition of the importance of the need for teachers to keep up with changes in teaching and learning in organizational areas, curriculum, infrastructure and pedagogy. This evolution has led teachers to create or adopt appropriate tools to effectively support the use of ever-changing digital technologies.

New information and communication technologies are profoundly improving the way we inform, communicate and train. This technological advent has revealed a new way of learning, known as e-learning. It is based on access to online, interactive and sometimes personalized training, distributed over a network (Internet or Intranet) or other electronic media. This access facilitates the development of learners' skills, making the learning process independent of time and place (Madani, Bengourram, Erritali, Hssina, & Birjali, 2017).

In recent years, technology has significantly transformed our lifestyle, the way we communicate and especially the way we learn, opening up a wide range of new opportunities, with innovative products and emerging fields becoming more and more present in our daily lives. Technological evolution has changed and modernized traditional teaching methods, facilitating the use of innovative means of learning and testing. At the same time, the Internet has revolutionized all fields, becoming the most important source of information and communication, deeply integrating into our everyday life. Education sectors around the world have witnessed a profound digital transformation, accelerated by the rapid evolution of ICT. This transformation has been catalyzed in particular by the need to adapt to increasingly diverse learning environments and the changing expectations of modern learners and teachers. E-learning, as an educational method that uses digital resources to facilitate access to learning, independent of geographical or temporal constraints, has become a central pillar in global educational strategies.

Contextualizing the growth of e-learning requires a detailed analysis of the factors contributing to this expansion. One of these factors is the globalization of education, which promotes democratized access to learning resources. Today's learners, coming from diverse cultural and socio-economic backgrounds, demand flexible and personalized educational solutions that meet their specific needs. In addition, the growth and penetration of the Internet has facilitated the expansion of e-learning platforms, transforming traditional teaching methods into interactive and multidimensional learning experiences.

Simultaneously with these technological developments, a change in approach to pedagogy has been observed. Modern learning theories such as constructivism, which emphasize the active role of the student in constructing knowledge, are increasingly integrated into the curriculum design of e-learning programs. These theories promote a student-centered approach, contrasting with the traditional educator-centered model. In this context, adaptive learning systems, which use algorithms to customize the content and pace of learning according to each student's ability and progress, become essential for maximizing pedagogical efficiency.

With the evolution of technology, new challenges and opportunities arise for the effective integration of ICT solutions in education. This includes the need to ensure data security, promote equity in access to technology and adjust teaching methodologies to optimize the use of digital platforms. Privacy and ethical issues, as well as the risks of digital segregation, require special attention to guarantee that all learners can equally benefit from the advantages of e-learning.

In this complex and ever-evolving context, this thesis, entitled "*Contributions on adaptive learning systems in e-learning technologies*" aims to explore how systems using adaptive learning can be optimized to meet the emerging needs of modern education by investigating specifically how these systems can be designed and implemented to improve the accessibility, personalization and effectiveness of the learning process.

This research can be useful because it will present adaptive e-learning systems as an integrated part of the e-learning process (alternative to traditional learning) by describing theoretical approaches, dimensions, design and architecture, highlighting some perspectives for future research actions, also offering adaptive learning testing in the university environment by creating a system that uses these tools in the educational process.

The thesis is structured in seven chapters, each addressing essential aspects of research on adaptive learning systems in e-learning technologies.

The first chapter of the thesis, "*Introduction*", explores the fundamentals of e-learning, highlighting the general context of its development and popularity at the global level. Information and communication technologies (ICT) have brought significant improvements in the ways of information, communication and training, revealing a new way of learning known as e-learning. This type of learning, based on access to interactive and personalized online training, distributes knowledge through networks (Internet or Intranet) and other electronic supports, allowing the development of learners' skills independently of time and place. The motivation and utility of research is heightened by the need to keep pace with changes in teaching and learning. Educational institutions and teachers must adopt and create appropriate tools to support the effective use of digital technologies. The research aims to explore and implement innovative solutions for improving the quality and efficiency of education through adaptive e-learning based on artificial intelligence. This is motivated by the desire to invest in solutions that can significantly improve the educational process, providing better access to resources and personalizing learning experiences according to the individual needs of learners.

The research methodology details the approaches used to assess students' academic performance, motivation and engagement. The research methodology flow presented in this chapter details the objectives, research techniques and expected results. Research hypotheses are formulated to test the effectiveness of adaptive learning systems and to identify the benefits, challenges and best practices associated with the use of these advanced technologies.

The second chapter, "*Field analysis*", explores in detail the main educational theories and how they are integrated into e-learning. Behaviorism, cognitivism, constructivism and connectivism are analyzed, each theory having specific applications in the development of e-learning platforms. Behaviorism focuses on observable responses and immediate feedback, while cognitivism emphasizes internal mental processes and the organization of information. Constructivism encourages the active construction of knowledge through direct and collaborative experiences, and connectivism emphasizes the importance of connections and networks in the digital age. These theories provide a solid pedagogical framework for creating and implementing e-learning methods that are tailored to the diverse needs of learners. The chapter also details various forms of e-learning and their practical applications, such as mobile learning, micro-learning, social learning, digital learning, gamification, virtualization and blockchain in education. Each of these forms is analyzed to highlight the associated benefits and challenges. The chapter emphasizes the importance of adapting and combining these forms to enhance the educational experience. The conclusions of the chapter suggest that the integration of educational theories and modern technologies can create an effective and personalized learning environment capable of meeting the diverse needs of learners.

Chapter three, "*Study on the challenges in implementing e-learning in educational institutions in the context of the COVID-19 pandemic*", examines the major challenges faced by educational institutions in implementing e-learning in the context of the COVID-19 pandemic. The pandemic forced a forced acceleration of the digitization process, forcing educational institutions to adopt online learning solutions in a very short time. This rapid transition was not properly planned, leading to numerous technical and pedagogical difficulties. Educational institutions have had to transfer course, seminar, laboratory and even practice, mentoring and career counseling activities to the online environment. The sudden change highlighted serious problems related to the digitization of education in Romania, many institutions being unprepared for this radical restructuring. Challenges included insufficient infrastructure, limited digital skills of teachers and students, and lack of adequate technical support. In this context, the adaptation of contents and methodologies to suit the new requirements was essential, and the institutions had to face immediate requirements to recalibrate the hardware and software infrastructure to support a large number of simultaneous users.

This chapter emphasizes the importance of digital skills and continuous training to ensure the quality of the online educational process. Good practices and lessons learned from this forced transition period are identified, which can be used to continuously improve e-learning systems. The conclusions drawn show that while the pandemic has exposed many shortcomings, it has also served as a catalyst for innovation and rapid adaptation in education. Institutions that had already implemented e-learning solutions were able to adapt more easily, demonstrating the advantages of a well-developed digital infrastructure integrated into the educational strategy.

Chapter four, "*Research on adaptive learning in e-learning platforms*", provides a comprehensive review of the literature on adaptive learning in e-learning platforms, emphasizing the theoretical foundations that support this modern pedagogical approach. Adaptive learning customizes the learning experience to the needs and styles of individual learners, using data collected about them to dynamically adjust educational content and instructional methods. This personalization increases the efficiency of the learning process and the engagement of students, allowing them to progress at their own pace and benefit from specific and relevant feedback. The concept and context of adaptive learning are explored in detail, highlighting the key differences between traditional and adaptive e-learning platforms. While traditional platforms deliver the same content to all learners, adaptive platforms use advanced algorithms to tailor content and teaching methods to each learner's individual performance and preferences. This leads to a significant transformation of the learning experience, making it more interactive and effective, and better responding to the diverse needs of learners.

The impact of artificial intelligence (AI) and machine learning in e-learning is analyzed through the lens of how these advanced technologies are revolutionizing the educational process. AI algorithms collect and interpret data about learner behavior, detecting patterns and providing personalized recommendations. The use of AI enables the creation of interactive and adaptive learning environments that dynamically react to learner needs, thereby improving academic outcomes and ensuring a deeply personalized learning experience.

The directions and aims of the research in this chapter are addressed through a rigorous study of the specialized literature, using advanced methods for the selection and analysis of relevant articles. The methodology includes a literature review performed with the software VOSviewer, which helps identify and visualize bibliometric networks and key terms associated with adaptive learning in e-learning platforms using AI/ML algorithms. Research findings highlight current trends and emerging applications of adaptive learning, demonstrating its potential to transform education by personalizing and optimizing the learning experience for each learner.

Chapter five, "*Creating a machine learning based system for the e-learning platform*", explores the implementation of a machine learning based e-learning system, highlighting the crucial role of this technology in education. Machine learning is essential for creating adaptive systems that respond to the individual needs of learners. This involves the use of advanced algorithms that can analyze student data and adjust teaching materials and methods to optimize the educational process.

The proposed system for adaptive e-learning includes three main pillars, each playing a specific role in personalizing the learning experience. Pillar I focuses on the learner, where an individualized profile is created based on learning styles and past performance. Data collection is done through initial surveys and monitoring of activities on the platform. Classification algorithms and factor analysis are used to identify predominant learning styles and customize the educational materials provided to learners.

Pillar II involves the system part of the platform, where learner data is analyzed in detail to tailor content and learning experiences. Machine learning algorithms are used to identify patterns and provide personalized recommendations. This includes continuous assessment of learner progress and adjusting teaching methods based on individual performance. The system's database stores all course materials and user information, ensuring easy access to resources and continuous feedback for constant content improvement.

Pillar III focuses on the teacher, providing tools and resources to support personalization of teaching methods. Teachers receive detailed information about learner performance and preferences, allowing them to adjust teaching materials and methods to maximize educational effectiveness. Real-time feedback and continuous assessment of learner progress are essential for prompt interventions and additional support, thus ensuring a personalized and effective learning experience for each student.

Chapter six, "*Description of the study on the evaluation of the impact of adaptive learning*", describes in detail the study carried out to evaluate the impact of adaptive learning on the motivation and academic performance of students. The context of the study is based on the need to overcome the limitations of traditional teaching methods, which fail to adapt to the individual needs of students. Adaptive learning, supported by artificial intelligence (AI), offers a promising solution by personalizing and creating an engaging learning experience. The study sought to analyze how these learning systems can transform education by improving student motivation and academic performance. The research methodology included a diverse sample of students, divided into two groups: an experimental one, which used the adaptive learning system, and a control group, which used traditional learning methods. By using a satisfaction questionnaire, learner motivation was measured, while the comparative analysis of academic performance between the two groups highlighted the possible advantages of adaptive systems. The study also included analysis of learning behavior by monitoring activities and evaluating progress on modules.

The study results demonstrated a significant positive impact of AI-based adaptive learning on students' academic performance and motivation. The experimental group obtained higher academic averages compared to the control group, confirming the hypothesis that the adaptive learning system improves academic results. The majority of students in the experimental group reported increased motivation and greater commitment to the learning process, and their learning behavior was more consistent, showing significant improvements in problem-solving and critical thinking skills.

The study concluded that the use of AI-based adaptive learning can transform the educational experience, providing tangible benefits in academic performance and student motivation. However, it was noted that there are also challenges, such as the complexity of implementing adaptive technologies and individual variations in students' adaptation to new learning methods. These findings emphasize the need for long-term observation to determine the durability of the observed benefits and to ensure broad acceptance of these innovative technologies.

The thesis demonstrates that e-learning, supported by modern technologies and adapted educational theories, represents an effective and necessary method for contemporary education. The analysis of the field showed that the integration of educational theories such as behaviorism, cognitivism, constructivism and connectivism can provide a robust framework for the development of e-learning platforms, thus improving the learning process through personalization and interactivity. Adapting these theories to the digital environment allows for the creation of varied and effective educational experiences that better meet the needs of learners.

The study on the challenges of e-learning implementation in the context of the COVID-19 pandemic revealed multiple difficulties, but also significant opportunities for innovation and rapid adaptation. Institutions that have managed to implement effective e-learning solutions have demonstrated that a well-prepared digital infrastructure can ensure the continuity of education and can respond flexibly to the demands of a changing educational environment. Lessons learned during this period can serve as a basis for future improvements and better preparedness for similar challenges.

Research on adaptive learning has highlighted the significant potential of artificial intelligence and machine learning algorithms in personalizing learning experiences. The study of the specialized literature and the results of the bibliometric analysis showed that adaptive learning can transform education by continuously adapting the educational content to the needs and individual performances of the learners. This not only improves academic achievement, but also increases student motivation and engagement, giving them a more satisfying and relevant educational experience.

In conclusion, the thesis confirms that the use of advanced technologies and innovative methodologies in e-learning, such as systems based on machine learning, can bring substantial benefits to education. The correct and strategic implementation of these solutions can significantly improve the quality of the educational process, ensuring more efficient and personalized learning. However, the long-term success of these technologies requires rigorous planning, ongoing teacher training, and constant adaptation to the changing needs of learners.