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From the Pandemic to Chatbots – Revolutionary Changes in the Digital Learning Environment between 2019 and 2024

Theses of the PhD Dissertation



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Introduction

The expansion of digital technologies has been one of the most defining processes in education in recent decades, fundamentally transforming the traditional frameworks of teaching and learning. The development of information and communication technologies (ICT) has enabled the emergence of electronic learning environments, which have redefined not only the ways of acquiring knowledge, but also the organization of the learning process and the roles of learners (Komenczi, 2013; Szűts, 2020).

The period between 2019 and 2024 brought particularly intensive changes. The COVID-19 pandemic forced a global transition to digital modes of education, during which students and teachers rapidly adapted to online learning environments (UNESCO, 2021). This "forced digitalization" not only exposed shortcomings in technological infrastructure but also highlighted inequalities in digital competencies and access (Racskó, 2017).

Following the pandemic, education reached another turning point with the emergence of artificial intelligence-based applications. Tools such as chatbots and adaptive learning systems offer opportunities for personalized learning, immediate feedback, and more effective support of the learning process (Molnár, 2019; Selwyn, 2014). At the same time, these new technologies raise pedagogical, ethical, and methodological challenges, prompting educational stakeholders to develop new approaches.

For Generation Z, the digital environment is a natural medium, and therefore their learning habits and expectations differ from those of previous generations. The demand for interactivity, flexibility, and instant access has become a defining factor, necessitating the development of new types of learning environments (Prensky, 2001; Tapscott, 2009).

This research is situated within this dynamically changing educational and technological context and aims to explore how the pandemic and the emergence of AI-based tools have influenced digital learning environments, with particular emphasis on the experiences and practices of high school students.

1. Topic and Aim of the Research

The focus of this research is the examination of the transformation of the digital learning environment, with particular attention to the changes that occurred between 2019 and 2024. This period is characterized by two mutually reinforcing, systemic influences shaping educational practice: on the one hand, the forced digitalization triggered by the COVID-19 pandemic, and on the other, the rapid emergence and spread of artificial intelligence-based tools.

The dissertation is based on a complex interpretation of the digital learning environment, encompassing the use of e-learning tools, the role of interactive learning environments, learning activities conducted on social platforms, and the function of user-generated content in education. The study does not approach the issue solely from a technological perspective, but rather from the standpoint of students' experiences, attitudes, and practices, with particular emphasis on the perspective of high school students.

The primary objective of the research is to explore how and to what extent the digital learning environment has transformed during the examined period, and how these changes are reflected

in students' everyday learning practices. Within this framework, the study is structured along three interrelated dimensions.

The first dimension focuses on mapping the pre-pandemic state. In this phase, the research aims to examine students' digital device usage habits, the prevalence of e-learning tools, and their attitudes toward online learning environments. This baseline provides an opportunity to interpret and compare subsequent changes.

The second dimension centres on the period during the pandemic. In this phase, the research seeks to analyse how the forced digital transition affected learning processes, tool usage, and students' attitudes. Particular attention is given to factors such as infrastructure, access to technology, levels of digital competence, and perceptions of the effectiveness of online learning environments.

The third dimension investigates the impact of the emergence of artificial intelligence-based tools. The aim is to explore the role that AI-based applications – especially chatbots – play in the learning process, and how they influence students' learning strategies, attitudes, and future expectations. The study also examines the opportunities and challenges these tools present for education.

An additional objective of the research is to compare the results of the different stages of investigation, enabling a dynamic interpretation of the changes in the digital learning environment. This makes it possible to identify the lasting effects of the pandemic and the emergence of AI tools on education, as well as the extent to which these effects have been integrated into everyday learning practices.

Overall, the research aims not only to describe these phenomena but also to interpret and contextualize them. The findings may contribute to a better understanding of the development of digital pedagogy and support the formulation of practical conclusions that can assist educational systems in adapting to a rapidly changing technological environment.

2. Theoretical Framework and Context

The study of digital learning environments requires a complex theoretical approach, as the phenomenon lies at the intersection of multiple disciplines – primarily education science, information society theory, and educational technology. The theoretical framework of the dissertation is grounded in the concepts of the information and knowledge-based society, the development of information and communication technologies (ICT), the emergence of electronic learning environments, as well as user-generated content and the educational applications of artificial intelligence (AI) (Komenczi, 2006; Szűts, 2020).

The emergence of the information society has fundamentally transformed the ways in which knowledge is created and transmitted. Developments in microelectronics, computing, and network communication have enabled the global production and distribution of digital content, leading to the decentralization of learning (Ceruzzi, 2003; Castells, 2010). In a knowledge-based society, learning is no longer confined to institutional frameworks but extends to informal and non-formal learning spaces, resulting in the emergence of new learning models (Komenczi, 2006; Komenczi, 2013).

In this environment, the use of ICT tools and the level of information literacy become determining factors. Information literacy encompasses not only technical skills but also the ability to critically interpret and ethically use information (Racskó, 2017). The effectiveness of digital learning environments is closely linked to the digital competencies of both learners and educators, making this a key issue for educational systems (Komenczi, 2013; Szűts, 2020).

The development of electronic learning environments can be understood through the emergence and expansion of e-learning. While the concept of e-learning appears in various forms in the literature, a common characteristic is that it relies on technological support for the learning process and enables flexibility in time and space (Komenczi, 2006; Radácsi & Benedek, 2005). Modern e-learning systems increasingly integrate interactive and collaborative elements that promote active learner participation and enhance the effectiveness of the learning process (Komenczi, 2013).

Interactive learning models and user-generated content play a significant role in the transformation of learning environments. The emergence of Web 2.0 technologies has enabled learners to become not only consumers but also active creators of learning content. Social platforms and learning networks contribute to collaborative knowledge construction and the strengthening of collaborative learning forms (Seitzinger, 2018; Wheeler, 2010; Forgó, 2014). This approach aligns with constructivist learning theories, which view learning as an active process of meaning-making (Komenczi, 2006; Selwyn, 2014).

An important element of the theoretical background is the study of Generation Z, whose members have been socialized in a digital environment. Online communication, social media, and digital tools are natural for them, significantly influencing their learning habits and expectations (Prensky, 2001; Tapscott, 2009). For Generation Z learners, interactivity, rapid feedback, and visual content are of particular importance, necessitating the application of new pedagogical approaches (Komenczi, 2013; Szűts, 2020).

The COVID-19 pandemic played a decisive role in the development of digital learning environments, bringing about radical changes in education. During the forced transition to digital learning, online learning forms became dominant in a short time, accelerating the spread of e-learning tools and platforms (UNESCO, 2021). The pandemic highlighted infrastructural shortcomings, inequalities in access, and differences in digital competencies, all of which significantly affect learning outcomes (Racskó, 2017; UNICEF, 2023).

In recent years, digital education has entered a new phase of development with the emergence of artificial intelligence-based technologies. AI tools – particularly chatbots and adaptive learning systems – can personalise the learning process, supporting independent learning, and providing real-time feedback (Molnár, 2019). While these tools offer new opportunities for improving learning efficiency, they also raise pedagogical and ethical questions, such as the transformation of the teacher's role and the need to rethink assessment methods (Selwyn, 2014; Szűts, 2020).

When examining digital learning environments, it is essential to consider their social embeddedness. Educational systems are in constant interaction with technological and societal changes, meaning that digital solutions represent both opportunities and challenges. On the one hand, they expand learning opportunities; on the other, they may create new forms of inequality, particularly in terms of access and competencies (Kozma, 2015; Forray, 2015).

Overall, the theoretical framework highlights that the transformation of digital learning environments is a multifactorial process involving technological, pedagogical, and social factors. The aim of the dissertation is to explore the interrelationships among these factors, with particular attention to how the pandemic and the emergence of AI have reshaped the conditions and practices of learning. The theoretical background thus provides a foundation for the empirical investigations and enables a comprehensive interpretation of the results.

3. Research Questions and Hypotheses

The aim of the research is to explore the transformation of the digital learning environment between 2019 and 2024, with particular emphasis on the effects of the pandemic and the emergence of AI-based tools. The study was conducted in several interrelated phases, enabling the temporal comparison and interpretation of changes. Accordingly, the research questions and hypotheses are organized around three main dimensions, following the logic of the research phases.

3.1. Hypotheses Related to the Pre-Pandemic State

H1. Students consider the role of online-organized study groups important in building and maintaining student communities, regardless of their educational profile.

H2. There is no significant difference between urban and rural students in their internet usage habits.

H3. There is no difference between Hungarian and Romanian students in their evaluation of the role of online learning groups.

3.2. Open Questions Related to the Pre-Pandemic State

Q1. Is it generally characteristic that students prefer using mobile computing devices (e.g., netbooks, mobile phones) for both personal and school-related activities?

Q2. Do most students believe that they possess sufficient knowledge of hardware, software, and internet usage to complete their tasks?

Q3. Are most students members of at least one study-related group, typically organized on a social media platform?

Q4. Is it true that content created by students is often inaccurate, incomplete, or insufficient for completing their tasks?

Q5. Is it true that students primarily use the internet for content searching and are not concerned with the quality or legal aspects of information retrieval?

3.3. Hypotheses and Open Questions Related to Changes During the Pandemic

H4. The importance of participation in study groups increased for students during the pandemic.

H5. Based on their experiences during quarantine, students evaluate predominantly online education positively.

Q6. How did students' perceptions of mobile technology and their own ICT equipment change?

Q7. To what extent did students' and teachers' perceived ICT competencies change as a result of online education?

Q8. How did students' internet usage habits change?

3.4. Hypotheses and Open Questions Related to the Effects of Artificial Intelligence

H6. Students do not attribute significant importance to the social and economic consequences of AI technologies (e.g., job loss, disappearance of occupations).

H7. Students do not attribute significant importance to the ethical consequences of AI technologies (e.g., biased algorithms, privacy violations).

Q9. How do students evaluate the internet as an information source necessary for using AI tools?

Q10. What are students' attitudes toward the use of AI technologies?

Q11. How do students perceive the impact of AI technologies on their future studies and careers?

The formulated hypotheses enable a structured examination of changes in the digital learning environment and allow for comparisons across different time periods. The research methodology – questionnaire-based data collection conducted in multiple waves, complemented by focus group interviews – is suitable for empirically testing the hypotheses and drawing well-founded conclusions.

4. Research Methodology

The aim of the research was to empirically examine the transformation of the digital learning environment between 2019 and 2024, with particular emphasis on the effects of the pandemic and the emergence of AI-based tools. The study was conducted in multiple phases, enabling both the temporal comparison of changes and the separate analysis of different influencing factors. Accordingly, the methodological design of the research can be interpreted as a longitudinal empirical study based on multiple waves of data collection.

The research was carried out in three consecutive data collection phases. The first survey focused on mapping the pre-pandemic state, examining students' digital device usage habits, internet use, and attitudes toward e-learning tools. The second data collection took place during the pandemic, following the transition to digital education, and aimed to identify changes, particularly in the use of online learning environments and the transformation of learning practices. The third survey was conducted after the emergence of AI-based tools, enabling the examination of the impact of these technologies on the learning process.

The primary method of data collection was a questionnaire-based survey. During the design of the questionnaires, groups of questions were developed in line with the main dimensions of the research. These included ICT tool usage, internet usage habits, the use of social platforms, participation in online learning groups, as well as the application of e-learning and AI-based tools. The questionnaires predominantly consisted of closed-ended questions, allowing for quantitative analysis, but also included open-ended questions to enable a more detailed exploration of respondents' opinions.

Ensuring comparability was an important consideration in the design of the questionnaires. Therefore, some questions remained consistent across the different waves of data collection, while others were modified in accordance with the specific objectives of each phase. This approach made it possible to analyse changes over time and to incorporate new phenomena – such as the use of AI tools – into the study.

Quantitative data collection was complemented by qualitative methods. Following the second phase of data collection, a focus group interview was conducted to allow for a deeper interpretation of the questionnaire results. During the interview, participants shared their views on e-learning tools, interactive learning environments, and the role of user-generated content. This qualitative approach enabled a more nuanced understanding of students' attitudes and experiences.

The target group of the research consisted of high school students from the Partium region. The sample included multiple educational institutions with different academic profiles, ensuring the diversity of the study. During sampling, background factors such as school type, students' social background, and access to digital tools were also taken into account.

In the data analysis phase, both quantitative and qualitative methods were applied. Questionnaire data were processed using statistical techniques, allowing for the identification of relationships between variables. In addition to descriptive statistics, multivariate analyses were also employed, contributing to the interpretation of complex phenomena. Qualitative data were analysed through content analysis of the focus group interviews, which complemented the quantitative results and provided deeper insights.

The methodological structure of the research enabled a multidimensional examination of changes in the digital learning environment. The multi-phase approach proved particularly suitable for tracking the effects of the pandemic and AI tools over time, as well as their integration into learning practices.

Overall, the research methodology ensured a reliable and valid analysis of the investigated phenomena and provided the opportunity for a comprehensive interpretation of the transformation of the digital learning environment. The combination of quantitative and qualitative methods contributed to presenting a complex picture of students' experiences and the digital transformation of education.

5. Research Results

The aim of the research was to examine the transformation of the digital learning environment between 2019 and 2024, with particular emphasis on the effects of the COVID-19 pandemic and the emergence of AI-based tools. The study was conducted in three consecutive phases, allowing for the comparison of changes over time and a dynamic interpretation of the processes

involved. The longitudinal approach proved particularly suitable for revealing the directions of development in digital education and the cumulative effects of different influences.

5.1. Pre-Pandemic State

The first phase of the research focused on mapping the digital learning environment prior to the pandemic. The results indicate that the majority of students regularly used digital devices, and internet use had become an integral part of their daily lives. The frequency of computer and mobile device use was high; however, these tools were primarily not used for learning purposes.

A more detailed analysis of ICT usage revealed that students generally evaluated their own digital preparedness positively, while their assessment of the digital preparedness of schools and teachers was lower. This discrepancy suggests that students' technological socialization is progressing at a faster pace than institutional adaptation, which may lead to tensions in the educational process in the long term.

The analysis of internet usage habits showed that students primarily used the internet for information searching, social communication, and entertainment. Although learning-related use was present, it was not dominant. Students generally had a relatively positive view of the internet as a source of information, although concerns about reliability were also noted. The combined use of traditional and digital information sources proved to be typical.

The use of social platforms was widespread, with students spending a significant amount of time on these platforms. Online study groups were present, but they mainly served communication and information-sharing functions. The role of user-generated content in the learning process was not yet significant, and its perceived reliability was mixed.

The use of e-learning tools during this period was limited and primarily played a supplementary role. Both students and teachers regarded these tools as supporting traditional forms of education rather than replacing them.

5.2. Changes During the Pandemic

The second phase of the research examined changes resulting from the pandemic. The results clearly showed that the digital learning environment underwent a radical transformation in a short period of time. Online education became widespread, and the use of e-learning tools increased significantly.

During the digital transition, infrastructure and access to technology became key factors. Although most students had access to basic devices, the quality and stability of access varied considerably. This contributed to the emergence of a so-called "new digital divide," which manifested not only in access to devices but also in digital competencies and learning opportunities.

The organization of the learning process was fundamentally transformed. The use of platforms and virtual learning environments became widespread, and online learning became part of students' daily routines. The role of mobile technology became particularly important, as it often provided access to education.

Teachers' digital competencies proved to be a decisive factor in the success of the learning process. In cases where teachers were better prepared, online education was more effective. At the same time, several challenges emerged, including difficulties in assessment, maintaining student motivation, and issues related to trust and control.

Students' experiences were mixed: flexibility and freedom in time management were perceived as advantages, while the lack of personal interaction and excessive screen time were identified as disadvantages.

5.3. Effects of Artificial Intelligence Tools

The third phase examined the impact of AI-based tools. The results indicate that these tools have rapidly spread among students and are playing an increasingly significant role in the learning process.

The use of AI-based applications was primarily focused on information searching, problem-solving, and learning support. Students generally had a positive attitude toward these tools and considered them effective. AI contributed to the personalization of learning and the provision of immediate feedback.

At the same time, new challenges emerged, particularly regarding the reliability of information, the role of independent thinking, and ethical issues. Some students approached these technologies critically, while others increasingly integrated them into their everyday learning practices.

Based on the findings, it can be concluded that the digital learning environment has undergone a significant and lasting transformation. The pandemic accelerated the process of digitalization, while the emergence of AI opened new dimensions in learning. These changes are significant not only from a technological perspective but also at the pedagogical level, and they will shape the future development of education in the long term.

6. Conclusions and Practical Implications

Based on the research findings, it can be concluded that the digital learning environment underwent a significant and multi-layered transformation between 2019 and 2024. Two key factors lie behind these changes: the forced digitalization triggered by the COVID-19 pandemic and the rapid emergence and spread of AI-based tools. The study clearly demonstrates that these processes are not temporary but will shape the functioning of educational systems in the long term.

The results from the pre-pandemic period showed that although digital device usage was widespread among students, its integration into educational practice was not yet dominant. A considerable gap existed between students' digital presence and the digital practices of education. The pandemic rapidly reduced this gap, as the introduction of online education forced the integration of digital tools into the learning process. However, this transition was not always conscious or methodologically grounded, highlighting shortcomings in the preparedness of educational systems.

One of the most important conclusions of the research is that the digital learning environment will not return to its pre-pandemic state but is moving toward a hybrid model. In this model,

traditional face-to-face education and digital learning forms complement each other. This shift requires a new pedagogical approach in which learning is no longer confined to fixed times and spaces but becomes a flexible and personalized process.

The emergence of AI-based tools has further reinforced this transformation. Such applications – especially chatbots – enable the individualization of learning, provide immediate feedback, and support independent learning. The findings indicate that students are open to these technologies and are increasingly incorporating them into their learning strategies. At the same time, these tools introduce new challenges, particularly regarding the credibility of information, control over the learning process, and ethical considerations.

The transformation of the digital learning environment highlights the crucial role of digital competencies. For students, technical skills alone are insufficient; the ability to critically evaluate and responsibly use information is equally important. For teachers, the development of digital pedagogical competencies becomes essential, as they determine how technology is integrated into the learning process.

Several practical implications and development directions can be derived from the research findings.

First, the development of digital infrastructure in educational institutions is essential. Adequate access to devices and stable internet connectivity are fundamental prerequisites for effective digital education. The study highlights that disparities in access significantly influence learning opportunities, making the reduction of the digital divide a key priority.

Second, the modernization of teacher training and professional development is of paramount importance. The effective use of digital tools is not only a technical issue but also a methodological one that requires new pedagogical approaches. The role of the teacher is evolving from that of a knowledge transmitter to that of a facilitator and mentor who supports students' independent learning.

Third, greater emphasis should be placed on interactive and collaborative learning forms in educational practice. The findings suggest that students value community-based learning and cooperation, which can be effectively supported by digital environments. The conscious integration of user-generated content can enrich the learning process and increase student engagement.

Fourth, the conscious integration of AI-based tools into education is necessary. This includes the development of ethical and legal frameworks, as well as preparing students for the responsible use of such technologies. AI does not replace the teacher but provides a new tool for supporting the learning process.

Another important conclusion of the research is that the transformation of the digital learning environment is not homogeneous. Changes affect different groups of students to varying degrees, highlighting the presence of social and educational inequalities. Therefore, educational policy decisions must take these differences into account and develop measures that ensure equal opportunities.

Overall, it can be concluded that the transformation of the digital learning environment is a complex and multifactorial process involving technological, pedagogical, and social factors.

The research indicates that the future of education lies in flexible, adaptive, and learner-centred systems capable of integrating digital technologies and responding to continuous change.

The findings of the dissertation contribute to the advancement of digital pedagogy and provide a foundation for further research, particularly in the field of AI applications in education. In addition, they offer practical guidance for educational institutions, teachers, and policymakers in the conscious and effective development of digital learning environments.

7. Summary

The aim of the dissertation was to conduct a comprehensive examination of the transformation of the digital learning environment between 2019 and 2024, with particular emphasis on the effects of the COVID-19 pandemic and the emergence of AI-based tools. The multi-year approach of the research made it possible to explore changes in the learning environment over time and to understand how various technological and social influences build upon each other and shape learning practices.

The first phase of the study highlighted that the use of digital devices was already widespread among students before the pandemic; however, their application for educational purposes was not yet dominant. A significant gap existed between students' digital presence and educational practice, suggesting that educational systems had not fully utilized the potential of digital technologies. During this period, the digital learning environment functioned primarily as a supplementary element rather than a defining component of education.

The pandemic period brought radical changes, as online education became widespread in a very short time. This forced transition accelerated the process of digitalization, making the digital learning environment a fundamental form of education. The findings indicate that this transformation was significant not only at the technological level but also in pedagogical and organizational terms. The organization of learning processes, student roles, and teachers' responsibilities all changed, while shortcomings in infrastructure and digital competencies also became apparent.

One of the most important consequences of the pandemic is that the digital learning environment has become permanently integrated into educational practice. The results suggest that education will not return to its previous exclusively face-to-face format but will move toward a hybrid model. In this model, traditional and digital learning forms complement each other, requiring new pedagogical perspectives and methodological approaches.

The emergence of AI-based tools has further deepened this transformation. These applications – especially chatbots – offer new opportunities for the individualization of learning, the support of independent learning, and the provision of immediate feedback. According to the findings, students are open to these technologies and increasingly integrate them into their learning strategies. At the same time, the use of AI introduces new challenges, particularly in relation to the credibility of information, the role of independent thinking, and ethical considerations.

An important conclusion of the research is that the transformation of the digital learning environment is not uniform. Different groups of students adapt to these changes in varying ways and to different extents, highlighting the presence of the digital divide and educational inequalities. Differences in access, digital competencies, and institutional background have a significant impact on learning opportunities and outcomes.

The dissertation emphasizes that the development of digital competencies is essential for all participants in education. For students, the development of information literacy and critical thinking is crucial, while for teachers, strengthening digital pedagogical competencies is necessary. The role of the teacher is evolving from that of a knowledge transmitter to that of a facilitator who supports students' independent learning and navigation within the digital environment.

Overall, it can be concluded that the transformation of the digital learning environment is a complex, multifactorial process involving technological, pedagogical, and social factors. The research indicates that the future of education lies in flexible, adaptive, and learner-centred systems capable of integrating digital technologies and responding to continuous change.

The findings of the dissertation contribute to a better understanding of the development of digital pedagogy and provide a foundation for further research, particularly in the field of artificial intelligence in education. In addition, they offer practically relevant conclusions that can support educational institutions, teachers, and policymakers in the conscious and effective development of digital learning environments.

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9. Author's Publication List

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