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The Current State of Digital Literacy Research in China: A Literature Review

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Abstract: The purpose of this study is to analyse the current research status, hotspots and development trends of teachers' digital literacy in China. The article uses Citespace to visualize and analyse 1,129 relevant Chinese literature published between 2007 and 2024 in China Knowledge Network CNKI. The study found that (1) the research on teachers' digital literacy in China started in 2007 while the number of studies has increased significantly in recent years as well as the research topics have become increasingly diversified. (2) The research hotspots mainly

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focus on the connotation of digital literacy, the necessity of cultivation, the relationship with rural revitalization, and the strategies for improving digital literacy in higher education and basic education stages. Based on the research results, this paper puts forward suggestions with a view to providing valuable references and lessons for the development of the enhancement of teachers' digital literacy in China.

Keywords: digital literacy, teachers, literacy review, research progress

1. Introduction

In today's fast-changing digital technology, digital literacy has jumped up to become a key element in measuring individual competence and social progress.

Gilster (1990) designed the concept of digital literacy in the book Digital Literacy. Israeli scholar Eshet-Alkalai (1994) summarized that the main content of digital literacy contains five aspects: picture-image literacy, recreation literacy, branching literacy, information literacy, and social-emotional literacy. With the popularization of the Internet of Things and Artificial Intelligence and the rapid progress of digital technology, digital literacy not only affects individual learning and work efficiency, but also largely determines the economic competitiveness and social progress of a country and region. The global digital literacy framework contains seven digital competency domains and twenty-six specific competencies (Zhang & Sheng, 2019). The education system has an important responsibility in developing digital literacy. China's education system is in a critical period of digital transformation, and there is an urgent need to accelerate the process of improving teachers' digital literacy.

The Central Committee for Cybersecurity and Informatization issued (2021) the Outline of Action for Enhancing Digital Literacy and Skills for All People. The document defines "*digital literacy and skills*" as "*a collection of qualities and abilities such as digital access, production, use, evaluation, interaction, sharing, innovation, safety and security, ethics and morality, etc. that citizens in the digital society should have for learning, working and living"*. This may be the first time that "digital literacy" is clearly defined in an official document in China, and also reflects China's generalization and summary of the concept of digital literacy at home and abroad (Liu & Cen, 2023).

The Central Internet Information Office, the Ministry of Education and other four departments jointly issued (2022) the "Key Points for Enhancing Digital Literacy and Skills of the Whole Population in 2022", which puts forward the number of "high-quality courses for basic education" as the main indicator. In the same year, the Ministry of Education of China released the "Teachers Digital Literacy" standard, which mentions that the framework of teachers' digital literacy includes five aspects: digital awareness, knowledge and skills of digital technology, digital application, digital social responsibility and professional development (Ministry of Education of the People's Republic of China., 2022). The Central Office of the Internet Information Office and other four departments issued (2024) the "Key Points for Enhancing Digital Literacy and Skills of the Whole Population in 2024", which clarifies the annual work objectives and deploys 17 key tasks in six areas.

With the introduction and implementation of relevant policies, teachers' digital literacy faces higher requirements. Despite the growing importance of digital literacy, many teachers still encounter many challenges in actual teaching, such as insufficient adaptation to new technologies, lack of information literacy and effective application of digital tools. Therefore, we hope to provide a theoretical basis and practical reference for improving teachers' digital literacy through a comprehensive and in-depth analysis of teachers' digital literacy and exploring the latest developments in this field.

2. Methods

2.1 Inclusion criteria

2.1.1 limited to research related to Chinese teachers' digital literacy.

2.1.2 Articles published on CNKI (China Knowledge Network).

2.1.3 Search by “theme=digital literacy AND theme=education AND theme=teacher OR theme=teacher trainee OR theme=pre-service teacher OR theme=in-service teacher”, exact match.

The search results were organized by removing some entries such as journals unrelated to the topic and no authors, resulting in 1,738 relevant papers spanning the period 2007-2024.

2.2 Research questions

This paper focuses on the following key research questions:

Q1: Analysis of the current situation of research on teachers' digital literacy in China.

Q2: Analysis of hot spots of digital literacy research for teachers in China.

Q3: Analysis of research frontiers and trends of teachers' digital literacy in China.

2.3 Data analysis

We used Citespace 6.3.1 software to visualize and analyze the 1738 articles selected in the previous section. In this paper, we use a variety of visual analysis methods such as literature co-citation, co-occurrence cluster analysis, keyword co-occurrence, keyword clustering, etc. to explore the development process of the research on the improvement of teachers' digital literacy in China (Chen et al., 2015).

This paper adopts the methods of annual analysis graph visualization, visualization of carrier institutions and authors, research theme co-occurrence matrix, and annual cross-analysis visualization of major research themes to analyze the current status of teachers' digital literacy research in China. Keyword co-occurrence analysis, keyword clustering and other methods are used to analyze the hotspots of teachers' digital literacy research in China. The development trend of digital literacy related research is analyzed by keyword chronogram, and the emergent word analysis of keywords is used to explain the emerging trend of research field aggregation.

3. Results

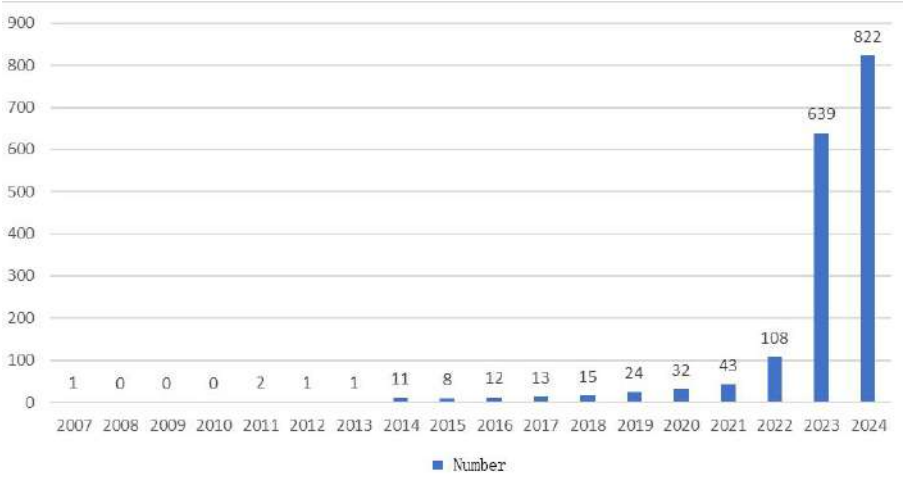
3.1 R1: Analysis of the current situation of research on teachers' digital literacy in China.

3.1.1 Visual analysis of the year in which the article was published

The selected 1738 CNKI literature data were imported into Citespace to get the annual data statistics of the loaded articles, and the data were imported into an Excel sheet to create an annual analysis chart of the loaded articles of the domestic teachers' digital literacy research for visualization and analysis (shown in Fig. 1).

Figure 1

Annual analysis of articles on digital literacy research for teachers in China



China's research on teachers' digital literacy began in 2007 when Liu Qiang (2007) first mentioned the training of teachers' ability to use information technology for teaching and learning in his interpretation of the European Union's digital learning program. China's research on teachers' digital literacy was thus kicked off, but because digital literacy

was not defined as a standard concept in China at that time, there was relatively little research literature in the field from 2007 to 2021, with limited research content and little relevance. In January 2020, in order to interrupt the spread of the new Crown Pneumonia outbreak to campuses, the Ministry of Education issued a delayed start notice and initiated a " The call for stopping classes without stopping teaching and learning", which undoubtedly puts forward higher requirements for teachers' digital literacy, and the epidemic pushes China's higher education teaching from offline teaching to online, Xiamen University Xue Chenglong et al. (2020) pondered on the reform of higher education online teaching steering and coping strategies, to realize the comprehensive enhancement of the teachers' informatization literacy and online teaching ability. The "Action Program for Enhancing the National The issuance of the "Outline of Action for Enhancing Digital Literacy and Skills for All" in 2021, China has a standard definition of "digital literacy and skills", and due to the continued spread of the new crown epidemic has had a huge impact on the education system in all countries around the world, scholars began to make suggestions for online teaching, including more prominent Dong Lili et al. (2021) through the interpretation of the EU's "Digital Education Action Plan (2021-2017)". Digital Education Action Plan (2021-2017) to think about the new picture of digital education in the post epidemic era, elaborating on the current challenges, actions and reflections to realize the overall improvement of teachers' digital competence, digital literacy and digital teaching skills. In addition, Du Yanyan et al. (2021) used the DigComp Edu Check-In survey tool to conduct a small-scale survey and analysis of 464 teachers in two provinces in the north of China, and summarized a variety of effective ways to improve the digital literacy of primary and secondary school teachers, such as improving teachers' perception of the value of digital literacy and meeting teachers' personalized learning aspirations for digital literacy. Immediately after November 2022, the Ministry of Education released the standard of Teachers' Digital Literacy, which includes five first-level dimensions, 13 second-level dimensions and 33 third-level dimensions. In response to the national policy, scholars in China have launched research around teachers' digital literacy, and the number of articles issued in 2023 has been on a straight upward trend, from about double-digit number of articles issued, to more than six hundred articles in 2023, and rising year by year. Overall, although the development of teachers' digital literacy in China is still in the preliminary stage, the importance attached to it has risen sharply in recent years, and the research in related fields has attracted extensive attention.

3.1.2 Institution and author visualization and analysis of the text

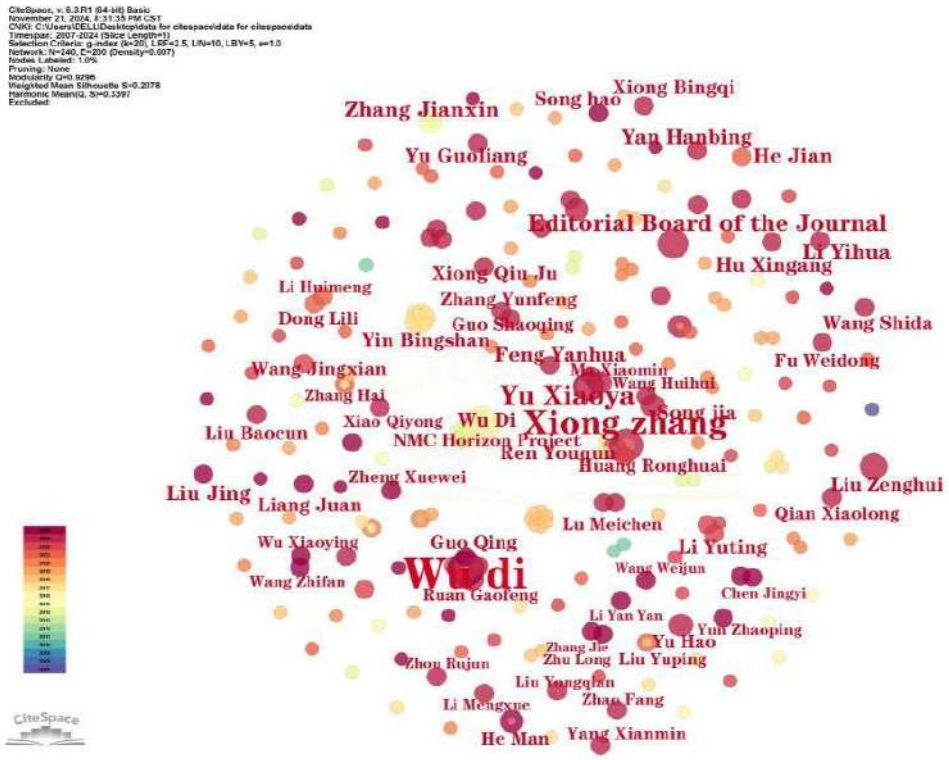
Using Citespace software, set the node type of the corresponding data as Institution and Author to draw the analysis graph. In order to facilitate the observation of the analysis graph, this paper sets the number of displays and the size of nodes in Citespace, and at the same time adjusts the position of the nodes in the analysis graph, so that there is as little blocking as possible between the contents of the graph.

Figure 2

Analysis of the institutions that carry research on teachers' digital literacy in China

Figure 3

Analysis of the authors of the articles contained in the research on digital literacy of teachers in China



We can judge the number of occurrences of the institution and authors by the size of the appearing institution name and author name, the larger the font indicates the greater the number of research outputs in the field, and vice versa the smaller the font is the less. As can be seen in Figure 2, the institutions with the largest output of research literature on teachers' digital literacy in China are the six ministry-affiliated teacher training universities, and the number of articles issued, in descending order, is East China Normal University (53), Beijing Normal University (44), Central China Normal University (43), Southwest University (30), Northeast Normal University (22), Shaanxi Normal University (20), followed by Jiangsu Normal University (19) and Guangxi Normal University (19) tied for seventh. At the same time, the more the number of articles issued, the more the institution's cooperation branch is huge, the top ten institutions in the number of articles issued, except for East China and Central China Normal University, which have more cooperation, the rest of the institutions basically cooperate with teacher training colleges and universities in their own provinces or neighboring provinces. The main institutions engaged in the field of teachers' digital literacy research in China are mostly teacher training colleges and universities, especially concentrated in teacher training colleges and universities directly under the Ministry of Education, and the research departments are mainly colleges of education, colleges of teacher education, colleges of artificial intelligence, and so on. Other provincial teacher training colleges or general teacher training universities have published less relevant literature in this field, and there is very little cooperation with primary and secondary schools around the country.

From this, we can initially conclude that the research on teachers' digital literacy at all levels and types of teacher training colleges across the country is still relatively small, and that many important research topics in this field have not yet been developed.

From Figure 3, we can see that Wu Main (8 articles), Xiong Zhang (7 articles), and Yu Xiaoya (5 articles) are the most prolific in this field, while the rest of the authors have published no more than 5 articles. Wu et al.(2023) has conducted several in-depth studies on the path of teachers' digital literacy enhancement in the context of digital transformation of education, and has interpreted the standard of Teachers' Digital Literacy in depth, which provides ideas and references for the theoretical and practical research on teachers' digital literacy in China from the connotation of teachers' digital literacy, the analysis of the standard of Teachers' Digital Literacy, and the evaluation path of Teachers' Digital Literacy. Xiong et al.(2022), on the other hand, mainly researches the improvement of teachers' digital literacy in information technology courses, and he mentions in From Information Technology to Information Technology - Dialogue on the Compulsory Education Information Technology Curriculum Standards (2022

Edition) that frontline teachers should, on the one hand, teach according to the requirements of the standards and utilize all kinds of teaching resources and, on the other hand, bring into play their own digital literacy and skills, and innovate their own teaching mode. Yu Xiaoya mainly draws inspiration from the analysis of the development of teachers' digital literacy and related policies in foreign countries, and she brings a lot of inspiration for the development of this field in China by studying the characteristics of teachers' digital literacy in four countries, namely, Canada, Japan, South Korea and the United Kingdom (Yu et al., 2023). It can be seen that several of the scholars with the largest number of publications have their own research scope and hardly collaborate with each other. The most cited of the independently issued articles in this field is Yuan Zhenguo's (2023) Digital Transformation of Education: What to Turn, How to Turn, which proposes that the current key tasks of education digitization are to innovate educational scenarios, to develop digital resources, to improve teachers' digital literacy, and to govern digital education with digital thinking. The sparseness of the distribution of nodes in the figure also shows that the communication among scholars is limited to a few high-productivity authors, most of whom come from the same institution, and other authors are not closely connected, and most of the authors are members of colleges and universities or national educational institutions, and there are relatively few primary and secondary school frontline teachers.

Overall, there is a lack of communication and integration between most of the scholars due to the different scopes of research that different scholars focus on, and there is still a need to improve both the depth and popularity of research in this field among primary and secondary school frontline teachers.

3.1.3 Analysis of relevant research themes in the article

This paper categorizes the themes of China's teachers' digital literacy research with the help of the visual analysis tool of China Knowledge Network, and draws a co-occurrence matrix analysis chart of the main themes of domestic teachers' digital literacy research (Fig. 4), as well as an annual cross-analysis chart of the main themes of domestic teachers' digital literacy research (Fig. 5).

Figure 4

Analysis of the co-occurrence matrix of the main themes of digital literacy of teachers in China

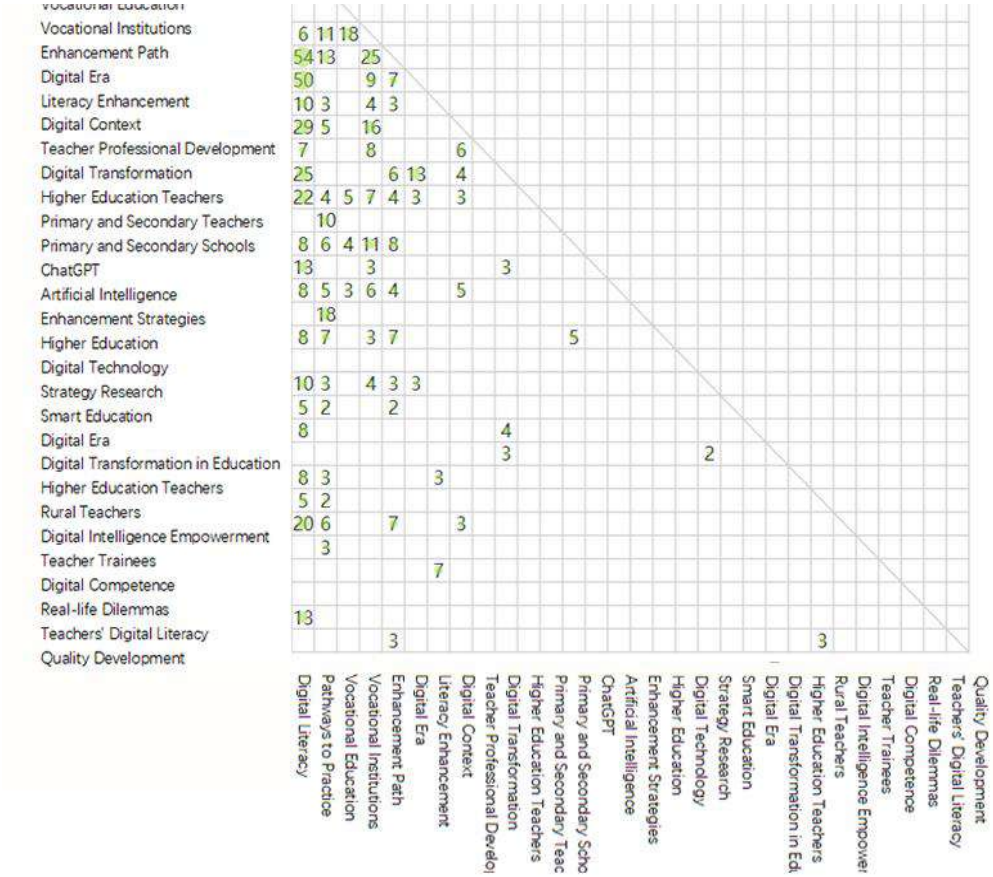
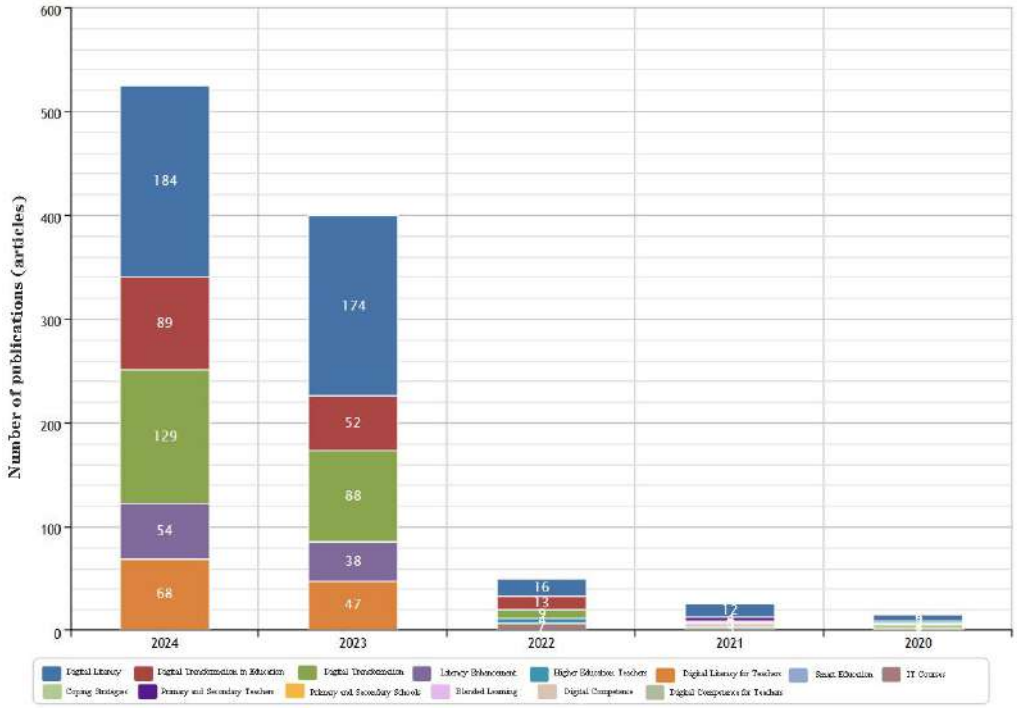


Figure 5

Annual cross-tabulation of the main themes of digital literacy of teachers in the country



As can be seen in Figure 4, under the core theme of “digital literacy”, “enhancement path” and “digital era” are the two most relevant themes. In addition, “practice path”, “digital context” and “digital transformation” are also closely related to this core theme. Among them, the newer research themes include “Artificial Intelligence” and “ChatGPT”. As we all know, the rapid rise of ChatGPT has attracted a lot of attention in the field of education, and its ability to deal with complex teaching tasks is expected to reshape the current teaching model. The leap in artificial intelligence technology not only brings new teaching tools and methods, but also brings complex emotional experiences for teachers' professional development, prompting them to reflect on and update their educational concepts (Kasneci E et al.,2023). Wu et al. (2023) analyzed the opportunities and challenges of ChatGPT for teachers' professional development, and proposed an “motivation-empowerment-promotion-quality-enhancement-effectiveness” approach. ChatGPT empowers teachers' professional development, providing theoretical and practical references for improving teachers' digital literacy. Through these studies, it can be seen that the focus of the research on “improving teachers' digital literacy” is concentrated in the areas of “path”, “digitalization” and “artificial intelligence” and “Artificial Intelligence”.

Figure 5 shows that in addition to the core theme of “digital literacy”, the themes with more research each year include “digital transformation of education” and “digital transformation”, “Literacy Enhancement”, ‘Teachers in Higher Education’, and ‘Teachers’ Digital Literacy”. These themes are the key research directions in the field, and although the number of related documents fluctuates from year to year, the distribution of the number of articles published in each theme has basically remained stable. This shows that “digitalization” and “literacy enhancement” have always been the core issues in the field of teachers' digital literacy enhancement, and have had a profound impact on the development of the field.

3.2 R2: Analysis of hot spots of digital literacy research for teachers in China.

3.2.1 Keyword co-word analysis

(1) Keyword Frequency Analysis

Keywords can be used to describe the main research content and direction of the literature, and if the keywords include the corresponding topic, it means that the literature also belongs to the category of selected literature. In a specific research field, the keywords that appear many times are high-frequency keywords, indicating that scholars have studied the corresponding content more, and this part of the content is also the research hotspot of the field. We

analyzed the exported literature data for keyword frequency in Citespace software, and obtained the keyword high-frequency analysis mapping of digital literacy research in China (Fig. 6) as well as the high-frequency statistics Table 1.

Figure 6

Plot of high-frequency analysis of keywords for digital literacy research on teachers in China

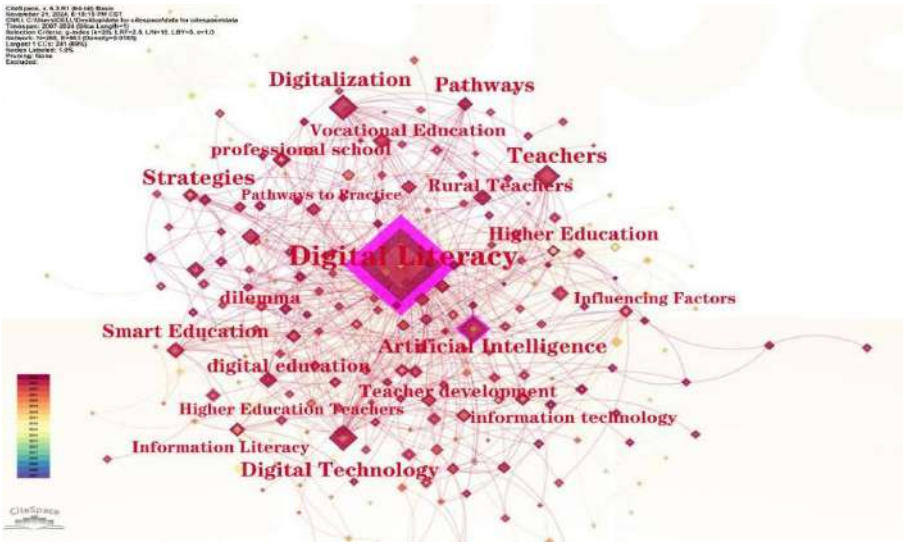


Table 1

Statistics of high-frequency keywords of digital literacy research for teachers in China

Keywords	Year	Frequency	Keywords	Year	Frequency	Keywords	Year	Frequency
Digital Literacy	2014	481	Enhancement Strategies	2021	37	Teacher Training	2021	22
Digitization	2018	80	Higher Education	2016	34	Information Technology	2014	22
Digital Technology	2019	76	Rural Teachers	2021	33	Talent Cultivation	2019	22
Artificial Intelligence	2017	72	Digital Age	2022	30	Influencing Factors	2017	21
Teachers	2021	56	Enhancement Path	2023	29	Digital Education	2019	21
Higher Education Teachers	2020	45	Smart Education	2020	27	Digital Competence	2019	20
Vocational Education	2022	43	Higher Education	2023	25	Basic Education	2019	20
Higher Education Institutions	2016	40	Vocational Schools	2023	23			

In Figure 6, the frequency of keywords can be judged by the size of the circle and the size of the font, from which it can be seen that the words “digital literacy”, “digitization” and “digital technology” have larger fonts and circles, indicating that they appear most frequently. From the figure, it can be seen that “digital literacy”, “digitalization”, “digital technology” and other words have larger fonts and circles, indicating that their frequency is the highest. The inside of the circle is composed of different colors, and each color corresponds to the color area of the time slice. From the center of the circle to the boundary, it indicates the time range from the appearance of the keyword belonging to the circle to the last, each color represents a time slice, and the width of the circle where each color is located determines the frequency of the keyword within the time slice corresponding to the color, and the higher the frequency, the larger the width (Han & Xu, 2023). The largest circle in Figure 6 is digital literacy, in which different colors represent different years, and red is the outermost color, which is the last occurrence of the keyword digital literacy in the collected data,

i.e., there are more studies in the field of digital literacy in 2024. Regarding the development of this field in China, as can be seen in Table 1, the word "digital" appears frequently in the research in this field, which is because it is in the context of the era of digital transformation that digital competence has gradually become the "catalyst" for teachers to effectively develop their professional competence (Xu & Wu, 2023). "It also means that with the digital transformation in all fields of society, digital literacy is becoming a necessary literacy for teachers. And scholars such as Chen Yue propose that digital teaching competence is the ontological construction of teachers' teaching, which can be used as a teaching tool by means of digital technology such as artificial intelligence (Chen et al., 2015). Therefore, keywords such as "digital technology" and "artificial intelligence" are highly discussed in the field of teachers' digital literacy. Combined with the analysis of the visualization of the carrier institutions, the six ministry-affiliated teacher training colleges and universities have the most research results in this field, which indicates that the current research in the field of teachers' digital literacy is mainly concentrated in the higher education stage, so the keywords of "college teachers", "vocational education", "teacher education", Therefore, keywords such as "college teachers", "vocational education", and "teacher trainees" are also hot topics in the research of this field. 2021: On July 26th, the Ministry of Education and other nine departments issued the "Directed Training Program for Excellent Teachers in Less Developed Regions of the Midwest" to solve the problem of the source and arrival of primary and middle school teachers in less developed regions of the Midwest through a directional approach (Qin, 2021), and to improve the teaching force of primary and middle school teachers in less developed regions of the Midwest from the source. The quality of primary and secondary school teachers in the less developed regions is improved from the source, so from 2021 onwards, "rural teachers" and "enhancement strategy" have become hot keywords in the field of teachers' digital literacy research.

(2) Analysis of Keyword Centrality

Centrality refers to a keyword mediator between two documents, i.e., a keyword that is at the center pivot, or a keyword that connects more than one document. The larger the centrality data corresponding to a keyword, the closer the keyword is connected to other keywords. In this paper, the corresponding keyword centrality data can be obtained by directly exporting the knowledge graph according to the keyword nodes, and the high school centrality keyword statistics Table 2 is obtained.

Table 2

Keyword statistics for high school centrality in digital literacy research for teachers in China

Keywords	Year	Centrality	Keywords	Year	Centrality	Keywords	Year	Centrality
Digital Literacy	2014	1.04	Online Teaching	2020	0.28	Development Strategies	2018	0.23
Higher Education	2016	0.73	Response Strategies	2018	0.27	Open University	2019	0.21
Educational Technology	2015	0.55	Information Technology	2014	0.26	Curriculum Standards	2016	0.21
Training Modes of Education	2018	0.46	MOOCS	2020	0.25	Hot Spots	2018	0.21
Challenges	2018	0.40	Higher Education Teachers	2020	0.24			
Learners	2021	0.37	Information Literacy	2016	0.23			

Table 2 shows that the centrality of the keywords "digital literacy", "higher education", and "educational technology" are all higher than 0.5, which shows that these keywords are very much related to the content of digital literacy development and play a key role in connecting the whole research system of digital literacy development. It can be seen that these contents are greatly related to the contents of digital literacy and play a key role in connecting the entire digital literacy research system. From the perspective of centrality, we can still conclude that the research on digital literacy in China mainly focuses on the higher education stage. At the same time, research in this field focuses on the exploration of digital literacy "cultivation mode" for teachers and the development of new teaching resources such as "online teaching" and "catechism". This fully demonstrates that the current research system in this field can fully respond to the current context, and the research system is also relatively sound.

3.2.2 Keyword clustering analysis

Clustering is to divide a class of keywords with a high degree of association closeness into a collection, from which some hidden features that may exist between keywords can be discovered. Using Citespace to cluster analysis of the domestic digital literacy development related literature, we get the keyword cluster analysis map (Figure 7), and generate the keyword cluster analysis Table 3, in which the Q value of this cluster analysis is 0.8511 and the S value is 0.9545, which are both close to 1, and the clustering results are reasonable.

Figure 7

Cluster analysis mapping of high form keywords for digital literacy research on teachers in China

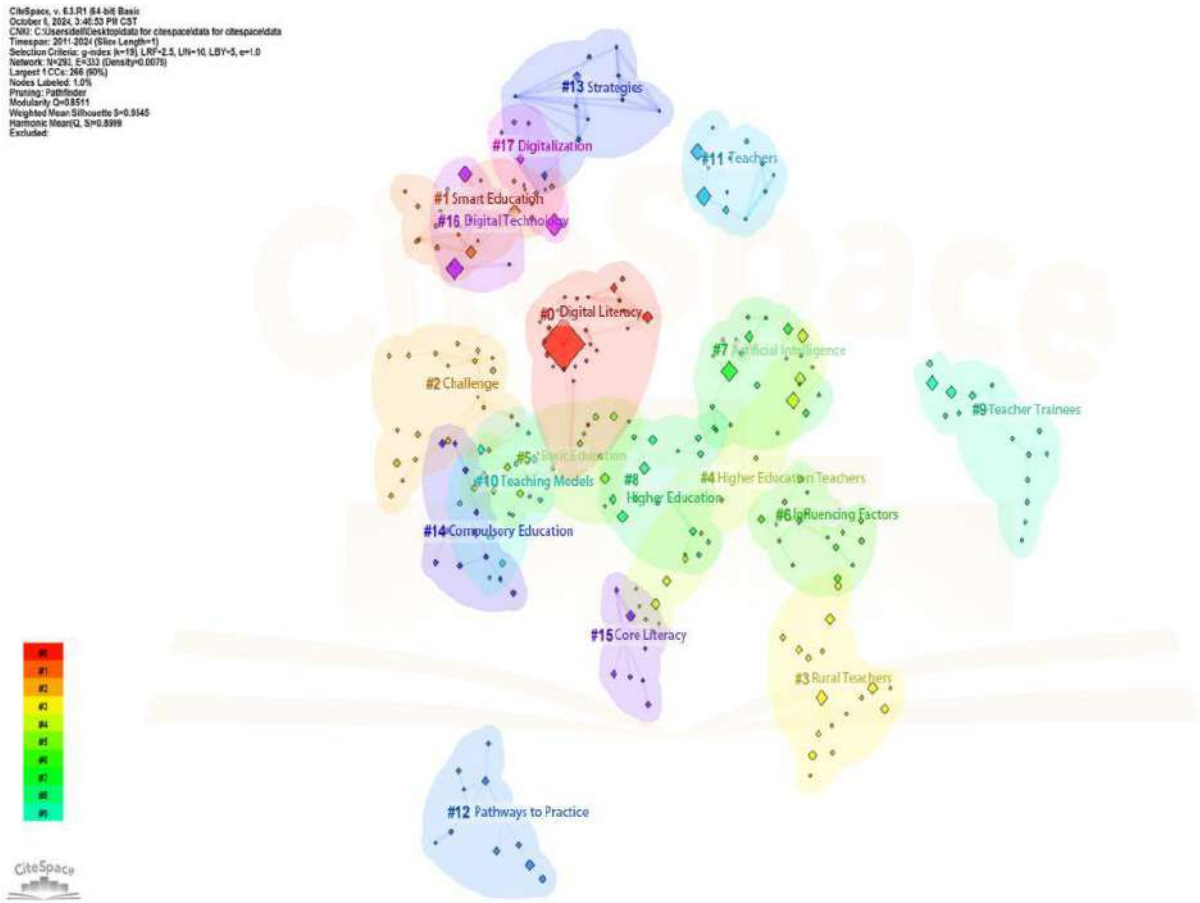


Table 3

Cluster analysis table of keywords of digital literacy research for teachers in China

Scales	Silhouette	Cluster ID	Mean (Year)	Top Terms (LLR)
28	1	0	2018	Digital Literacy (91.69,1.0E-4); Digital Education (27.8, 1.0E-4); Digital Economy (17.45,1.0E-4); Higher Education (12.24, 0.001); Digitization (10.53,0.005)
19	0.994	1	2020	Intelligent Education (35.72,1.0E-4); Information Technology (30.08, 1.0E-4); Educational Equity (19.57,1.0E-4); Strategic Research (13.02,0.001); Teacher Training (13.02,0.001)
19	0.885	2	2020	Challenges (29.59, 1.0E-4); Development (22.14, 1.0E-4); Value (14.72, 0.001); Technology Adoption (14.72,0.001); Trends (14.72, 0.001)
18	0.967	3	2022	Rural Teachers (48.67, 1.0E-4); Colleges and Universities (21.11, 1.0E-4); Civics and Political Science Classes (18.26, 1.0E-4); Rural Education (17.08, 1.0E-4); Rural Revitalization (16.91, 1.0E-4)

18	0.944	4	2021	Higher Education Teachers (35.03,1.0E-4); Pathways (33.57, 1.0E-4); Promotion Pathways (25.75,1.0E-4); Dilemmas (20.64, 1.0E-4); Digital Age (19.15,1.0E-4)
18	0.936	5	2022	Basic Education (24.04,1.0E-4); Information Literacy (23.11, 1.0E-4); Teaching Reform (18.13,1.0E-4); Informatization (18.01, 1.0E-4); Intelligent Age (16.61,1.0E-4)

As can be found in Figure 7, 17 clusters other than digital literacy were obtained from the cluster analysis of keywords, namely “smart education”, “challenges”, “rural teachers”, “basic education”, “influencing factors”, “artificial intelligence”, “digital literacy”, and “digital literacy”, “college teachers”, “basic education”, “influencing factors”, “artificial intelligence”, “higher education”, and “digital literacy”, “higher education”, “teacher educators”, “teaching models”, “teachers ”, “Pathways to Practice”, “Strategies”, “Compulsory Education”, “Core Literacy ”, “digital technology”, and “digitalization”. Then, according to the keywords contained in each cluster shown in Table 4.3, combined with the research content of the literature in which each keyword is located, we can summarize the 17 clusters into the following five themes: research on the connotation of digital literacy, research on the necessity of digital literacy cultivation, research on digital literacy and rural revitalization, research on the influencing factors of digital literacy and strategies for improving it (higher education level), and research on the current situation analysis of digital literacy and improvement Strategy (Basic Education Stage).

(1) Research on the Connotation of Digital Literacy

Research on the connotations of digital literacy involves Cluster #11 “Teachers”, Cluster #15 “Core Literacy”, and Cluster #16 “Digital Technology”. The concept of digital literacy is inextricably linked to teachers, digital education, digital technology and information literacy, and has evolved with technology. Internationally, digital literacy was proposed earlier, especially in the field of education, and the research report Digital Literacy in the Curriculum released by the UK FutureLab in 2010, for the first time, made it clear that teachers' digital literacy should be closely aligned with the needs and practices of teaching and learning in the subject, and listed a number of core elements that make up teachers' digital literacy (Hague & Payton, 2010). In contrast, China's conceptualization of teacher digital literacy came relatively late, and it was not until the release of Digital Literacy for Teachers in 2022 that it attracted widespread attention in the education community.

Nevertheless, concepts similar to digital literacy have been proposed in China before that. For example, the Education Informatization 2.0 Action Plan released by the Ministry of Education (MOE) in 2018 emphasized the improvement of information literacy and promoted the transition from enhancing the IT application capabilities of teachers and students to comprehensively improving information literacy (Ministry of Education of the People's Republic of China, 2018). And even earlier, in the Standards of Educational Technology Competence for Primary and Secondary School Teachers (for Trial Implementation) released in 2004, the professional competence that teachers should have first clarified for the construction of educational informatization, emphasizing the necessity for teachers to effectively use technology in teaching (Ministry of Education of the People's Republic of China, 2004).

It can be seen that the development of teachers' digital literacy in China has been progressing step by step, from the initial information technology application ability to the proposal of information literacy, and then to the establishment of the concept of digital literacy, this process shows the continuous enrichment and deepening of the connotation of digital literacy. Meanwhile, information literacy, digital technology and other related concepts have played a role in the development of digital literacy, laying a solid theoretical foundation for the research and practice of teachers' digital literacy.

(2) The Digital Literacy Imperative Study

The study of the need for digital literacy development covers several key themes, including cluster #2 “Challenges”, cluster #7 “Artificial Intelligence”, and cluster #10 “Teaching Models”. Driven by the rapid development of technology and the wave of digitization, the cultivation of teachers' digital literacy has become an urgent issue for educational development. Qiu et al. (2023) pointed out that in the face of the strong rise of artificial intelligence, education not only has to maintain its adherence to humanistic values, but also needs to actively respond to the challenges brought about by technological innovation, and to reposition the roles and functions of teachers, which puts forward brand-new requirements for teachers' digital literacy. The traditional teaching mode is difficult to meet the demand for flexibility and technology application in the digital era, so the reform of teaching mode based on digital technology has

gradually become a research focus. Yang et al. (2023) proposed that with the entry of artificial intelligence tools such as ChatGPT into the classroom, the teaching mode has changed from the “teacher-student” binary structure to the “teacher-machine-student” ternary structure, which breaks the limitations of the traditional teaching mode and provides new perspectives for improving teachers' digital literacy. Digital literacy provides new perspectives and practice opportunities. At the same time, the change of teaching mode is not only the simple application of technology tools, but also involves the change of teachers' thinking on teaching design and their understanding of the deep integration of technology. Teachers not only need to use digital technology flexibly and redefine the teacher-student relationship, but also need to have the ability to design for complex digital learning environments (Yin et al., 2018), in order to realize the transformation from the traditional classroom model to a new technology-supported teaching model. This change makes the improvement of teachers' digital literacy more urgent and necessary.

(3) Research on Digital Literacy and Rural Revitalization

The research on digital literacy and rural revitalization mainly includes cluster #3 “rural teachers”. Rural education is a “depression” in the digital transformation of education, and rural teachers, as the first element, can provide strong support for cracking the reality of digital transformation of rural education by improving their digital literacy level (Cui & Xu, 2024). In order to promote educational equity and narrow the gap between urban and rural education, improving the digital literacy of rural teachers has become an urgent task. However, the enhancement of rural teachers' digital literacy faces many dilemmas, such as insufficient policy support, lack of digital education resources in schools, and weak overall digital literacy ability of teachers and students (Deng & Deng, 2024).Zhu (2024) proposed that strengthening the informatization construction of rural schools, rationally constructing digital teaching teams for rural teachers, as well as creating digital teaching communities are important measures to effectively attract and retain young teachers. Ren Shenghong et al. emphasized the sharing of localized educational resources through digital technology, the development of school characteristics, and the construction of a “task-driven” training system to improve the digital literacy of rural teachers (Ren et al., 2024). Taking 12 schools in one province as an example, Xu (2023) proposed through field research that we should promote the change of teachers' concepts, accelerate the digital construction of schools, and build a social learning and exchange platform to help improve the digital literacy of rural teachers. These studies not only provide specific paths for rural teachers' digital literacy enhancement, but also lay a theoretical and practical foundation for the realization of rural revitalization and educational equity. By strengthening the informatization construction and teacher training in rural schools, the digital education gap between urban and rural areas can be effectively narrowed, thus promoting the coordinated development of rural education and economy, and contributing to the realization of the rural revitalization strategy.

(4) Research on Digital Literacy Influencing Factors and Enhancement Strategies (Higher Education Stage)

Research on digital literacy in the higher education stage focuses on the two core topics of influencing factors and enhancement strategies, and covers cluster #1 “smart education”, cluster #4 “higher education teachers”, cluster #6 “influencing Factors”, Cluster #8 ‘Higher Education’, Cluster #9 ‘Teacher Trainees’, and Cluster #13 ‘Strategies’. Higher education, as the main ground for research on teachers' digital literacy in China, covers both the digital literacy training of college teachers and emphasizes the training of the pre-service teacher group, teacher trainees. Together, the two have contributed to the rapid transformation of higher education in the digital era. First of all, the factors affecting the digital literacy of college teachers are diversified and complex, which are not only related to the individual's technical ability, but also constrained by external conditions such as policies, resources and technological environment. Han et al. (2022) analyzed the core elements of digitization of higher education teaching from the perspectives of students and teachers, and proposed to formulate corresponding supportive policies from the levels of government, social organizations as well as colleges and universities, respectively, in order to strengthen the digital literacy of college teachers. Secondly, the cultivation of digital literacy of teacher trainees, as an important reserve force of future teachers, has also attracted much attention. Wang et al. (2023) constructed the U-G-S-E “three-learning” model from the perspective of intelligent education literacy of teacher educators, in order to comprehensively improve the intelligent education literacy and practical ability of teacher educators. In addition, for the specific cultivation path of digital literacy for teacher trainees, Yang et al. (2024) constructed a digital literacy framework for teacher trainees based on the standards of Digital Literacy for Teachers, proposed a “primary and secondary parallel” cultivation mode, integrated the first classroom and the second classroom, and provided a dual support system of “in-school teachers + inter-school teachers” for teacher trainees to enhance their digital literacy and practical ability. The dual support system of “in-school teachers + inter-school teachers” provides better guidance for the improvement of digital literacy

of teacher trainees. At the same time, an intelligent assessment system based on digital technology has been further explored, which strengthens the all-round assessment and feedback of teacher trainees' digital literacy and ensures that they receive comprehensive and solid digital literacy training during their school years. Through the analysis of influencing factors and the implementation of enhancement strategies, the study of teachers' digital literacy in the field of higher education provides a solid theoretical foundation and practical path for promoting teachers' professional development. It not only promotes the professional literacy of in-service teachers in the digital era, but also lays a solid foundation for the training of teacher trainees with a high level of digital literacy, so that they can better adapt to the future challenges of education.

(5) Research on the Current Situation Analysis and Improvement Strategies of Digital Literacy (Basic Education Stage)

Research on digital literacy in the basic education stage is closely related to the basic education reform, mainly covering cluster #5 “basic education” and cluster #14 “compulsory education”. At this stage, the improvement of teachers' digital literacy is not only a key link in building a high-quality teaching force and deepening the reform of teacher education, but also strategically important in promoting the high-quality development of basic education in terms of caring for the student body, innovating classroom forms, and optimizing the cooperation of teaching and research. However, there are still many problems in the current practice, such as the lack of clarity in goal orientation, the lack of attention to pre-service education, the evaluation index has not yet been formed, and many other practical misconceptions and value bias have blocked the effective development of digital literacy of basic education teachers (Jing & Lv, 2023). To cope with these adjustments and solve these problems, UNESCO supports the global promotion and development of teachers' digital literacy by providing open educational resources, developing a framework for promoting teacher education, and organizing teacher training programs (Kong & Wang, 2023). Jing & Lv (2023), on the other hand, put forward a strategy to promote the development of digital literacy among basic education teachers around five dimensions: discipline, environment, resources, evaluation and parenting. Combined with and China's national conditions, Yang & Yu (2023) taking the research and training initiatives taken by the Information Technology Application Enhancement Project for Primary and Secondary School Teachers 2.0 as a starting point for reflection, put forward digital practice paths oriented to the enhancement of teachers' digital literacy at the levels of research and training implementation and quality management. These strategies and practices provide a systematic operational guide for the improvement of digital literacy of education-based teachers. The cultivation of digital literacy in the basic education stage is not only a renewal of the content and form of education, but also the key to promoting the reform of basic education and improving the quality of education. Only through systematic strategies and measures can we truly realize the common growth of teachers and students and lay a solid foundation for the development of education in the new era.

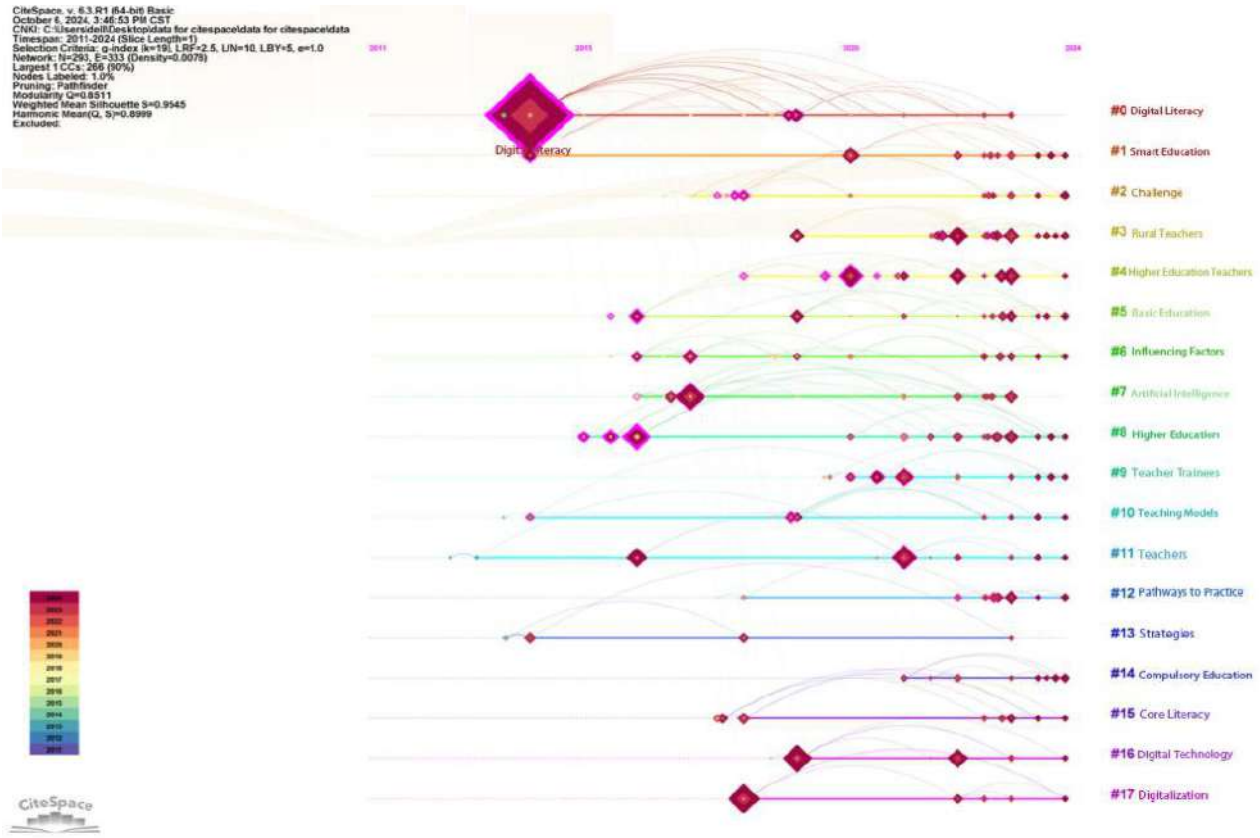
3.3 R3: Analysis of research frontiers and trends of teachers' digital literacy in China.

3.3.1 Analysis of Keyword Timing Chart

Studying the changes of keywords over time is conducive to analyzing the development trend of digital literacy-related research and revealing emerging keywords, which in turn shows the research frontiers in the field. Using Citespace software, on the basis of the previous cluster analysis, node type selects keyword, term type selects Noun Phrases, and after drawing the corresponding knowledge graph, select Timeline View in the Layout tab of the Control Panel window (Timeline View) to generate the corresponding time series graph. Timeline View in the Control Panel window (Layout tab) can produce the corresponding timing diagram (Figure 8).

Figure 8

Chronological chart of keywords of digital literacy research for teachers in China



As can be seen from the figure, since 2011, the research on teachers' digital literacy in China has been expanding, covering multiple directions, and new keywords have appeared almost every year. This indicates that the research on teachers' digital literacy has always maintained a high level of attention during this period. Through further analysis, the development of research on teachers' digital literacy in China can be roughly divided into the following three stages:

(1) 2011-2015: connotation definition stage

In this stage, scholars, inspired by the EU Digital Literacy Framework, began to explore the concept of digital literacy and its connotation. Many domestic studies began to expand information literacy to a broader digital literacy, focusing on the basic definition and practical significance of digital literacy. Ren et al. (2014) pointed out that information literacy mainly focuses on basic knowledge and basic skills related to information activities; while digital literacy rises to be a citizen's survival skill, which, in addition to emphasizing basic knowledge and skills, also emphasizes communication, innovation, management and security. By combining international theories and domestic policies, such as the Opinions of the Ministry of Education on Promoting the Construction of Teacher Education Informatization, studies during this period proposed a variety of evaluation criteria for teachers' digital literacy based on connotation definitions. For example, Wang (2015) proposed an assessment framework for teachers' digital literacy containing five first-level indicators, including basic teachers' digital literacy, applied teachers' digital literacy, developmental teachers' digital literacy, and safeguarded teachers' digital literacy, as well as 12 second-level indicators on the basis of the evaluation standards for teachers' literacy of Li Lixin, Du Zhuo Ming, and Fan Yuanyuan, etc., which has made the domestic research system of teachers' digital literacy more complete.

(2) 2015-2020: path exploration stage

In this stage, with the rapid development of artificial intelligence, big data and other technologies, the path to improve teachers' digital literacy has become the focus of research. Scholars have proposed diverse enhancement strategies from teacher education practice, combining new technologies and digital tools. For example, She Yabin and Huang Jiao-hua advocate improving teachers' digital literacy through updating concepts, systematic training, and

technological safeguards. Research began to focus more on teacher training, teacher self-improvement and systematic support strategies during this period. The research in this phase focuses on exploring effective paths to improve teachers' digital literacy in different contexts, and a series of more mature practical strategies have gradually been formed.

(3) From 2020 to the present: the stage of theory-practice integration

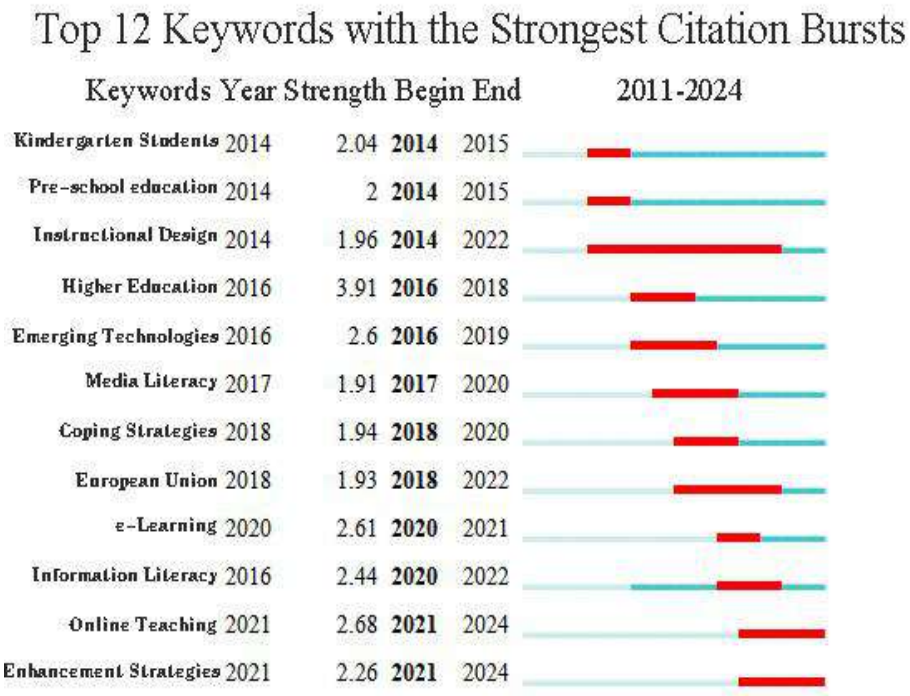
Since 2020, research on teachers' digital literacy in China has entered a stage of deep integration of theory and practice, with a significant increase in the number of studies and an increasingly diversified theme, reflecting the importance of digital literacy at all educational levels. First, the promotion at the policy level has provided a strong institutional guarantee for the improvement of teachers' digital literacy. In order to help teachers actively adapt to new technological changes and enhance their awareness and ability to utilize technology to improve education and teaching, the state initiated and implemented the “Primary and Secondary School Teachers' Information Technology Application Ability Enhancement Project 2.0”, which greatly promoted the in-depth development of digital literacy-related practices and research among teachers. Secondly, with the continuous development of technology, researchers have gradually focused on the multi-dimensional composition of digital literacy. Yang Xiaohong et al. proposed the “combination of main and auxiliary” cultivation system, emphasizing that teachers' digital literacy should include information analysis, critical thinking and innovation ability, which provides a scientific basis for the cultivation of teachers' digital literacy. In addition, the practice-oriented nature of the research has become more prominent, focusing on exploring how to effectively integrate the enhancement of digital literacy into the classroom and the process of teachers' professional development. The school-based, classroom-based, application-driven, innovation-focused, accurate assessment and research-training combination path effectively realizes the linkage between theory and practice. The research at this stage not only reflects the progress of policy-driven and theoretical deepening, but also pays more attention to the wide application of educational practice, gradually forming a more complete theoretical and practical system, which provides an important support for educational reform and teachers' professional development.

3.3.2 Keyword emergent word analysis

By analyzing the emergent words of keywords, emerging trends in the research field can be revealed, indicating the research activity of a certain field in a specific time period. The higher the intensity of the emergent words, the more attention is paid to the research of the related topics in that time period. In this paper, we used CiteSpace software to analyze the literature screened in the CNKI database for emergent words to identify the trends in the field of teacher digital literacy research in China. Figure 9 shows the results of keyword emergent word analysis in the field of teachers' digital literacy in China.

Figure 9

Analysis of keyword emergent terms in the study of digital literacy of teachers in China



As can be seen from the figure, new emergent words have appeared almost every year since 2014, which indicates that scholars and research institutions in China have always invested in research in this field. Among them, “higher education” has the highest emergence intensity of 3.91, indicating that this topic has attracted a great deal of attention in the research on teachers' digital literacy. This is closely related to the rapid development of digital transformation and online education in recent years, followed by “online teaching” and “online teaching” with an intensity of more than 2.6 respectively. The intensity of the rest of the emergent words is below 2.5. Combined with the analysis of the previous keyword timing chart, it can be found that at the early stage of the research on teachers' digital literacy, the research mainly focuses on macro-concepts and broad themes, such as “smart education” and “teaching mode”. However, with the depth of research, studies in recent years have gradually focused on specific educational fields, such as “higher education” and “basic education”, and closely integrated with the context of digital transformation. This indicates that the content of the research is gradually developing in a more detailed and application-oriented direction, and the relevance, practicality and feasibility of the research is also gradually improving. It can also be predicted that in the future, the trend of China's teachers' digital literacy research may pay more attention to the in-depth study of “small-scale” issues, i.e., a more refined and specific research direction will become the main trend. This trend not only reflects the development needs of discipline segmentation, but also provides more precise guidance for educational practice.

3.3.3 Analysis of realistic research trends in the social environment

With the changes in the social environment, the research on teachers' digital literacy has shown a new trend.2022 The Ministry of Education released the education industry standard of Teachers' Digital Literacy, which proposed a systematic framework for teachers' digital literacy for the first time. The framework not only clarifies the definition and requirements of digital literacy for teachers in China, but also covers five key dimensions: digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development. This signifies that the connotation of teachers' digital literacy has been expanded from the traditional technical operational skills to a more comprehensive literacy requirement. Teachers not only need to have strong technical skills, but also need to be able to understand and utilize digital technologies, as well as take on the corresponding social responsibility to continuously promote their professional development.

For this reason, the focus of current and future research should not be limited to the digital literacy of in-service teachers, but should also be extended to specific groups such as teacher trainees and pre-service teachers. The teacher training system in higher education and vocational education, especially the path and strategy of digital

literacy enhancement for teacher trainees, urgently needs to be explored in depth. This is not only to meet the needs of the modernization of education in China, but also an inevitable trend in the development of the teaching profession in the digital era. In addition, with the promotion of national policies and the implementation of major projects such as the “Excellent Teacher Program” and the “National Excellence Program”, the research theme of teachers' digital literacy needs to be further expanded, involving “rural teachers”, “digital teachers”, “digital teachers” and “digital teachers”. The topics of research on teachers' digital literacy need to be further expanded to cover hot social issues such as “rural teachers”, “digital resource sharing” and “educational equity”. By focusing on these specific issues, we can promote the balanced distribution of digital resources, promote equity in urban and rural education, and enhance teachers' ability to adapt to teaching in the digital context, so as to build a teacher education system with Chinese characteristics in the context of the new era. Future research should be to expand both the breadth and depth of teachers' digital literacy, to comprehensively cover all stages from pre-service training to in-service development, and to respond to national policies and social demands to build a more complete research system in order to promote the continuous development of teachers' professional competence in the digital era.

4. Discussion

Through systematically combing the current research status of the field of digital literacy of teachers in China, this paper summarizes the main features and trends presented in the development process of this field, which are specifically manifested in the following aspects:

4.1 Synergistic development of policy leadership and theoretical practice

In recent years, under the vigorous promotion of national policies, the improvement of teachers' digital literacy in China has made remarkable progress. The Ministry of Education and other relevant departments have issued a series of policy documents, such as the “Information Technology Application Ability Enhancement Project for Primary and Secondary School Teachers 2.0” and the “Teachers' Digital Literacy” industry standard, which clearly define the core connotation of teachers' digital literacy and its enhancement path. These policies not only provide a systematic framework for the theoretical construction of teachers' digital literacy, but also promote extensive exploration of teacher training and teaching practice nationwide. The previous analysis of the literature shows that the guidance of policies has played a key role in promoting the deepening of theoretical research and practical application of teachers' digital literacy. At the theoretical level, researchers have gradually clarified the multidimensional composition and evaluation criteria of teachers' digital literacy by interpreting policy documents. In particular, the multi-dimensional systematic framework of digital awareness, technology application ability, social responsibility and professional development has laid a solid theoretical foundation for the research on teachers' digital literacy. At the practical level, policy-driven teacher training programs and teaching practice applications have prompted teachers to use digital tools and resources more extensively in their teaching activities, thus enhancing their own digital literacy, and these practical activities not only help teachers effectively adapt to the digital teaching environment, but also provide a practical basis for theoretical research, which in turn enriches the theoretical system of teachers' digital literacy. This policy-driven two-way interaction model fully embodies the mutual integration of theory feeding practice and practice enriching theory, and promotes the sustainable improvement of teachers' digital literacy.

4.2 Diversification and Refinement of Research Topics Expansion

With the continuous deepening of the research on teachers' digital literacy in China, the research topics have shown a trend of increasing diversification and refinement. In terms of research objects, full coverage from pre-service teachers (teacher trainees) to in-service teachers has become the main feature of current research. Research on teachers' digital literacy is no longer limited to the professional development of in-service teachers, and the current situation of digital literacy among pre-service teachers (teacher trainees) and their cultivation paths have gradually received widespread attention. Researchers have begun to explore how to help teacher trainees improve their digital literacy through curricula, practical teaching and training in digital tools, so as to ensure that they are able to play a leading role in future educational practices, and to promote the innovation of digital teaching and the continuous improvement of educational quality. This comprehensive focus on the digital literacy of pre-service and in-service teachers not only expands the scope of the research object, but also provides an all-encompassing enhancement strategy for teacher education. On the regional front, with the country's continued focus on educational equity, the

improvement of rural teachers' digital literacy has become a key topic of research in recent years. Due to the imbalance between urban and rural educational resources, rural teachers face many challenges such as lack of digital resources and insufficient technical support. Policy guidance and exploration of local practices have prompted researchers to gradually focus on how to help rural teachers overcome the difficulties in digital teaching through policy favoritism, resource allocation and targeted training. Such research has explored in-depth from the practical methods of technology training, the effectiveness of resource use to the construction of digital platforms and other dimensions, providing practical paths to enhance rural teachers' digital literacy. In addition, research has gradually focused on more specific topics, including in-depth studies on the different needs and challenges of digital literacy for teachers of different levels of education (basic education, higher education, and vocational education) as well as for teachers of specific disciplines, and in-depth discussions on a specific dimension of teachers' digital literacy. The diversification and refinement of such research not only deepens the construction of the theoretical system of teachers' digital literacy, but also provides differentiated guidance for teachers of different educational backgrounds and fields, and promotes the formation of a more targeted and systematic digital literacy enhancement path, thus promoting the digital transformation and innovative development of the entire education system.

4.3 Exploration of Technology-Enabled Digital Literacy Enhancement Paths

With the rapid development of technology, the path to enhance teachers' digital literacy gradually shows the characteristics of technology empowerment. Literature analysis shows that emerging technologies such as artificial intelligence, big data, and virtual reality have been widely used in the assessment and cultivation of teachers' digital literacy, promoting the innovation of the traditional assessment mechanism and the diversification and personalization of cultivation strategies and cultivation paths. At the assessment level, with the help of big data analysis, teachers' digital literacy performance can be monitored in real time, helping them identify their own development space. Based on the innovative application of online assessment tools and self-assessment platforms, teachers can receive customized feedback to enhance their digital literacy. At the cultivation level, the application of technology provides teachers with rich learning paths. For example, the rise of online training, MOOC courses and interactive learning platforms empowers teachers with the freedom to flexibly choose their learning modes, while sharing experiences and resources with their peers through collaborative tools, creating an active learning community. In particular, the introduction of generative AI technology has provided a new impetus for personalized learning. Generative AI is able to generate personalized feedback and resources based on the specific needs of teachers, helping them to learn deeply in key areas of digital literacy, thus significantly enhancing the relevance and effectiveness of their digital literacy development paths. In addition, generative AI shows great potential for application in teaching simulation and classroom scenario construction, helping to improve their ability to cope with complex teaching scenarios. However, although technological empowerment provides new opportunities for teachers' digital literacy enhancement, there are still some current challenges. Teachers' acceptance of new technologies and the ease of access to them are key barriers that need to be addressed. In the future, the exploration of technology-enabled digital literacy enhancement will continue to deepen, and the focus will be on smarter assessment tools and broader technological applications, especially the further application of generative AI in personalized learning and teachers' continuous professional development.

5. Conclusion

By comprehensively sorting out the research on digital literacy of teachers in China and based on the results of the above analysis, we provide the following suggestions for the subsequent development of related research:

5.1 Deepen theoretical research and clarify core concepts and research boundaries

Currently, the research on teachers' digital literacy is still ambiguous in terms of connotation definition and theoretical foundation. Therefore, the pace of theoretical research should be accelerated to clarify the core elements and boundaries of teachers' digital literacy in the context of education in the new era, and its interrelationships with teachers' educational technology competence, information technology application competence, information literacy, artificial intelligence literacy and teachers' professional development. Based on a multidisciplinary perspective, we explore the synergistic effect between these factors and promote the systematic theoretical construction of teachers' digital literacy. In addition, combining China's national conditions and educational realities, drawing on international

cutting-edge research results, creating a theoretical system of teachers' digital literacy that meets local needs, and accumulating more basic local research reflecting Chinese characteristics, in order to fully guide and plan the development of the field of teachers' digital literacy, and laying a solid theoretical foundation for the subsequent research.

5.2 Constructing a dynamic assessment system to promote accurate assessment and feedback

At present, there is room for improvement in the dimensional coverage and accuracy of the existing assessment tools for teachers' digital literacy, making it difficult to fully reflect teachers' performance in teaching practice. Therefore, it is recommended to build a flexible, dynamic and multi-intelligent assessment system that incorporates teachers' digital technology application, teaching design innovation and professional growth into the assessment. Big data and artificial intelligence technologies should be used to develop real-time assessment tools to dynamically capture the actual performance of teachers' digital literacy. At the same time, a personalized feedback mechanism should be emphasized to help teachers understand their own strengths and weaknesses, and provide targeted development advice to ensure that the assessment is not only a static assessment tool, but also a guide and driving force for the improvement of teachers' digital literacy.

5.3 Strengthening Policy Support and Promoting Sustainable Development of Teachers' Digital Literacy

Policies play an important leading and safeguarding role in the process of enhancing teachers' digital literacy. It is recommended that national and local policy frameworks be further improved to provide stable support for the sustainable development of teachers' digital literacy. Through policy guidance, in-depth cooperation among education departments, schools and research institutes at all levels in curriculum development, resource allocation and teacher training should be promoted to facilitate the popularization and deepening of digital literacy. At the same time, localities should be encouraged to summarize innovative practical experiences, promote excellent models, and form a nationwide library of practical cases of teachers' digital literacy enhancement, so as to promote the overall enhancement of teachers' digital literacy.

Through a systematic analysis of the current status of research on teachers' digital literacy in China, this paper reveals three major features and trends in the field, namely, the synergistic development of policy leadership and theoretical practice, the diversification and refined expansion of research topics, and the exploration of technology-enabled paths for digital literacy enhancement. **Based on this, suggestions are made to strengthen theoretical research, improve the measurement system, and enhance policy support.** In the future, with the continuous advancement of technology, the research on teachers' digital literacy will be more in-depth and diversified, and at the same time, we should keep exploring how to provide more accurate and effective solutions for teachers' professional development through technological innovation and policy support. This will not only have far-reaching significance for the professional development of individual teachers, but will also positively promote the improvement of overall education quality.

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A Case Study: An Investigation into Foundation Pathway Teachers' Beliefs of Incorporating Digital Pedagogy in Their Practice to Increase Student Engagement

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Abstract: This case study investigates the beliefs of Foundation Pathway teachers at INTO University of Exeter (IUoE) regarding the incorporation of digital pedagogy into their teaching, focusing on the Technological, Pedagogical and Content Knowledge (TPACK) framework as the theoretical foundation. By employing a qualitative research design involving semi-structured interviews with seven teachers, the study uncovers the extent to which these teachers believe that digital tools can foster an interactive and engaging learning environment for their students. The results indicate that teachers strongly believe that digital pedagogy has improved student engagement to some extent. However, they also recognise certain challenges associated with using digital tools that could potentially hinder student engagement. This case study suggests that the integration of digital pedagogy contributes to the development of a more productive classroom environment.

Keywords: digital pedagogy, TPACK, digital tools, student engagement, higher education

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1. Introduction

The COVID-19 pandemic has prompted the adoption of new digital practices in education that can encourage dynamic and purposeful learning. According to Alberola-Mulet et al. (2021), the pandemic has made the integration of digital technology into traditional classrooms increasingly noticeable. Furthermore, Rapanta et al. (2021) and Shaikh (2023) state that the way teachers view teaching and learning has changed due to digitalisation in education. Singh et al. (2021) advocate that incorporating digital pedagogy into traditional classrooms can engage students in learning. Bećirović (2023a) highlights that digital pedagogy involves new approaches to engage students in order to achieve educational objectives. These approaches can be used in virtual, blended, and in-person settings and central to this educational transformation is the use of digital technologies (Bećirovic, 2023b). Joint Information Systems Committee (JISC) (2020) defines digital pedagogy as "the study of how digital technologies can be used to best effect in teaching and learning." Foundation teachers at INTO, a faculty at the University of Exeter (IUoE) believe that integrating digital pedagogy into teaching practices can enhance student engagement, resulting in an improved learning experience for their students. Wang et al. (2022) explain that student engagement is the outcome of individual and influences in the classroom. Shernoff et al. (2016) emphasise that supportive teachers and classmates, challenging goals, and authentic tasks are essential in enhancing student engagement in higher education.

2. Research Problem

Student engagement plays a crucial role in enhancing the quality of education and achievement of students in higher education, as emphasised by Kuh (2009). The integration of digital pedagogy into face-to-face delivery can help increase student engagement. Antunes et al. (2021) report that some teachers perceive technology as a means to overcome obstacles that could hinder student engagement. In this context, students may be considered confident users of technology, and when supported by powerful tools, they can be empowered, leading to improved academic performance (Venter, 2017). Thus, this case study aimed to explore the beliefs and challenges faced by Foundation Pathway teachers at IUoE when integrating digital technologies into their practices to increase student engagement with teaching and learning activities and materials. These teachers believed that using digital tools with interactive features can enhance learning experiences and promote student engagement. This belief is supported by Shulman (2002, p38), which states that "learning begins with student engagement, which in turn leads to knowledge and understanding." Moreover, investigating the beliefs and methods used by teachers can help understand the impact of digital transformation initiatives on education (Alhawsawi et al., 2023). This investigation was guided by the following research question:

RQ1: How do teachers' beliefs about digital pedagogy influence their use of digital tools to enhance student engagement in their practice?

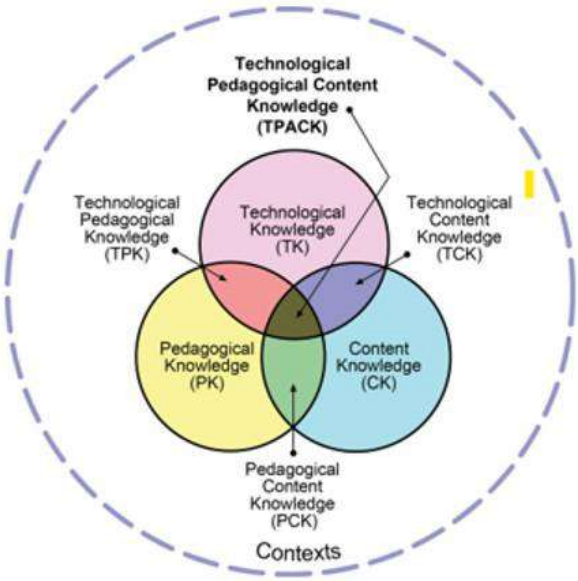
RQ2: What challenges do teachers perceive when incorporating digital tools in their practices?

3. Theoretical Framework

The Technological Pedagogical Content Knowledge (TPACK) framework is employed in this study to examine teachers' beliefs regarding the integration of digital pedagogy into their practices. This framework was chosen due to its clear and practical approach to evaluating the use of technology in a professional setting (Sobel & Grotti, 2013).

Figure 1

TPACK framework and its components (Koehler et al., 2017)



Koehler et al. (2017) classify teacher knowledge into three main categories in Figure 1: Content Knowledge (CK), which encompasses the teacher's subject matter expertise and is the 'WHAT' of a lesson; Pedagogical Knowledge (PK), which relates to teaching strategies and methods, and answers the 'HOW' of a lesson; and Technological Knowledge (TK), which refers to the teacher's familiarity with technologies and resources that facilitate teaching and learning, and pertains to the 'WHY' of a lesson. This framework emphasises the interplay and integration of all three types of knowledge, focusing on a teacher's ability to effectively teach with technology in their respective contexts. In this case study, the TPACK framework is employed to examine how Foundation Pathway teachers integrate digital tools in their teaching practices and the extent to which they believe that technology integration can enhance student engagement.

4. Research Design and Method

Case study

The qualitative research design in this empirical research was a small-scale case study. As a qualitative research method, a case study methodology is flexible and adaptable, and it allows researchers to explore diverse research questions across multiple disciplines and settings as outlined by Yin (2018). He further notes that case studies have the capacity to gather comprehensive and in-depth data. Stake (1995) emphasises that the holistic and naturalistic nature of case studies enable a thorough examination of the phenomena within their authentic contexts. Additionally, case studies allow for the findings generate can contribute to practical implications and directly application to real-world scenarios (Yin, 2018; Stake, 1995). Creswell (2009) note that semi-structured method of the case study enabled the researcher to explore the potential of blending digital technologies with face-to-face delivery to increase student engagement. According to Ruslin et al. (2022), the method of semi-structured interview in this small-scale case study enables researchers to collect thorough information and evidence from participants. Additionally, it offers flexibility for researchers to maintain research focus.

Semi-structured interviews

In this case study, the semi-structured interview questions were designed based on the two research questions above with specific focus on investigating the benefits and challenges of incorporating digital pedagogy in the practices of Foundation pathway teachers at IUoE. The semi-structured interview questions listed below yielded rich and comprehensive data on teachers' experiences and beliefs regarding the use of digital technologies in their practices.

Semi-structured interview questions

1. What are your beliefs about the role of digital tools in enhancing student engagement in your module?
2. How do you select and use digital tools in your teaching practice?
3. What types of digital tools do you use in your teaching?
4. What are the criteria and challenges you consider?
5. How do you measure and evaluate the impact of digital tools on student engagement in your module? What are the indicators and methods that you use?
6. How do you communicate and collaborate with other teachers and students regarding the use of digital tools in your module?
7. What are the benefits and difficulties you experience?
8. How do you learn and develop your skills and knowledge on using digital tools in your teaching practice? What are the sources and opportunities that you access?

The chosen research design and method reflect the researcher's pragmatist stance, which emphasises "problem-centred, pluralistic, and real-world practice-oriented approaches" (Creswell, 2009, p6). The researcher believes that investigating Foundation Pathway teachers' real-world practice of using digital pedagogy is necessary to fully understand the extent of the impact of embedding digital pedagogy in enhancing student engagement.

Study population

This case study was conducted at INTO, a faculty at the University of Exeter in the United Kingdom. The student population in this faculty is very diverse and are mostly international students from various parts of the world. The Foundation Pathway in this faculty aims to prepare and equip these students with the necessary academic skills to achieve academic success in their future university courses. The participants in this case study were seven Foundation Pathway teachers teaching Economics, Academic English, Psychology, World Politics and International Relations, Social and Environmental Science, Current Global Issues and Academic Tutorials. These teachers provided their consent to participate in this case study because they are experienced in using digital pedagogy to engage their students with module contents and they are open to exploring innovative ways to enhance their teaching practices.

Data collection, coding and analysis

The 40-minute interviews were conducted, recorded and transcribed in Microsoft Teams. The transcripts were then coded and summarised using hierarchy charts and a codebook in NVivo. Hierarchy charts in NVivo facilitate the recognition of data patterns and relationships and thus, enabled the researcher to compare coding across various sources and identify key themes. To enhance the code created in NVivo, the codebook function offered detailed explanations and definitions of codes and hence, acts as a thorough record of the codes, provide valuable inspections, and evaluations of the data. The data were analysed using Braun and Clarke (2006, p87) thematic analysis's six phases, as outlined in Table 1. This approach is inductive as the themes emerged from the transcripts during the coding process.

Table 1

Six phases of thematic analysis (Braun & Clarke, 2006, p.87)

Phase	Description of the process
1. Familiarising yourself with the data.	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes.	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes.	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes.	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.

5.	Defining and naming themes.	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6.	Producing the report.	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis

5. Findings and Discussion

From the semi-structured interviews, the teachers employed various digital tools to incorporate digital pedagogy into their practices. These tools are divided into different categories, as presented in Table 2. They are embedded into the Moodle page of different modules to provide ease of access to students and to support face-to-face classroom delivery.

Table 2

Digital tools being used to integrate digital pedagogy in teachers' practices

Type of digital tools	Examples
Audio-video	BBC podcasts
	TED talks
	YouTube videos
Lecture recording software	Flashback
	Panopto
Microsoft 365 applications	Forms
	Teams
	OneDrive
Moodle resources	Gallery
	Journal
	Quiz
Online Whiteboards	ClassroomScreen
	Web whiteboard
	Padlet
Game element	Kahoot!
	Quizlet
Asynchronous workbook	Pearson MyLab
Other	Qualtrics
	Perplexity AI

Classroom implementations of digital tools

In Table 2, YouTube videos were specifically used to introduce new topics as the selected videos tend to be quite short and hence, can engage students with the topic and to provide a basic understanding of the topic. BBC podcasts and TED talks tend to be longer, approximately, 10 to 15 minutes in length. Their purpose was to help students to explore more about the topic and examine different opinions about the topic in Academic English.

Panopto and Flashback were used to record lectures for subjects such as Psychology and Economics. Flashback is particularly useful to highlight specific content in online videos and recording the screen while a specific lecture was being recorded. Lectures recorded in Panopto provides the teachers with a tool to measure student engagement with the lecture content as it shows the percentage of access by each student.

Microsoft 365 applications such as Forms, Teams and OneDrive are used to gather feedback from students on topics, ease of sharing documents for collaborative work and ease of communication between students and teachers and among students. These applications were used in modules such as Academic Tutorials and Academic English.

The gallery resource in Moodle was used to display students' generated images in the module, Current Global Issues. This resource also allowed students in the whole cohort to access the gallery, and this made them appreciate the work produced by their peers. The journal resource required students to input texts and teachers used this as a form of formative assessment. The quiz resource was used to check students' understanding and learning of a certain topic. This was another form of formative assessment in Economics.

The online whiteboards which included ClassroomScreen, Web whiteboard and Padlet were used to brainstorm and share ideas on a particular topic or concept and encouraged collaboration among students. These resources were used in modules including Academic English, World Politics and International Relations

Digital tools which incorporate game elements such as Kahoot! and Quizlet were utilised in Social and Environmental Science used Kahoot! in Psychology to check students' understanding of module content and as well as to make learning fun and engaging.

Pearson MyLab was used in Economics in conjunction with the textbook and as an extension of the lecture and seminar contents.

Qualtrics was used in Academic English as a survey tool for contents in PowerPoints. Perplexity AI was used in Psychology to summarise long journal articles to make them easy to understand especially for Foundation pathways students.

Moodle logs analysis

The teachers embedded these tools in their module Moodle sites. By embedding these tools in Moodle, the teachers were able to access the activity log to monitor students' engagement with these tools. The Moole log services as an invaluable instrument to monitor students' interactions with various course resources. The teachers utilised this feature to examine the types of materials accessed, the frequency of the access and the duration of their engagement. This means that this data provides the teachers with a means to assess students' engagement with course content and identify any resources that may not be effective in facilitating learning. This data is accessed by applying filters to the logs based on individual users, course, activity, and date. Therefore, the teachers can obtain comprehensive insights into individual and class-wide engagement. The implication is these insights allows for the teachers to adjust their instructional approaches and offer targeted assistance where necessary (Moodle, 2008).

The semi-structured interview data are presented under the following themes which are guided by the two research questions above.

Teachers' beliefs about the incorporation of digital pedagogy to enhance student engagement (RQ1)

Data collected from the teachers emphasise a range of beliefs which outline the effectiveness of digital tools in increasing student engagement in their modules. In total, there are fifteen beliefs mentioned in the interview data as outlined in Table 3.

Table 3

Teachers' beliefs of incorporating digital pedagogy to increase student engagement

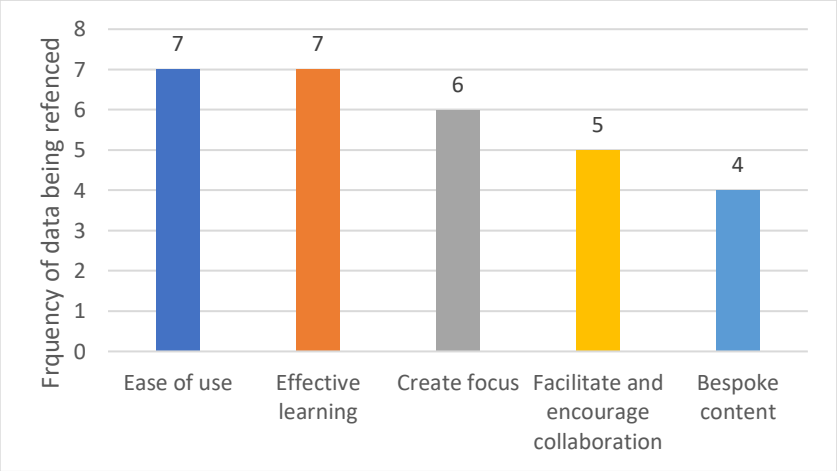
Teachers' beliefs	Frequency	T1	T2	T3	T4	T5	T6	T7
Ease of use	7							
Effective learning	7							
Create focus	6							
Facilitate and encourage collaboration	5							
Bespoke content	4							
Facilitate progress	3							

Teachers' beliefs	Frequency	T1	T2	T3	T4	T5	T6	T7
Interactive	3							
Instant and personalised feedback	2							
Part of students' lives	2							
Prepare students for university studies	2							
Another resource	1							
Mitigate potential cheating in quizzes	1							
Prepare students for future career	1							
Support traditional teaching	1							
To be at the students' level	1							

However, only the most frequently referenced by the teachers are presented in Figure 2.

Figure 2

Teachers' beliefs of incorporating digital pedagogy to increase student engagement



All teachers who participated in this small-scale case study frequently cited the ease of use and effectiveness of digital tools for learning, which offer a variety of content, simplify lessons, and save time. The digital tool being referred to in this context was YouTube. Teacher 4 noted that *"… because you can put the subtitles on so students have lower English ability, can follow it."* The user-friendly nature of digital teaching tools facilitates seamless incorporation into teachers' instructional practices, ultimately leading to enhanced subject comprehension for students. As YouTube is easy to use, students can focus more on their learning than struggling to use the technology. This approach also ensures that technology is being used to enhanced learning rather than as an add-on which could sometimes disrupts the flow of the lesson. Therefore, teachers can promote and encourage a more dynamic and productive learning environment that enhanced student engagement by highlighting the user-friendliness of digital resources within the Technological Knowledge (TK) component of the TPACK framework. According to Kohler et al. (2013), the Technological Knowledge (TK) component of TPACK include the teachers' technological skills and knowledge in facilitating the incorporation of digital pedagogy in their practices. This component assists teachers in selecting and implementing appropriate tools which correspond with their instructional objectives, thus enhancing students' engagement, leading to improved academic performance.

An equal number of teachers also recognise that digital resources accommodate diverse learning preferences among students and promote efficient learning. For instance, Teacher 2 mentioned *"The students are able to see the information in slightly different ways, so if they perhaps prefer listening to it, they can do that. Or they prefer reading it."* Additionally, Teacher 3 indicated *"even the quietest of students, … get really interested in it as well because it's just another way of demonstrating what they know without feeling under pressure to have to say and answer."* This belief is also evident in a study conducted by Rafique (2023), in which students actively participated in activities because

they were given a 'voice' through the use of digital tools. Therefore, it is believed that digital tools improve the learning process by enhancing engagement and promoting inclusivity, leading to more effective education. This belief of inclusivity illustrates the pedagogical knowledge (PK) and technological pedagogical knowledge (TPK) components of TPACK. According to Koehler et al. (2013), when inclusivity is incorporated, the TPACK framework's effectiveness is enhanced, particularly in the aspects of Pedagogical Knowledge (PK) and Technological Pedagogical Knowledge (TPK). This approach considers and meet the diverse needs and viewpoints of students. Therefore, the relevance and efficacy of instructions are increased, and teachers also gain deeper insights into their students' unique challenges and strengths. Ultimately, this can lead to a more equitable and enhanced academic performance.

Digital resources, such as audio-videos and web-based materials, are employed to create focus among students and direct their attention to the topic being taught. This is usually carried out at the start of lessons and to review content at the end, as referenced by the six teachers. These resources are designed to be stimulating, visually interesting, and multisensory. For example, Teacher 1 stated *"a short YouTube video tends to be a bit more engaging than having students read a text, … allows them to focus in a bit of a different way, … it's all about that stimulation and finding different methods of getting them to do things, to keep them engaged."* Based on the study by Roodt et al. (2017), YouTube can effectively engage students in learning by increasing their participation in classes. Hence, effective digital pedagogy is crucial for capturing and maintaining students' attention, which is essential for optimal learning. This belief of catering for the diverse learning needs of students relates to the pedagogical knowledge (PK) and technological pedagogical knowledge (TPK) aspects of TPACK.

Five teachers highlighted that digital pedagogy promotes student collaboration, as it enables students to contribute, share, and explain ideas using Padlet and Web whiteboards, which enhances teamwork skills and encourages learning from peers, as highlighted by Teacher 7, *"They I like it when one group, … can post quite a good set of ideas and because it's on the screen in front of them, the groups that maybe haven't come up with such good ideas. Oh, that's what we should be thinking about."* Learning from peers helps students comprehend the subject matter better, and also develops their teamwork skills, which are valuable in real-life situations, such as collaborating with colleagues in the workplace to accomplish goals and finish projects. In relation to TPACK, this belief aligns with the intersection between pedagogical knowledge (PK) and technological pedagogical knowledge (TPK) aspects of TPACK. Group projects and peer interaction are enhanced through tools like shared documents, online forums, and digital whiteboards. These platforms encourage students to develop essential skills such as critical analysis, effective communication, and collaboration (Koehler et al., 2013). In support of this, D'Angelo (2018) advocates that the integration of technology in the curriculum can provide students with the opportunity to enhance their academic abilities and equip them with the skills needed to face challenges in the real world.

The capacity to create custom content for their modules can also increase student engagement, as endorsed by four teachers. Digital tools such as Moodle quizzes, Kahoot!, Padlet, and Quizlet empower teachers to create personalised academic resources. Teacher 5 claimed *"personalised question I think it's important"* and Teacher 6 stated *"I can provide them with better content."* In this context, customisation enables a personalised learning experience that addresses individual student needs, leading to greater engagement and motivation. The importance of technology in customising the learning experience was emphasised by Shemshack and Spector (2020). They assert that technology can play a pivotal role in this process. The ability to create custom content using digital tools to provide a personalised learning experience that addresses individual students' needs captures the interplay between all TPACK components, which emphasise the integration of technology, pedagogy, and content knowledge.

The challenges of incorporating digital pedagogy (RQ2)

Teachers also highlighted some challenges when trying to incorporate digital pedagogy into their practices. They identified nineteen challenges as presented in Table 4.

Table 4

Teachers' beliefs of the challenges in incorporating digital pedagogy to increase student engagement

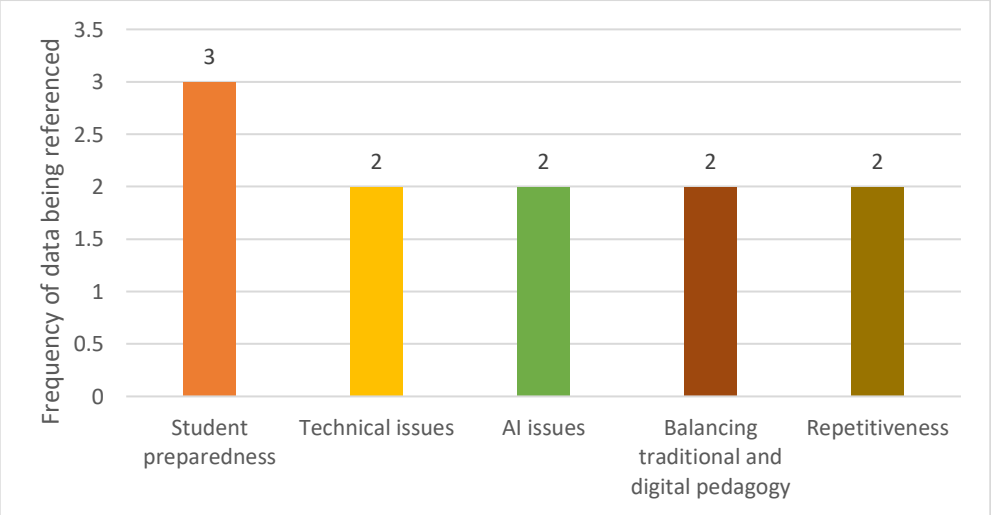
Challenges	Frequency	T1	T2	T3	T4	T5	T6	T7
Student preparedness	3							
Technical issues	2							

Challenges	Frequency	T1	T2	T3	T4	T5	T6	T7
AI issues	2							
Balancing traditional and digital pedagogy	2							
Repetitiveness	2							
Scrolling down the page	1							
Use not supported by the institution	1							
Finding engaging resources	1							
Insufficient pre lesson discussion	1							
Length of resources	1							
Too much screen time	1							
Too much information to process	1							
Time consuming	1							
Quality of content	1							
Privacy and security	1							
No download log in OneDrive	1							
Lack of use of online tools	1							
Completion rate	1							
Limited time to store data	1							

However, only the most frequently referenced are reported in this case study as seen in Figure 3.

Figure 3

Teachers' beliefs of the challenges in incorporating digital pedagogy to increase student engagement



The primary issue identified is student preparedness, as mentioned by three teachers. Some students fail to access the assigned materials outside of the classroom, either as homework or as part of a flipped learning activity. This lack of motivation to study independently appears to be a contributing factor. According to Alenezi et al. (2023), students may have trouble exercising self-discipline in higher education context. An example of this is in Teacher 6's response, *"they just seem to not watch it,"* Students' unpreparedness leads to ineffective learning. This unpreparedness also results in limited participation and ultimately reduced academic performance due to an incomplete understanding of the subject

matter. Consequently, teachers may need to allocate more time to reteaching or reviewing content to these students, making the teaching and learning process ineffective.

Teachers also pointed out technical issues as a challenge and this is also one of the issues outlined in Alenezie et al. (2023). These include hardware malfunctions and connectivity problems, such as Wi-Fi issues that prevent students from downloading materials. For instance, Teacher 6 explained that "*Internet connectivity issue can be a problem*." Teacher 1 elaborated on this view, noting that *"Sometimes I do ask students to listen on their own devices, and if I plan for that to happen once or twice, they've been Wi-Fi issues. So, students haven't been able to download it. So, we've ended up doing it as a whole class anyway*." These issues can disrupt the learning process and cause frustration for both students and teachers. They can also be time-consuming to resolve, which can hinder student engagement and lead to ineffective learning.

The interview data also reveals some concerns about the improper use of Artificial Intelligence (AI) among students, as mentioned by two teachers. Students have been using AI to write essays and answer quizzes set by teachers. For example, Teacher 4 stated that students *"easily copy and paste the question and get the answers."* Furthermore, AI-generated information can be inaccurate and potentially lead to misinformation, as pointed out by Teacher 6 who mentioned *"the misinformation."* This issue is emphasised by Monteith et al. (2024), who reported that frequent mistakes and misinformation make generative AI models unreliable. Consequently, teachers and students require proper guidance and training to effectively utilise AI and enhance learning.

Teachers also reported that balancing traditional and digital pedagogy is a challenge. As Teacher 3 noted, "*there is still a bit of a journey in terms of finding the balance and how to manage that balance".* The overuse of digital tools can reduce human interaction. In support of this, Meinokat and Wagner (2022) suggest that students may miss out on non-verbal communication, emotional support, and social learning opportunities.

Teachers expressed concern about repetitiveness, which could arise from overreliance on the same digital tools. As Teacher 7 pointed out, *"I don't want padlet to become just the same old, same old in the seminars."* This suggests that the students may become disengaged. Therefore, striking a balance between consistency in effective teaching and variety in maintaining student engagement is important. As regard the use of AI, Teacher 6 highlighted a concern about the repetitive nature of AI in which they mentioned *"I mean the main challenge there is obviously the repetitiveness when it comes to AI. I mean when you let it write anything at some point it starts to repeat the things in different way."* In this context, repetitive AI-generated content may lack originality and creativity. Consequently, this can lead to monotony and reduced student engagement. This situation can also negatively impact the learning experience because students are not provided with different perspectives on understanding the topics and concepts being taught.

Overall, while integrating digital pedagogy into teachers' practices can increase student engagement, these challenges highlight significant barriers that need to be addressed to fully utilise digital tools for enhancing student engagement.

Implications for teacher professional development

Digital technologies such as Generative AI tools are developing at a rapid pace. Thus, teachers will need to keep pace with emerging digital technologies and instructional strategies through training sessions within the faculty. These training sessions can be conducted by learning technologists assigned to IUoE and the teachers who participated in this case study and other teachers who are confident and currently incorporating digital pedagogy in their practices. Other methods of teacher professional development involve This can be achieved through online forums such as Microsoft Teams, and peer mentoring, where teachers can share experiences and share best practice among the teachers in this faculty

Limitations

Although some documentation, such as Moodle logs and feedback forms were provided to corroborate the interview data, the case study could have been strengthened if there had been opportunities to observe lessons when digital tools were used. Additionally, it would have been beneficial to elicit the opinions of students regarding the effectiveness of digital tools in increasing their engagement with module content and materials. Addressing the identified challenges is crucial to enhancing learning and maintaining the quality of education in educational settings. Consequently, additional research could be conducted to address these challenges.

5. Conclusion

The investigation of the integration of digital pedagogy by Foundation Pathway teachers at IUoE into their practices to increase student engagement offers valuable insight into the impact of a technology-enhanced learning approach in an educational setting and the digitalisation of education. These findings suggest that effective incorporation of digital tools into teaching practices, as described by the TPACK framework, can lead to increased student engagement, improved learning outcomes, and better academic achievement. In this context, the use of digital tools that align with the TPACK framework and Foundation Pathway teachers at IUoE has provided a more interactive and engaging learning environment for students. However, there are challenges for teachers and students in using digital tools. Teachers and students face challenges, such as a lack of student preparedness, technical and AI issues, the need to balance digital and traditional teaching methods, and the repetitive nature of AI-generated content. These challenges can impede the effectiveness of digital tools in increasing students' engagement. However, potential solutions to the challenges highlighted in this case study have not yet been addressed. Addressing these issues is crucial for the successful integration of digital technology into educational settings to maximise student engagement which could result in improved academic success.

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The Perspective of Medical School Students on Distance Education

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Abstract: This study examines the impact of this transition on medical students at a public university by focusing on their academic performance, emotional well-being, and adaptability to remote learning environments. Since the COVID-19 pandemic prompted an unprecedented shift from traditional classroom learning to online platforms across global educational systems, it is crucial to understand how students navigated these changes and adapted to the new learning conditions. This study collected qualitative data from 65 medical students through semi-structured interviews. The findings reveal significant effects on study habits, emotional well-being, and curriculum engagement. The findings reveal a mixed response to distance education in medical schools. While some students experienced increased flexibility and, in some instances, improved academic performance, significant challenges also emerged. These challenges included a decline in practical skills, heightened emotional distress, and technical

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issues that obstruct effective learning. The study emphasizes the necessity for hybrid educational models that combine the advantages of online flexibility with essential in-person interactions, particularly for training practical skills in medical education. It recommends enhancing online educational platforms to better support medical training during crises. Emphasis is placed on developing a robust technical infrastructure alongside comprehensive mental health support systems.

Keywords: distance education, medical students, qualitative analysis

1. Introduction

Technological advancements and innovations influence all social life and institutions, including higher education. As the number of medical students in higher education continues to grow, new approaches have emerged to address the information needs of the 21st century. In this context, new behaviors and roles for academicians have emerged in response to the unique demands of distance education, which is becoming increasingly essential in 21st-century university settings. Distance education has transitioned educational materials into interactive virtual environments, making learning more accessible and adaptable. Technological advancements have enhanced the practicality and cost-effectiveness of distance education in higher education. Specifically, the economic benefits of efficiently allocating limited resources across different geographic locations and time zones have expanded the reach of distance education, creating a broader market for remote learners (Totaro et al., 2005; Moore & Kearsley, 2012). As Clark (2022) noted, distance education has a rich history spanning nearly 300 years, beginning in the 1700s when Caleb Phillips from Boston offered shorthand lessons via weekly mail. The first instance of electronic distance learning emerged in the 1920s, with courses broadcast over the radio. The rise of the internet has since initiated a significant transformation in distance education, enabling a wide range of educational institutions, associations, and organizations to provide remote courses, especially in healthcare technology. Distance or online learning is not a novel concept; however, it signifies a substantial transformation from traditional classroom models, particularly for academic medical professionals (Kentnor, 2015). Additionally, it delineated essential strategies for developing effective online learning platforms within the medical field, highlighting the necessity of user-friendly and intuitive website design and incorporating self-assessment tools to enhance learner engagement (Schneider & Council, 2021).

Dron (2021) has extensively explored the concepts of distance education and educational technology. His work emphasizes that teaching is fundamentally a technological process involving various forms of "distance" between learners and teachers. These distances can be physical, temporal, structural, social, emotional, cognitive, cultural, pedagogical, or technological. He suggests that understanding these multiple dimensions is crucial for effective distance learning. Since the early 1980s, distance education has undergone remarkable growth on both national and international scales. It has transitioned from early correspondence education primarily relying on print-based materials into a global movement leveraging various technologies. As an alternative to conventional education, distance education provides degree-granting programs, addresses illiteracy in developing nations, offers training opportunities for economic advancement, and enriches curricula in non-traditional educational contexts. The potential of distance education is extensive, presenting solutions to numerous educational challenges and promising a progressive future for medical education. Various technologies have been employed as delivery systems to facilitate this learning mode (Gunawardena & McIsaac, 2013).

The global COVID-19 pandemic has profoundly disrupted traditional education, leading universities worldwide to suspend in-person classes to curb the spread of the virus. In response, many medical schools transitioned to online learning, where instructors and students are often separated by distance and time, fundamentally altering how medical knowledge is imparted and absorbed. In December 2019, the emergence of a new virus outbreak known as COVID-19 in Wuhan, China, rapidly escalated into a global pandemic, significantly impacting numerous nations (World Health Organization [WHO], 2020). The WHO formally declared this outbreak an international public health emergency on January 30, 2020 (WHO, 2020). The swift transmission of the virus has compelled many countries to implement stringent measures to curb its spread. Various organizations have experienced profound disruptions due to the pandemic, and the closure of educational institutions has adversely affected children, young adults, and adults alike (UNESCO, 2020). Hughes et al. (2020) assert that the COVID-19 pandemic has posed considerable challenges across all dimensions of healthcare. The imposition of lockdown measures and the necessity for social distancing have markedly

diminished teaching opportunities for trainees, severely restricting their hands-on learning experiences and exposure to authentic clinical environments.

Coman et al. (2020) emphasized that the global COVID-19 pandemic has profoundly affected higher education's teaching and learning processes, particularly regarding teacher-student interactions. Consequently, educational institutions were necessitated to transition all activities online. This shift, which effectively relocated classrooms to students' homes, may have transformed students' perceptions and experiences of online instruction. Furthermore, the pandemic prompted universities worldwide to suspend in-person learning to mitigate the spread of the virus. Specifically, medical schools implemented various policies to cease face-to-face education. Many institutions suspended clinical rotations and reduced hospital exposure hours for undergraduate and postgraduate students. This reduction in practical experience has raised significant concerns among medical students, residents, and fellows (Siddiqui, 2020).

The rise and widespread adoption of distance learning systems has necessitated a critical evaluation of the strengths and weaknesses of various programs. In response, many new initiatives have been developed to address the growing demands of higher education, promote flexible learning environments, and support lifelong learning (Gunawardena & McIsaac, 2013). Tran (2016) noted that students utilize Learning Management Systems (LMS) such as Blackboard, Desire2Learn, Moodle, and Canvas, among other platforms, to access online learning environments. These systems typically facilitate asynchronous learning, allowing students to engage with course materials and complete assignments at their own pace, from any location, and at times that work best for their schedules. This level of flexibility empowers learners to tailor their educational experience to their individual needs and availability.

Medical schools worldwide adopted various policies to suspend in-person education during the pandemic. Many institutions halted clinical rotations and reduced hospital exposure for undergraduate and postgraduate students. This substantial decline in hands-on experience and procedural training has raised serious concerns among medical students, residents, and fellows about the potential impact on their education and clinical proficiency (Ahmady, 2021). In medical faculties, information technology tools are generally user-friendly and straightforward to operate, which has proven to be a crucial advantage in addressing the challenges brought by COVID-19, allowing educators to continue providing instruction to students. The pandemic has transformed traditional classroom interactions into a model that emphasizes individualized instruction for asynchronous learning, enabling students to access educational material anytime and anywhere without limitations (Daroedono et al., 2020).

This study seeks to investigate the actual perceptions of medical school students regarding distance education, a topic of growing significance as the world transitions to remote learning alternatives. Gaining insight into the viewpoints of these students is essential for assessing the effectiveness and potential drawbacks of distance education in the medical field. Furthermore, the perspectives of medical professionals can provide valuable information about the advantages and challenges associated with distance learning in this sector. Consequently, this paper aims to address the following questions:

RQ1. What changes did the remote education process during the COVID-19 pandemic bring to your habits compared to in-person education?

RQ2. How did you feel when the pandemic began, and your university suspended in-person classes? What emotions and thoughts were you experiencing at that time?

RQ3. What challenges did you encounter during the initial and ongoing phases of the academic term? Did you effectively communicate these concerns to your instructors?

RQ4. What are the advantages and disadvantages of remote instruction in medical education?

RQ5. How did remote education impact your overall grades?

Medical Education within the Higher Education System

Turkey's medical education system is designed to provide comprehensive training for future healthcare professionals by integrating theoretical knowledge with extensive clinical practice. Regulated by the Council of Higher Education (YÖK), the system follows a six-year undergraduate program, where students acquire a strong foundation in basic medical sciences before progressing to clinical rotations and concluding with a one-year hospital internship. Public medical education programs adhere to this structure, with the final three years primarily focused on clinical training (YÖK, 2020). Students engage in theoretical lectures, seminars, and hospital rotations during this phase, ensuring a

well-rounded and practical learning experience. However, before the COVID-19 pandemic, medical schools in Turkey had not widely adopted distance e-learning as an instructional approach, relying instead on traditional in-person training. Although the pandemic necessitated a sudden shift to online education, integrating digital learning into medical training remains a challenge, given the essential role of hands-on experience in developing clinical skills. Following the national lockdown, medical students were compelled to swiftly transition to distance learning at home, with minimal preparation time. Both faculty members and students confronted unprecedented challenges and had to develop their skills to sustain the educational process rapidly (Başer et al., 2020). The pandemic was extremely challenging for pre-graduation medical education, requiring rapid and sometimes instant decision-making beyond the defined processes in an uncertain environment in Turkey. In this context, the pandemic period highlighted the need to strengthen existing decision-making mechanisms, increase awareness of the importance of quality cycles in medical education, and create opportunities to accelerate work in certain areas (Akan et al., 2021). For instance, infrastructure studies of committees and commissions, such as assessment and evaluation, curriculum, and program evaluation—whose preliminary work had already begun—were expedited and completed.

2. Methodology

2.1. *Research Design*

This study employs a qualitative research method rooted in a phenomenological design. This approach revolves around phenomena we may be familiar with but lack a comprehensive understanding. Phenomenological studies aim to explore individuals' experiences, perceptions, and the meanings they assign to a phenomenon (Yildirim & Simsek, 2018). This research investigates students' perspectives from the public university faculty of medicine regarding the distance education process in higher education in the aftermath of the COVID-19 pandemic, along with their insights into the challenges faced and suggested solutions.

2.2. *Study Group*

This study used convenience sampling, a purposeful sampling method that enhances the relevance of the information gathered from a smaller sample in relation to the research objectives. The participants were selected based on their ability to provide valuable insights into the phenomenon being explored (Patton, 2014). Convenience sampling offers advantages in terms of speed and ease, as it allows researchers to select participants who are nearby and easily accessible (Yildirim & Simsek, 2018). The study included 65 medical students, all of whom volunteered to participate—43 male and 22 female medical school students. These students were chosen for their experiences with remote education. Specifically, students from the 1st, 2nd, and 3rd years were selected, as they extensively use digital tools.

2.3. *Data Collection and Analysis*

This study employed semi-structured interviews to gather insights from medical students. The collected data were analyzed using content analysis, a qualitative research method. To ensure the clarity and relevance of the interview questions, the researchers consulted two experts in educational management (Patton, 2014), and the questions were further reviewed by specialists in medical education, leading to the final version of the interview format.

MAXQDA 24, a qualitative data analysis software, was used for data analysis and a descriptive analysis approach. Themes and sub-themes were identified from participants' responses, and frequency counts were used to determine how often each theme appeared. Direct quotations were included to reflect participants' perspectives. Each participant was assigned a unique code (P1–P65) to ensure anonymity in the reporting process.

The semi-structured interviews followed a structured protocol:

1. Introductory Phase – General questions to establish rapport.
2. Experience Sharing – Open-ended questions about participants' experiences with distance education.
3. Focused Questions – In-depth exploration of challenges and adaptations encountered.

The interview questions were pilot-tested with a small group of students to refine clarity and relevance, and each interview lasted approximately 45 to 60 minutes.

2.4. *Validity and Reliability*

Multiple data sources were incorporated to strengthen the validity of the findings. Academic performance data such as GPAs before and during the transition to online education were analyzed to establish potential correlations between students' experiences and their academic outcomes. Metrics regarding students' online participation (e.g., attendance

in virtual classes, completion rates for assignments) were collected to provide an objective measure of engagement and correlate with qualitative findings.

2.5. Methodological Limitations

The study has limitations. The use of convenience sampling may lead to a bias, as the sample may not fully represent the broader medical student population in Turkey, given that those who volunteered may have had more favorable views of distance education. Findings from a single medical school may not be generalizable to other institutions with different curricula and distance education approaches. The subjective nature of qualitative research means that respondents' interpretations of their experiences can vary significantly, potentially affecting the conclusions drawn from the data.

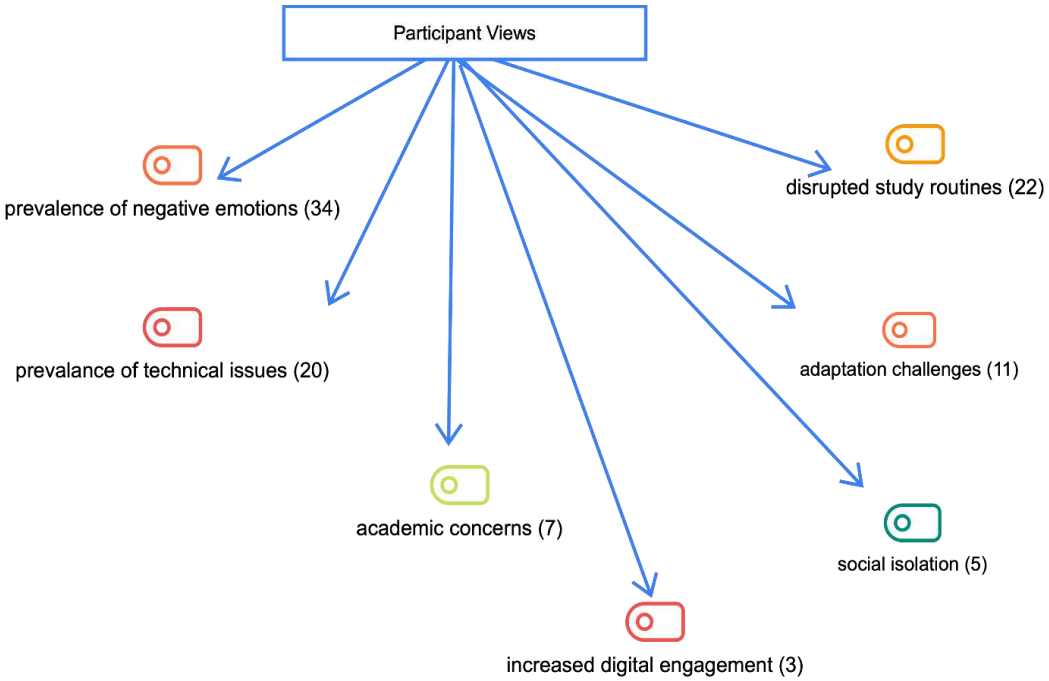
3. Findings

This section outlines the context and objectives of studying medical students' experiences while transitioning to distance education. Based on participants' experiences, the findings are categorized into primary themes and sub-themes.

RQ1. As regards the first research question, "What changes did the remote education process during the COVID-19 pandemic cause in your habits compared to face-to-face education?" the participants offered the following insights:

Figure 1

Themes 1: Changes in Habits Due to Remote Education During COVID-19



This first diagram illustrates the key themes identified from participants' responses regarding changes in habits due to remote education during the COVID-19 pandemic. The most prominent theme is the prevalence of negative emotions, with 34 participants indicating that emotional strain was a significant challenge for many during this period. Disrupted study routines (N:22) and technical issues (N:20) were also commonly reported, underscoring the practical difficulties students encountered while adapting to the online learning environment. Further, adaptation challenges (N:11) and academic concerns (N:7) suggest that the transition to remote learning posed considerable obstacles in adjusting to new educational methods and maintaining academic performance. On a social level, the theme of social isolation (N:5) reflects the loss of interaction and engagement typically found in face-to-face education. Notably, only a few participants (N:3) reported increased digital engagement, indicating that while some students embraced the digital transition, this was not the prevailing experience. In summary, the analysis reveals remote education's negative impact on students' emotional and academic habits, with technological and structural challenges playing key roles.

Some participants expressed their views as follows:

I used the internet actively and became more individualized P65. I disrupted my study routine, started listening to lectures less, and spent the time I used to prepare for class sleeping P45.

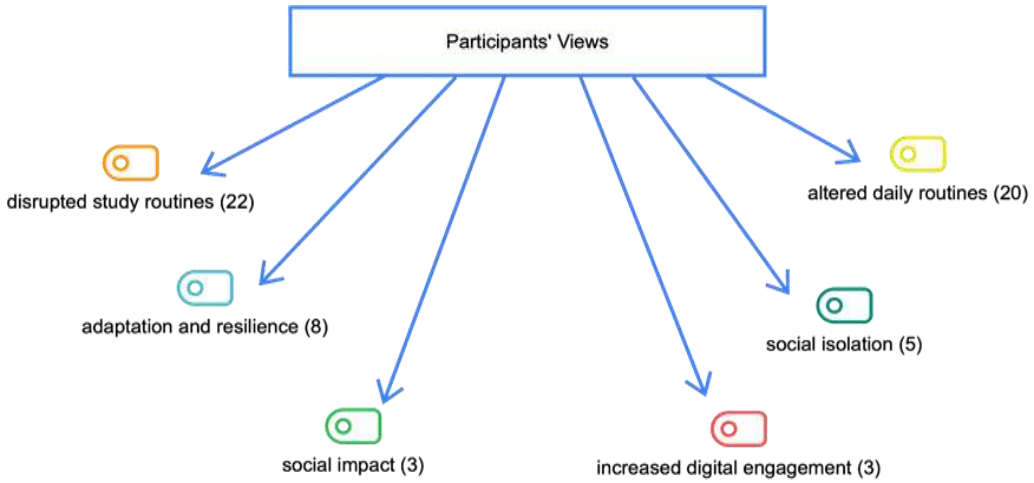
There was no change; my sleep pattern was disrupted, and my eating hours and routines changed P60. It was very productive, and I realized face-to-face education was ineffective P50.

My study routine was disrupted; I used more technological devices, woke up later, and felt more comfortable, but my study time decreased P12. I got used to studying online, experienced increased computer usage, studied in a relaxed environment at home, felt lethargic, and became more relaxed and undisciplined P6. I found more time to study, but my sleep pattern was disrupted, and my motivation decreased P1. Laziness increased, I moved less, and I felt good in a comfortable environment P23.

RQ2. In addressing the second research question, "How did you feel when the pandemic began and your university suspended in-person classes?" the participants shared a variety of thoughtful and insightful responses, which are detailed below:

Figure 2

Theme 2: Emotional Responses to the Suspension of In-Person Classes



The diagram outlines several key themes derived from participants' perspectives on the changes brought about by remote education during the COVID-19 pandemic. Notable concerns include disrupted study routines (N:22) and altered daily routines (N:20), indicating that the transition to online learning significantly affected academic and personal schedules. The theme of adaptation and resilience (N:8) highlights that, despite the challenges, some participants exhibited flexibility and strength in adjusting to the new learning environment. Conversely, social isolation (N:5) and social impact (N:3) underscore the negative effects of reduced social interaction during remote education. While only a small percentage of participants reported increased digital engagement (N:3), this suggests that a few individuals took advantage of remote education opportunities to utilize digital tools better. Overall, the analysis reveals a balance between challenges and coping strategies. Many participants struggle with disrupted routines and social isolation, while some demonstrate resilience and adaptability in navigating the digital learning landscape. This emphasizes the need for structured support to reduce disruptions and enhance social and academic experiences in distance education.

Some participants expressed their views as follows:

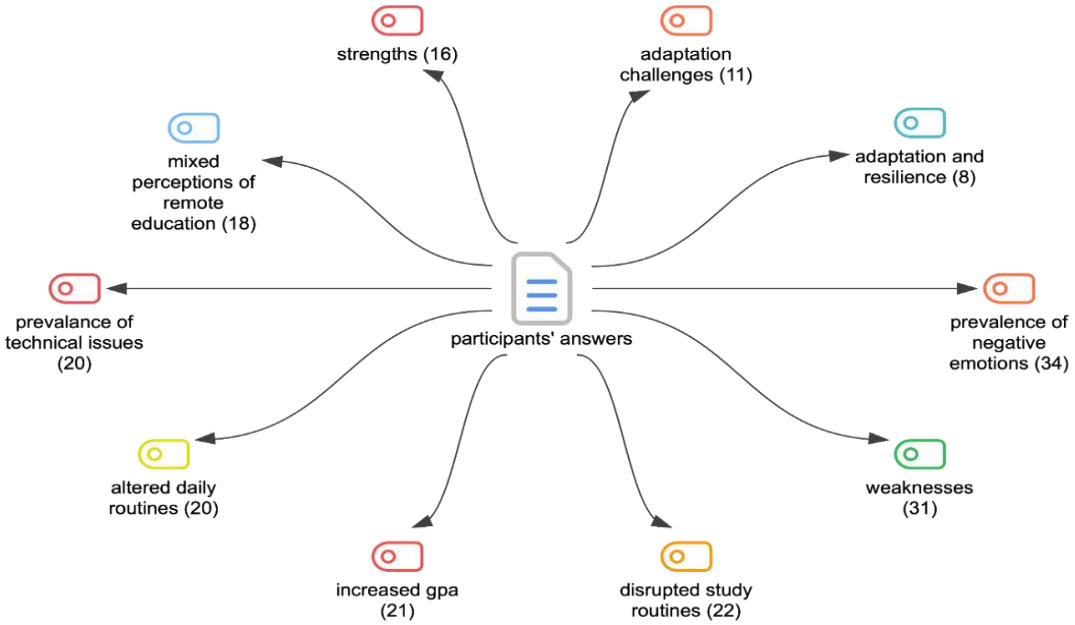
At first, I was happy, but as the process continued, problems arose (P3). It was an unwanted situation; boredom, concerns about the future, and uncertainty made me despair (P5). I was very sad (P6), I was very upset (P7), but then I became happy (P9).

Laboratory classes were disrupted, we could not socialize, and we became withdrawn. At first, it felt like a vacation, but then I experienced unhappiness P32. I wondered if I would ever go back to university again. I was very sad, and I felt terrible, P36. I was worried that people who did not deserve it passed their classes, and I felt sad because I felt sad, our social interactions were limited to P29. The classes were ineffective, and I felt uncomfortable because my routine had changed to P3.

RQ3. To address the third research question, "What issues did you encounter when classes commenced and continued? Did you communicate these challenges to your instructors as students?" The participants provided the following insights.

Figure 3

Theme 3: Challenges Encountered and Correspondence with Instructors



The third figure outlines the key themes from participants' responses regarding their emotions and experiences during the pandemic and the transition to remote education. The most prominent theme identified is the prevalence of negative emotions, documented 34 times, indicating that emotional challenges were widespread as students adapted to this new educational landscape. Closely following this is the theme of perceived weaknesses, mentioned (N:31) times, which reflects the sentiment that many participants felt their academic performance or personal capabilities had been adversely affected. Despite these challenges, positive outcomes were also reported, with (N:21) stating that students experienced increased GPAs, suggesting that some individuals achieved academic improvement amid the difficulties. Everyday struggles included disrupted study routines (N:22) and altered daily routines (N:20), showcasing the significant lifestyle changes brought about by the pandemic. Additionally, technical issues were highlighted (N:20) times, underscoring the practical difficulties that compounded the stress of remote learning. Conversely, participants demonstrated strengths (N:16) and a capacity for adaptation and resilience (N:8), indicating their ability to cope and adjust over time. The theme of mixed perceptions of remote education emerged (N:18) times, revealing that while many faced challenges, some students acknowledged advantages or maintained a more balanced perspective on the new learning environment. In summary, the analysis indicates that while remote education during the pandemic posed numerous emotional and practical challenges, a segment of students managed to adapt and even excel academically, highlighting the varied impacts of this unique experience.

Some participants expressed their views as follows:

Medical education should never be online (P36). There cannot be distance education in medical education (P65). It is good to be able to repeat the same class (P48). There is no strength; its comfort and convenience reduce practical skills. The positive side is that it is easy to access all classes with a single click (P3).

We reached classes quickly, but it was inefficient; having online skills and laboratory classes was inefficient(P62). The opportunity to listen to classes again is a strength (P55). It becomes inefficient when there are internet issues; it can only be online for theory classes. We missed out on practical classes; the only strength of theory classes was the opportunity to listen again (31)

The class recordings were a strength, but the lack of interactive participation was a weakness (P43). Apart from the class recordings, the lack of practical classes was weak (P17). Distance education has no strengths, and the lack of practical education has no strengths. It is healthier for students to learn on their own. Only being able to listen to classes again is a strength, but it negatively affects practical classes (P30).

RQ4. The fourth research question analyzes the strengths and weaknesses of remote teaching in medical education.

The data presents students' perceptions regarding the strengths and weaknesses of online education, particularly in medical education. The responses indicate a strong consensus on the limitations of online medical education, alongside a few acknowledged benefits.

Table 1

Themes 4: The Strengths and Weakness

Subthemes	Codes	N
Strengths	Recorded Lectures	65
	Ease of Access	60
	Flexibility and Convenience	30
Weaknesses	Practical and Laboratory Learning	65
	Lack of Interaction	55
	Reduced Skill Development	50
	General Inefficiency	50

As seen in Table 1, many students appreciated the opportunity to re-watch recorded lectures, which greatly aided their understanding of theoretical concepts (N:65). The ease of access to lectures and course materials with a single click was also highlighted as a key benefit (N:55). Additionally, some students found the flexibility and comfort of attending classes from home advantageous. However, this sentiment was not universally shared (N:35). On the downside, the most significant concern was the challenge of replicating practical and laboratory learning online, particularly in medical education, which heavily relies on hands-on practice (N:65). Furthermore, many students reported a lack of interaction during online classes, limiting their ability to engage in discussions or ask questions—crucial components of deeper learning in medical education (N48). Reduced skill development was another critical issue, as students felt online learning fell short in providing the necessary clinical and practical experience (N:55). Technical issues, such as frequent internet connectivity problems, also disrupted the learning process, further diminishing the effectiveness of online education (N:55). Lastly, many students viewed online medical education as generally inefficient, with some expressing that it offered no significant advantages. At the same time, the absence of structure and discipline contributed to a perceived inadequacy (N:45).

Some participants expressed their views as follows:

Medical education should never be online (P36). There cannot be distance education in medical education (P65). It is good to be able to repeat the same class (P48). There is no strength; its comfort and convenience reduce practical skills. The positive side is that it is easy to access all classes with a single click (P3).

We reached classes quickly, but it was inefficient; having online skills and laboratory classes was inefficient(P62). The opportunity to listen to classes again is a strength (P55). It becomes inefficient when there are internet issues; it can only be online for theory classes. We missed out on practical classes; the only strength of theory classes was the opportunity to listen again (31).

The class recordings were a strength, but the lack of interactive participation was a weakness (P43). Apart from the class recordings, the lack of practical classes was weak (P17). Distance education has no strengths, and the lack of practical education has no strengths. It is healthier for students to learn on their own. Only being able to listen to classes again is a strength, but it negatively affects practical classes (P30).

RQ5. For the fifth question, did remote education affect your average grades? The participants provided the following explanations.

Themes 5. The Impact of Distance Education on Grade Point Averages (GPAs)

Table 2

Themes 5: The Impact of Distance Education on Grade

Subthemes	Codes	N
Impact of Distance Education	Positive Impact on GPA	55
	Stable GPA	20
	Negative Impact on GPA	10

As seen in Table 2, the data provides valuable insights into how online education during the pandemic influenced students' academic performance, particularly their GPAs. Most students (N:55) reported an increased GPA among the responses collected. This indicates that the transition to online learning offered many a more flexible and supportive environment, enabling them to manage their time more effectively, eliminate commute times, and access self-paced learning resources. In contrast, (N:20) participants noted no change in their GPA, suggesting that their academic performance remained stable despite the shift to remote instruction. These students may have adapted well, maintaining strong study habits and routines that translated successfully into the online format. However, another group of (N:10) participants experienced a decreased GPA, revealing some students' difficulties with the new learning model. Issues such as a lack of motivation, technical difficulties, and limited interaction with instructors may have contributed to their decline in academic performance. In conclusion, while online education positively impacted the GPAs of many students, some faced significant challenges that resulted in either no improvement or a decrease in their academic performance. This variation in outcomes highlights differing levels of adaptability among students and underscores the necessity for more customized support during transitions to online learning.

Some participants expressed their views as follows:

My GPA increased, P3. My learning quality decreased. P7. *I saw an artificial increase, P8, but there was no change. P9, my exams went well, and my grades increased. My grades increased because I listened to the revisions P18* .

My grade increased, but that does not mean I learned P21. My GPA stayed the same, and not much change happened P56.

4. Discussion

The findings of this study reveal a complex and varied response to the shift to remote education during the COVID-19 pandemic, highlighting both the challenges and benefits experienced by medical students. Zhong (2020) highlights several critical factors that influence the effectiveness of online learning. Online learning may not adequately support students with kinesthetic learning styles and often fails to provide the social interaction commonly found in traditional classroom settings. These factors include limited access to resources, the availability of Internet connectivity, and students' capacity to engage in digital learning environments. Furthermore, meaningful interaction with instructors is vital.

Modern medical schools are evolving from traditional, lecture-based pedagogies that rely on large classes and face-to-face instruction to a more student-centered approach. With the integration of IT tools, medical education has become increasingly personalized, fostering small team-facilitated discussions. This transformation encourages medical students to engage in self-directed learning, promoting individualized and interprofessional education (Daroedono et al., 2020). Furthermore, Asma and Tezci (2023) highlighted that distance education is particularly beneficial for disciplines such as the social sciences, where theoretical content can be effectively conveyed and where large classroom sizes often present logistical challenges for in-person instruction. They observed that the flexibility and accessibility of online learning can enhance educational outcomes in these areas, especially in the post-pandemic context. However, they also pointed out the potential drawbacks of applying distance education to subjects like mathematics, sciences, and engineering, where hands-on, practical learning is essential. Reliance on virtual platforms may create disparities in these disciplines, as students may not have equal access to vital resources or experiential learning opportunities.

In line with the findings, Sindiani et al. (2020) emphasized that limited social contact, including social distancing and the ability to save time and resources by not commuting to university, were among the most notable advantages of online learning. Additionally, a more streamlined learning process was identified as another significant benefit. However, the disadvantages included the necessity for sufficient technical setup, lack of face-to-face interaction, and restricted access to clinical environments. Furthermore, distance e-learning has the potential to serve as an effective alternative to traditional methods for delivering high-quality medical education. Nevertheless, integrating distance learning encounters substantial challenges, particularly in ensuring the availability of essential infrastructure and formulating effective institutional strategies (Panahi & Borna, 2014).

The findings from this study provide valuable insights into the experiences of medical faculty students during the transition to remote education due to the COVID-19 pandemic. While remote learning presented some advantages, such as increased flexibility and improved GPAs for many students, the challenges proved more substantial, especially in medical education, where hands-on training and practical experience are vital.

A significant theme that emerged was the disruption of students' study routines and daily lives. Many participants noted decreased motivation and focus, difficulties adhering to structured schedules, and challenges associated with studying in less formal, at-home environments. This observation is consistent with other research indicating that remote education can lead to a decline in discipline and productivity, particularly when students are isolated from the traditional classroom setting (Pelikan et al., 2021). The findings suggest that students in medical programs, which demand high levels of engagement and structure, may have been especially vulnerable to these disruptions. Furthermore, the emotional strain of adjusting to this new educational format further exacerbated these challenges.

The emotional impact of remote learning emerged as a significant finding in our study. Many students expressed negative feelings such as sadness, frustration, and anxiety, often connected to uncertainty about the future, loss of social interactions, and the inability to engage in practical, hands-on activities. This is consistent with research indicating that social isolation and the lack of in-person engagement during the pandemic have negatively affected students' mental health (Son et al., 2020). In medical education, where peer collaboration and mentorship are vital to the learning experience, the absence of these social interactions may have led to feelings of withdrawal and disengagement. Furthermore, Guckian et al. (2021) noted that over 3.81 billion active social media users worldwide contribute to medical education by enhancing professionalism, blended learning, well-being, and mentoring within undergraduate programs. Nevertheless, earlier systematic reviews conducted prior to the recent surge in social media usage revealed a lack of high-quality empirical studies assessing its effectiveness in the context of medical education.

One of the primary weaknesses highlighted in the study was the inadequacy of online education for practical and laboratory-based learning, which is crucial for medical training. Participants consistently pointed out that, although online lectures provided certain advantages—such as easy access and the convenience of re-watching recorded sessions – they could not substitute for the hands-on experience essential in medical fields. Chick et al. (2020) observed that significant technical difficulties disrupted learning for many students, aligning with our findings on the prevalence of technical issues reported by medical students. This important observation emphasizes the limitations of remote education for subjects that require experiential learning, which is difficult to replicate in a virtual setting (Dedeilia et al., 2020). The absence of practical skill development and reduced opportunities for direct interaction with instructors impeded students' ability to engage with and comprehend the material thoroughly.

A commonly cited challenge during the pandemic was the prevalence of technical issues, such as unreliable internet access and platform failures, which disrupted the learning process. These challenges were not unique to medical students; they have been widely reported across higher education (Pokhrel & Chhetri, 2021). However, these issues were particularly detrimental for medical students because maintaining concentration during complex theoretical and clinical lessons is crucial. These disruptions likely contributed to feelings of frustration and disengagement among students.

Chick et al. (2020) introduced a flipped classroom strategy for specific conferences. In this well-supported teaching method, learners are provided with didactic materials through prerecorded video lectures, which they can view at their convenience prior to the conference. The authors transitioned weekday academic conferences to a teleconference format using GoToMeeting (LogMeIn Inc.), enabling trainees and staff to participate via live video. This approach allows lecturers to see participants, pose questions, and foster an interactive experience akin to in-person meetings. While most users log in from computers, the platform is also accessible on smartphones and tablets, enhancing engagement from any location. Comparable tools like Zoom, WebEx, and Skype offer similar functionalities. Furthermore, conferences (except those containing protected information) are recorded and stored in the cloud for residents to access later.

Interestingly, despite the various challenges encountered, many participants reported an increase in their GPA during the remote education period. This suggests that the flexibility of online learning—such as the ability to study at one's own pace and eliminate time-consuming commutes—may have enabled students to manage their time more effectively. However, several participants expressed skepticism about the validity of these GPA improvements, arguing that higher grades do not necessarily indicate enhanced learning or a deeper understanding of the subject matter. This raises concerns regarding the long-term implications of remote learning for students' readiness for clinical practice and examinations.

Although most participants encountered challenges, a smaller group exhibited resilience and adaptability, demonstrating their success in adjusting to the remote education model. This finding underscores the varying degrees of student adaptability, which may be influenced by individual learning styles, access to resources, and the level of institutional support. Future research could investigate strategies to assist students who face difficulties during such transitions, particularly in fields that demand intensive, hands-on training.

The findings emphasize the need for a more structured and interactive approach to online medical education. While theoretical content can be effectively delivered through online platforms, practical learning components should be preserved in face-to-face formats. Furthermore, medical programs should focus on enhancing the interactivity of online courses, ensuring that students have ample opportunities to interact with instructors and peers. Integrating technologies that facilitate simulation-based learning should also be prioritized whenever possible.

In conclusion, the shift to remote education during the COVID-19 pandemic presented both opportunities and challenges for medical students. While many students appreciated the flexibility that online learning offered, the overwhelming majority faced difficulties due to the lack of practical learning experiences, social interaction, and structured routines. These findings indicate that, although online education has its place in medical curricula, it must be thoughtfully balanced with in-person training to support the development of both theoretical knowledge and practical skills. Additionally, addressing technical issues and providing mental health support will be vital for enhancing the remote learning experience in the future.

5. Conclusion and Recommendations

The study highlights the substantial impact that remote education had on students' academic habits, emotional responses, and overall educational experiences during the COVID-19 pandemic. Several key themes emerged from the research, shedding light on the challenges and occasional benefits of this unprecedented shift in learning methods.

Participants reported significant disruptions to their study routines, with many struggling to maintain focus and motivation in a less structured and more isolated environment. Emotional strain played a crucial role, with feelings of uncertainty, sadness, and frustration particularly pronounced. The findings also indicated that technical issues posed a widespread challenge, complicating the transition to online learning. Nevertheless, some students adapted by embracing digital engagement and using recorded lectures.

Regarding emotional responses, the shift to remote education increased negative emotions, such as social isolation and anxiety about future academic and career prospects. However, some students exhibited resilience, discovering ways to cope with these challenges, especially by taking advantage of online education's flexibility.

The analysis of distance medical education underscored that the online format adversely affected specific disciplines, particularly those that necessitate hands-on practice. While some students valued the convenience of accessing recorded lectures, the lack of practical learning and interaction significantly detracted from their educational experience. Notably, the study revealed that online education positively impacted many students' GPAs, likely due to the greater flexibility in managing their time and accessing resources. However, some students expressed that the increase in grades appeared somewhat artificial, as it did not necessarily correlate with improved learning outcomes.

Overall, the findings suggest that remote education provided benefits such as flexibility and enhanced GPAs for some students, but the challenges faced were more pronounced. The emotional and academic difficulties encountered during the pandemic—including disrupted routines, technical challenges, and insufficient practical learning opportunities—highlight the urgent need for structured support and more interactive, hands-on elements in future online education. These findings emphasize the importance of addressing students' mental well-being and developing adaptable, student-centered approaches to remote learning.

One promising direction is the development and implementation of hybrid learning models that combine the flexibility of online learning with the essential hands-on experiences of face-to-face education. This is particularly important in medical education, where practical and laboratory-based learning cannot be fully replicated online. Future research could investigate the optimal balance between virtual and in-person education, especially for training in clinical skills.

Additionally, the emotional strain many students have experienced during remote education highlights the need for improved mental health support. Future initiatives should focus on integrating mental health resources into online education platforms. This could include counselling, peer support groups, and stress management workshops. Research could also explore the specific mental health needs of medical students and develop targeted interventions to address these challenges in both online and in-person learning environments.

Given students' diverse experiences and capacity for adaptability, future studies should consider exploring personalized teaching strategies that recognize and address individual learning styles and needs. The potential of adaptive learning technologies, which can respond to medical student performance and deliver tailored content or support, warrants further examination to address students' varying levels of engagement and success effectively.

Additionally, it would be beneficial for future research to investigate the long-term effects of the COVID-19 remote education experience on medical students' academic performance, career development, and mental health. Such studies could provide valuable insights into how healthy students transition back to in-person education and whether the skills or habits cultivated during distance learning continue to influence their medical careers.

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AI-Assisted Learning and Procrastination Patterns: An Exploratory Investigation of ChatGPT Usage in Higher Education

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Abstract: This exploratory pilot study investigates the potential relationship between ChatGPT usage and academic procrastination among EFL Master students. As AI tools become increasingly prevalent in educational settings, understanding their impact on student learning behaviours becomes crucial for digital pedagogy. Through a survey of 95 Master students at Ibn Khaldoun University of Tiaret, Algeria, this investigation examines students' self-reported ChatGPT usage patterns, procrastination levels, and perceptions of AI tools' influence on their academic habits. The exploratory approach reveals that while students recognize ChatGPT's utility for academic tasks, they also acknowledge its potential to facilitate procrastination behaviours. Findings suggest that moderate ChatGPT users demonstrate awareness of both benefits and risks associated with AI tool reliance. This preliminary investigation contributes to emerging discussions in digital education by providing initial insights into the complex relationship between AI assistance and self-regulated learning. The study offers a foundation for future research examining how educational institutions might develop frameworks for responsible AI integration while supporting student autonomy and critical thinking development.

Keywords: ChatGPT, AI tools, artificial intelligence in education, AIED, academic procrastination, critical thinking, memory retention, academic performance

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Introduction

In the past few years, there has been a revolution in the field of education caused by the advent of Artificial Intelligence. In consequence, learning methodologies have greatly changed through the inclusion of prevalent tools such as: ChatGPT in education. This latter, which is a generative AI model developed by Open AI provides human like generated texts which can be helpful in multiple academic tasks. It also has a chatting feature which later on results in a transcribed text that can be a source for note taking. ChatGPT providing a range of quick services is beneficial for students in many ways; hence, essay writing, paraphrasing and outlining became easy tasks that require few prompts and specific wording. However, the same beneficial features can make ChatGPT a double-edged sword as it can negatively impact students' motivation, acquired skills and their academic performance (Deng &Yu, 2023).

A number of studies in the field have discussed a growing rate of reliance on ChatGPT among learners, especially the ones struggling with academic workload and time pressure. There is a tendency for learners to delay their academic assignments; which is a result of ChatGPT's quick and easy execution contributing to the increase of procrastination. Additionally, many studies conclude that frequent use of ChatGPT is related to lack of cognitive effort, poor memory retention, increased levels of procrastination and decline of academic performance (Shabir et.al, 2024). Consequently, learners' engagement in critical thinking and autonomous learning is deteriorating by day which could lead to severely negative effects on their general knowledge retention and analytical skills.

Overall, the present article discusses the cause-and-effect relations between excessive usage of ChatGPT and academic procrastination. It explores how students' academic habits are affected through the 'illusion of ease' on their assignment completion and performance.

ChatGPT and Its Role in Learning

Since Open AI launched ChatGPT, it stood out as a sophisticated generative bot which is able to generate answers mimicking human like quality (Lock, 2022). The captivating thing about GPT is that it maintains conversations within context and not only random generation of responses (OpenAI, 2022). As an advanced AI model, GPT's popularity is snowballing due to its assistance capacity in academic tasks surpassing digital platforms like: Facebook or Instagram (Sier, 2022). Many claims also revolve around GPT revolutionizing traditional web searching platforms (Friedman, 2022).

Moreover, integrating Artificial intelligence in education brought along major changes in how learners approach learning. Tools like ChatGPT across the body of research have proved to be helpful in enhancing productivity and personalized learning providing services to refine students' works and offering instant feedback (Rahman *&* Watanobe, 2023*).* Research also discusses how GPT enhances students' engagement, satisfaction and learning outcomes (Winkler & Sollner, 2018).

On the other hand, many concerns are raised in the field of education regarding GPT's bias, privacy terms and validity of information it offers. Hence, scholars are divided on many ethical and pedagogical issues regarding AI in academia. Consequently, AI detectors have been introduced to identify AI generated works (Chechitelli, 2023), but it did not limit yet the widespread reliance of GPT and other AI models.

Understanding Academic Procrastination

Procrastination as a topic for research has a wide record across the various disciplines. It is a known and widespread issue in the field of education defined merely by the intentional postponement of academic assignments regardless of the negative outcome that it might generate (Svartdal & Løkke, 2022). Moreover, Ferrari and Diaz Moralez, (2014, p.1*)* explain the phenomenon as follows: "*It is associated with higher levels of stress and anxiety, weak impulse control, lack of persistence, lack of work discipline, lack of time management skill and the inability to work methodically*". Some of the contributing factors are purely psychological, as the quote denotes.

Similarly, Steel (2007) states that academic procrastination is the intentional delay of tasks like: presentation preparation, exam revision or assignment completion despite the negative consequences. Nowadays with the presence of external aid tools like GPT, procrastination grew uncontrollably bigger. Students now see no urgency to start their assignments early for they have the AI option ready to generate responses at any later stage before the

deadline. Hence, such behavior results in weaker academic performance and decreased cognitive engagement (Svartdal & Løkke, 2022).

ChatGPT as a Facilitator of Academic Procrastination

Recent research has raised growing concerns that the widespread use of ChatGPT may be fuelling academic procrastination by offering students rapid, easily accessible answers that reduce the immediate need for cognitive effort. As Imhof et al. (2023) point out, a central mechanism behind this phenomenon is what they term "*the illusion of ease*" – the perception that academic tasks are less demanding because ChatGPT can generate coherent and structured responses in seconds. This perception leads students to postpone engagement with assignments, relying on AI for last minute assistance.

While this may offer short-term relief, it often produces superficial outputs lacking the depth, critical thinking and reflective analysis typically required in higher education. This behaviour aligns closely with Steel's Temporal Motivation Theory (2007), which posits that procrastination results from dynamic interplay between expectancy, value, impulsiveness, and delay. GPT enhances the delay element by making it easier for students to postpone the initiation of tasks without facing immediate consequences. Moreover, GPT reduces another factor in procrastination which is aversiveness by offering quick solutions trespassing the discomfort of deep thinking and complex writing.

From the perspective of self-regulated learning, particularly Zimmerman's (2000) three-phase model of forethought, performance, and self-reflection. ChatGPT use can either support or undermine academic performance depending on how students incorporate it in their learning strategies. Students bypassing essential metacognitive processes through reliance on GPT may erode the development of autonomous learning skills.

In addition, Sweller's cognitive load theory (1998) offers another lens for analysis. While AI tools reduce extraneous cognitive load by simplifying tasks, they may also prevent students from engaging in germane processing which is the deep mental work needed for meaningful learning. Furthermore, Imhof et al. (2023) warn that frequent reliance on AI can negatively impact episodic and semantic memory functions leading to poorer long-term retention. The issue intersects with problems of about academic integrity, as ChatGPT may inadvertently encourage academic dishonesty by blurring the line between support and substitution. Some educators fear that GPT diminishes creativity and promote plagiarism – not always intentionally-through the growing dependence on machine generated ideas.

Lastly, Bandura's social cognitive theory (1986) emphasizes the importance of self-efficacy in academic achievement. Excessive use of ChatGPT may impair the students' confidence in their own abilities which can further exacerbate procrastination. Thus, students become less willing to initiate or persevere in challenging tasks. It becomes clear that habitual use of GPT can pose serious risk on the student's academic development, not only by enabling procrastination but also by weakening cognitive, motivational, and ethical dimensions of learning.

Methodology

This exploratory study investigates the awareness of EFL Master students at Ibn Khaldoun university of Tiaret regarding the relationship between ChatGPT usage and academic procrastination. The study sample consisted of 95 Master's students – both males and females – selected to represent a cross-section of the EFL post-graduate population ensuring a degree of sample representativeness. Moreover, the survey instrument designed for this study consisted of 10 different questions that varied in format, ensuring a balanced blend of qualitative and quantitative data collection.

The survey included a mix of closed-ended Likert scale and open-ended questions to thoroughly elicit insights on three dimensions: demographic information, behavioural use of ChatGPT and perception and attitudes related to Academic procrastination and AI dependence. Thus, closed-ended and multiple-choice items ensured ease of quantification; whereas, open-ended items allowed elaboration on personal views and experiences. In addition, the questionnaire was reviewed by two faculty members to ensure content validity, whose feedback helped greatly in refining clarity, relevance and neutrality of questions' wording.

Also, prior to full deployment, the survey underwent a pilot test involving a smaller section of the sample (10 students), whose feedback also resulted in minor adjustments that helped improve the instrument's usability and reliability.

Data Analysis

To begin with, 90% of the sample confessed having prior knowledge about ChatGPT as an AI model. Also, 53% of them confessed using it in their academic tasks with a frequency ranging from Complete to Moderate.

Table 1

Frequency of ChatGPT usage and procrastination rate

Do you use ChatGPT for academic tasks?	Low Procrastination	Moderate Procrastination	High Procrastination
No	15	27	2
Yes	7	36	7

As shown in the table above, among the 53% of respondents who use GPT, 67% of them rate their procrastination as moderate. This entails that Master students show awareness of their procrastination habit compared to reliance on GPT and both are estimated as moderate and not so severe. When asking comparative questions about the usefulness of ChatGPT and the way it may contribute to procrastination, this cross-tabulation summed up the responses.

Table 2

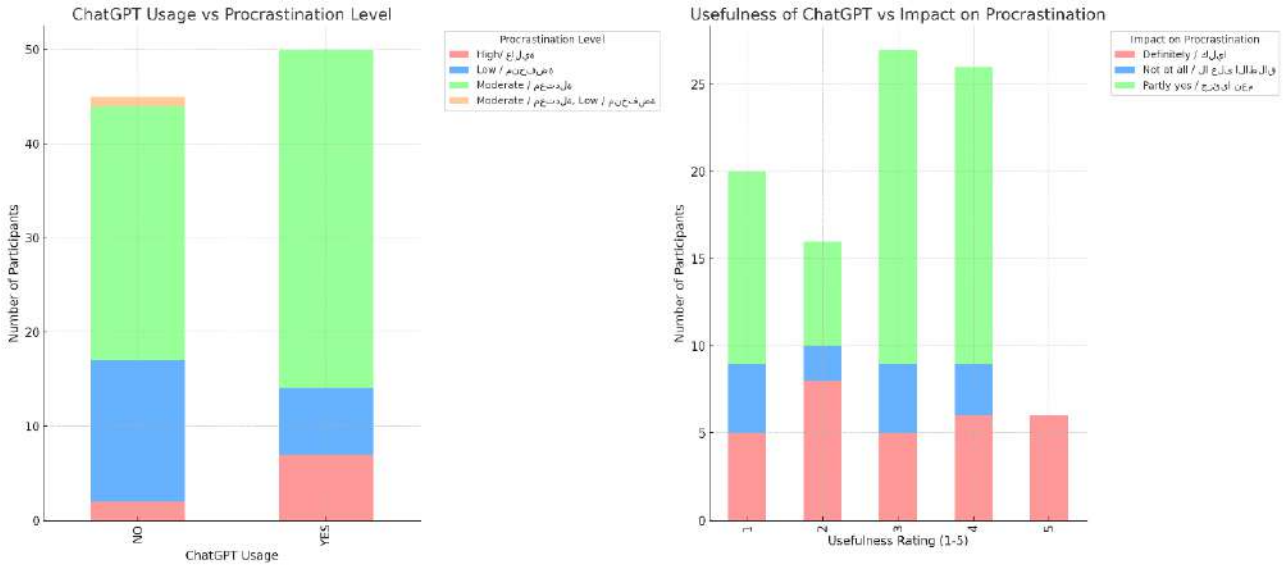
Perceived usefulness of ChatGPT and its impact on academic procrastination

Usefulness Rating (1-5)	Definitely increases procrastination	Partly increases procrastination	Does not increase procrastination
1	5	11	4
2	8	6	2
3	5	18	4
4	6	17	3
5	6	0	0

The results in the table above indicate that 23 respondents who view ChatGPT as very useful believe that it promotes procrastination, whereas the majority of those of view it as non-useful think definitely or partly that it promotes procrastination. This means that students though they realize some of ChatGPT's advantages and usefulness, they still identify it as partly or majorly a cause of academic procrastination.

Figure 1

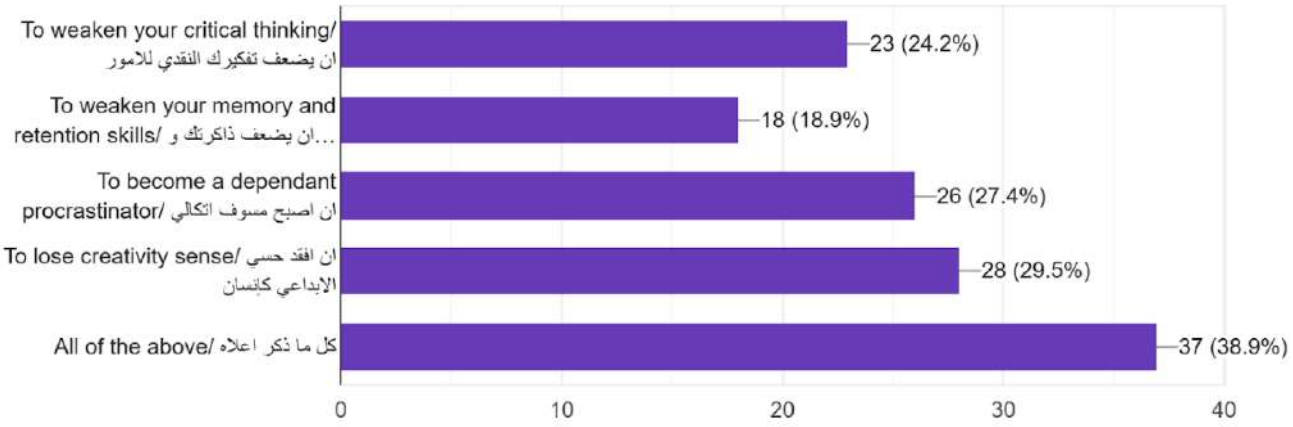
Visual representation of the results



To compare the findings, we can say that the majority of users of GPT claim having moderate levels of procrastination. They also perceive GPT as useful in majority, but believe it promotes procrastination. On another instance, when asked about how ChatGPT can impact your learning negatively in the future, 30% of respondents confessed fearing to lose creativity and originality. Meanwhile, approximately equal rates confessed fearing to suffer weak critical thinking skills and developing total procrastination. Meanwhile, 19% feared memory and retention loss.

Figure 2

Potential long-term impacts of reliance on ChatGPT



Overall, all participants confessed GPT would have a negative long-term impact on their learning distributed between the various options, however, 39% selected all the options as they strongly realized the drawbacks of overreliance on AI tools.

At the end of the survey when asked about potential precautions to limit the impact of ChatGPT on learning, students with a majority proposed the following:

- Prioritizing the human mind through centering tasks around real-life situations and problem solving.
- Banning AI tools or reinforcing detection implementation and proposing strict punishments.
- Elaborating structured mechanisms on how to adopt AI tools in education with a reasonable and calculated rate.

Discussion

The findings of this exploratory study suggests that ChatGPT plays a dual role in academic life, acting both as a supportive learning aid and as a potential enabler for procrastination. On one hand, its appeal lies in the convenience it offers in terms of instant access to coherent information, time-saving capacity and simplified academic assistance. However, this very efficiency can lead to behavioral shifts in task initiation. The data suggest that the more useful and efficient the students perceive GPT to be, the more likely they are to delay engagement with tasks, viewing the tool as a safety net for last-minute completion.

Interestingly, a substantial portion of students – particularly those identifying as moderate procrastinators – do not view GPT as a cause of procrastination per se. Instead, they view it as reinforcing existing procrastination tendencies rather than creating them. This nuanced understanding highlights the role of self-regulated learning in mediating technology use. Students' divergent views point to a level of metacognitive awareness regarding their study habits, time-management, and ethical engagement with AI tools. In fact, many respondents demonstrated a responsible and critically reflective approach to using ChatGPT, challenging the original hypothesis that AI tools inevitably lead to overreliance and diminished student agency.

The results may also reflect a broader shift in how students perceive digital tools, not merely as shortcuts but as resources to be strategically integrated into learning when used mindfully. This interpretation aligns with Zimerman (2000) model of self-regulation which emphasizes that learners can either use tools to enhance autonomy and efficiency or to circumvent genuine cognitive effort. With that being said, several limitations must be acknowledged. First, the study relied on self-reported data which are inherently subject to bias and may not accurately reflect actual

behavior. Second, the sample was limited to EFL Master students at one university which may affect the generalizability of the findings. Third, the design of the survey did not include longitudinal measures making it difficult to assess causal relationships between GPT and procrastination patterns.

To ensure GPT is used to enhance learning rather than hinder it, practical suggestions from students called for structured guidelines on AI use, proposing the elaboration of institutional frameworks on AI literacy curricula. Moreover, several participants proposed using AI as a starting point for critical reflection and deeper engagement such as: rewriting or commenting. Last, since procrastination is partly rooted in psychological and motivational factors, the institution may consider offering time-management workshops; Self-regulation training or embedded prompts in assignments that guide students to plan their AI use thoughtfully.

Conclusion

Despite the many benefits AI provides to its users in the academic field, it remains doubted and uncontrolled in the majority of the time. ChatGPT as a prominent advanced technology presents both opportunities and challenges in academia. While it promotes productivity, personalized content and quick interactivity with the user; it also contributes to procrastination if not used responsibly. Reliant usage of ChatGPT can result in weakened academic performance, poor retention and decreased memory. A balanced approach to integrate AI usage in completing academic assignments requires strengthened self-regulation strategies first. Promoting critical engagement and a structured framework for usage can contribute majorly into maximizing ChatGPT's benefits and minimizing its risks.

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Human-AI Interaction in Romanian Schools: Explorations of Algorithmic Empathy and Digital Co-Creation

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Abstract: This article explores the ongoing interaction between human intelligence and artificial intelligence (AI), with a particular focus on the concept of algorithmic empathy – a type of simulated affective response with tangible educational value – and on the dynamics of digital co-creation. Drawing on interdisciplinary perspectives and qualitative data collected through semi-structured interviews with 57 teachers and 542 students from Romania, the study explores how AI systems can support learning, foster innovation, and adapt to users' cognitive and emotional needs thematically analysed to provide in-depth insights. The analysis identifies key factors that shape effective human-AI communication, such as digital literacy, trust, personalization, and ethical awareness. While AI is perceived as a valuable tool for enhancing educational processes and decision-making, challenges related to transparency, over-reliance, and reduced human connection are also highlighted. The findings show that meaningful human-AI collaboration requires not only technological refinement but also a critical and ethical rethinking of the roles both actors play in a shared digital ecosystem. The study underscores the importance of algorithmic empathy and conversational digital literacy in sustaining user motivation, while warning against dependency and the erosion of critical inquiry. In educational settings, AI is best positioned as a complement to, not a substitute for, the human educator. These insights reinforce the need for human-centred, ethically grounded AI integration strategies, especially in environments where learning, equity, and emotional support intersect.

Keywords: human-AI interaction, algorithmic empathy, digital co-creation, conversational digital literacy, communication, ethics, education, innovation

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1. Theoretical Background and Study Purpose

In the age of "free intelligence," artificial intelligence (AI) has become a key issue of contemporary society, influencing a wide range of everyday life aspects-from healthcare and education to business and entertainment. Effective communication between AI and human users is essential to the proper functioning of these systems. This communication involves transferring information in a way that is easily understandable for humans and adaptable for AI (Floridi et al., 2018). As AI continues to grow more sophisticated, the importance of this interaction also increases, especially as society becomes increasingly dependent on such technologies. The main goal of this article is to examine the factors that enable efficient communication through a multidisciplinary lens, while also addressing the related challenges and emerging opportunities.

This study explores the evolving relationship between artificial intelligence (AI) and human cognition, highlighting how these two types of intelligence can collaborate to boost efficiency and drive innovation. It delves into the various elements that shape human-AI communication, particularly focusing on both ethical challenges and technological developments. The discussion also covers how different industries are being transformed by this interaction and considers future growth opportunities. A key insight from the analysis is that true innovation depends on balancing technical advancements with the development of human capabilities. Encouraging this balance helps us tackle complex problems more effectively. The research also points to the importance of upholding ethical principles to address the risks that could arise from widespread AI implementation (Russell & Norvig, 2021). Over the years, the human-machine relationship has evolved from the simple use of technological tools to a complex interaction involving artificial intelligence (Bostrom, 2014). Thus, communication between AI and human intelligence is crucial for building an effective partnership. This article explores these aspects, emphasizing the importance of developing AI systems that can adequately interpret and respond to users' needs.

A key element in understanding human-AI communication is the socio-cultural context in which this interaction takes place. Natural language, social norms, empathy, and the ability to interpret intent are core features of human communication, yet integrating these into AI systems remains a major challenge (Dignum, 2019). Therefore, studying how to facilitate effective communication between humans and AI calls for an interdisciplinary and transdisciplinary approach, drawing from cognitive science, linguistics, psychology, ethics, and computer science.

Furthermore, the motivation to explore this topic stems from the urgent need to create a digital education system that aligns with today's realities. In a world increasingly shaped by algorithms, digital literacy is no longer optional – it is a fundamental skill. Effective communication with AI requires not only technical knowledge, but also the ability to critically assess information, understand automated decisions, and engage with technology in an ethical and responsible way (Luckin et al., 2016).

The exponential increase in the use of AI in education – through adaptive platforms, conversational agents, and automated assessment systems – raises important questions about the identity and autonomy of both students and teachers. Within this context, the present study aims to establish a solid theoretical framework for understanding and improving human – AI communication, with the broader goal of contributing to the development of sustainable, human-centred educational practices.

The emergence of generative artificial intelligence, such as language models like ChatGPT, has fundamentally transformed the dynamics of digital interaction. These tools no longer serve merely as search engines or data processors, but as entities capable of sustaining coherent dialogue, offering feedback, and even supporting learning and reflection (Zawacki-Richter et al., 2019). For this reason, understanding how AI systems interpret user intent, emotions, and knowledge levels is becoming increasingly essential.

Furthermore, this digital transformation is accelerating the transition from a traditional, transmission-based pedagogy to one that is collaborative and exploratory, where technology becomes an active participant in the educational process. Communication between the user and AI gains formative significance, as such interaction encourages critical thinking, creativity, and self-directed learning. Nevertheless, there is a concern that over-reliance on automated responses could lead to cognitive passivity and a reduction in authentic human interaction (Selwyn, 2019).

Daugherty and Wilson (2018), in their work on collaboration between humans and machines, emphasize that artificial intelligence should not be seen as a replacement for human effort, but rather as a tool to enhance it. Within the educational setting, this viewpoint aligns with the idea of AI-supported teaching, where the role of the teacher

remains essential. AI, in this case, serves to personalize and simplify learning experiences, making the process more efficient without removing the human element.

The rationale for this study is also supported by the global context shaped by the COVID-19 pandemic, which has accelerated the adoption of digital technologies in education while simultaneously exposing deep-seated inequalities in access, gaps in technological literacy, and ethical challenges related to the mass use of AI. Thus, the relevance of these systems lies not only in their technical capabilities, but also in how they are perceived, accepted, and applied by teachers and students in real-world learning environments (Van den Berghe et al., 2021).

The article draws attention to the importance of focusing on human experience, especially in the context of how teachers engage with artificial intelligence. It argues that successful communication with AI isn't just about how the system performs technically – equally important are the cultural, social, and educational factors that shape how it's used. Instead of jumping immediately to trusting AI, the study suggests that we should first foster open, respectful conversations grounded in shared values, ethical integrity, and mutual understanding.

1.1. Communication channels

Artificial intelligence interacts with people through several communication channels:

- Text-based interfaces: One common method is through text-based platforms, such as chatbots and virtual assistants. These tools interpret what users type and respond accordingly. They use natural language processing (NLP) to mimic human conversation. Programs like ChatGPT are notable examples, continuously refining their interactions based on user feedback (Floridi et al., 2018).
- Voice-based interfaces: Systems like Alexa and Siri use voice recognition combined with NLP to understand spoken commands and perform tasks such as playing music or controlling smart home devices. Their ongoing development aims to enhance the naturalness and fluidity of voice interactions (Russell & Norvig, 2021).
- Visual interfaces: Tools such as dashboards, interactive visualizations, and augmented reality applications are widely used in education, creative industries, and complex data analysis. Augmented reality, for instance, enables users to overlay digital information onto the physical world, supporting faster and more intuitive decision-making (Bostrom, 2014).
- Embodied AI in physical robots: Robots equipped with AI capable of emotional and physical interaction are increasingly integrated into fields such as education, healthcare, and public administration (Floridi et al., 2018).
- Collaborative platforms: These tools aim to support meaningful collaboration between people and AI, particularly in situations that require teamwork, detailed coordination, or the handling of large amounts of data (Russell & Norvig, 2021).

1.2. Challenges in communication

- Lack of empathy: AI lacks the ability to fully grasp human emotions in the way a human conversational partner can. For example, a chatbot may detect certain emotional cues, but its interpretation remains limited by predefined data sets. This shortcoming can lead to impersonal or inappropriate interactions (Floridi et al., 2018).
- Language barriers: The complexity of natural language – including ambiguity, figurative expressions, and metaphor – can be difficult for AI to interpret. Challenges in understanding dialects, domain-specific jargon, or culturally embedded phrases can hinder accessibility and broader adoption (Russell & Norvig, 2021).
- Ethical and privacy concerns: The use of personal data in AI systems raises critical issues regarding data protection and information security. Security breaches may result in loss of user trust and serious legal implications (Bostrom, 2014).
- Technological limitations: Certain AI systems struggle with processing complex or contextually nuanced queries. In such cases, human intervention is often required to avoid errors or misinterpretations (Floridi et al., 2018).
- Algorithmic bias: AI algorithms may reflect the biases found in their training data. This can lead to unfair or discriminatory outcomes, ultimately undermining both the reliability and societal acceptance of AI technologies (Russell & Norvig, 2021).

1.3. Development opportunities

- Artificial empathy enhancement: The integration of algorithms capable of detecting and responding to human emotions. This includes recognizing facial expressions, analyzing vocal tone, and adapting responses according to the user's emotional context (Bostrom, 2014).
- Advanced personalization: Customizing communication based on individual user needs and preferences. For example, AI-powered educational platforms can adjust content to align with each learner's style and pace (Russell & Norvig, 2021).
- Real-time collaboration: Employing AI as a decision-making partner in complex scenarios by providing data-informed support. This is especially valuable in fields like medicine, where AI can process vast amounts of information rapidly to offer precise solutions (Floridi et al., 2018).
- Bias reduction: Advancing machine learning techniques to limit the influence of biases embedded in training datasets, promoting more equitable AI outcomes (Russell & Norvig, 2021).
- Multimodal interface development: Combining text, visuals, audio, and virtual reality to create more intuitive, immersive, and dynamic interaction experiences (Bostrom, 2014).

1.4. Real-world uses of artificial intelligence

- Education: Modern learning platforms powered by AI are increasingly used to personalize instruction. These tools can pinpoint where a student is struggling and offer tailored resources to help them progress (Floridi et al., 2018).
- Healthcare: AI is transforming medical diagnostics and patient care. Intelligent systems can now interpret medical images to catch signs of illness early on (Russell & Norvig, 2021).
- Business: Companies are leveraging AI to enhance strategic planning. Through data analysis and automation, these systems help forecast financial patterns, manage risks, and uncover potential growth areas (Floridi et al., 2018).
- Public Services: Government institutions apply AI to make their internal processes more efficient, reduce red tape, and provide citizens with better access to information (Bostrom, 2014).
- Cybersecurity: AI-driven technologies play a crucial role in identifying and reacting to cyber threats instantly. These systems analyze vast amounts of data to spot and address security issues as they happen (Russell & Norvig, 2021).

2. Methodology

The article adopts an interdisciplinary perspective, combining insights from fields such as computer science, psychology, linguistics, and ethics. The chosen methodology involves a systematic review of the academic literature, followed by a qualitative investigation of real-world cases and practical applications (Floridi et al., 2018), which offer relevant information on the challenges and opportunities in this field.

The qualitative data of the study include semi-structured interviews with a total of 57 teachers and 542 students across multiple Romanian schools. This focused thematic analysis was conducted on this sample of teachers and students to ensure deeper insight into their recurring patterns and perceptions.

A further methodological key aspect is the comparative analysis of various existing AI technologies, aimed at identifying their strengths and weaknesses. This approach helped to build a clear overview of the current state of the field and potential future directions for research, with a focus on user impact and communication effectiveness (Russell & Norvig, 2021).

To explore how effective communication occurs between human users and artificial intelligence systems in educational settings, the study employs a qualitative, exploratory methodology. This approach allows for a deeper understanding of user perceptions, behaviours, and motivations, going beyond the quantitative aspects of interaction.

2.1. Research objectives

The primary goals of this methodological endeavour are:

- To identify the factors that influence the quality of communication between humans and AI in educational contexts;
- To analyse how human users (teachers and students) perceive this type of interaction;
- To explore the role of algorithmic empathy and artificial emotional intelligence in facilitating effective communication;
- To assess the potential of AI in supporting student-centred learning.

2.2. Research method

The study is grounded in thematic analysis of data gathered through semi-structured interviews with a sample of 57 teachers and 542 middle and high school students from both urban and rural educational institutions. The interviews aimed to capture subjective yet valuable insights into real-world experiences with AI technologies (e.g., ChatGPT, Google Bard, adaptive platforms) in educational settings.

Criteria for participant inclusion included active involvement in secondary or high school education, willingness to participate, and prior exposure to AI-based platforms in an educational context. Participants who lacked basic digital literacy or had no prior contact with AI technologies were excluded. A purposeful sampling strategy was used to ensure diversity in terms of teaching disciplines, geographical location, digital competence, and school environment, thus aiming to reduce selection bias and enhance the representativeness of the findings.

2.3. Rationale for the qualitative approach

A qualitative approach was chosen because it offers an interpretive and flexible framework – crucial in an emerging field like human-AI communication combining a comprehensive literature review with semi-structured interviews conducted with **57 teachers and 542 students**. Participants were purposefully selected from a wide range of school environments, spanning both urban and rural areas across several counties. The sample encompassed individuals from lower secondary (grades VII-VIII) and upper secondary (grades IX-XII) education. The teacher cohort included professionals from diverse disciplines – such as S.T.E.M., humanities, and the arts – with varying levels of familiarity and practical experience in using AI-based educational tools. Interaction with intelligent systems involves nuanced contextual factors – such as trust, cognitive style, digital competence, or intrinsic motivation – that cannot be easily quantified. Participant discourse analysis provides meaningful insights into the adaptive and personalized nature of AI interaction, as well as the practical challenges users may face.

The student group was similarly diverse, reflecting a broad spectrum of academic orientations, socio-cultural backgrounds, and levels of digital literacy. Care was taken to include learners from institutions with and without prior involvement in AI integration initiatives, in order to maximize contextual diversity and reduce institutional bias.

Each interview, lasting between 30 and 45 minutes, followed a structured protocol covering four main areas: (**a**) firsthand experiences with AI platforms, (**b**) perceived advantages and potential drawbacks, (**c**) emotional responses and levels of trust in AI-generated content, and (**d**) future expectations regarding AI integration in education. To illustrate, participants were asked **open-ended questions** such as: "*How do you typically use AI platforms in your learning/teaching*?", "*Can you describe a positive or negative experience when using AI tools in the classroom*?", "*Do you feel AI systems understand your questions and needs*?", and "*How do you think AI might change your role as a teacher/student in the future*?" Sample questions included: "*How do you typically use AI platforms in your learning/teaching*?", "*Have you ever felt supported or misunderstood by an AI response*?", and "*What benefits or risks do you associate with AI in the classroom*?"

Data were analysed thematically, drawing on the six-phase approach developed by Braun and Clarke (2006). Coding was conducted independently by two researchers with 84% inter-rater agreement. The two researchers initially coded transcripts separately, identifying semantic and latent themes. Discrepancies in code interpretation or theme categorization were resolved through iterative discussions and consensus meetings. An audit trail of coding decisions was maintained throughout the process to ensure transparency and consistency in analysis. For example, in one case, the initial code 'student comfort' was assigned by the first researcher to excerpts describing AI's polite tone. The second researcher coded the same excerpts as 'perceived empathy.' Following a consensus meeting, both agreed to merge the excerpts under a refined theme called 'algorithmic empathy,' and this decision was logged in a shared

coding spreadsheet, annotated with justifications and timestamps. Discrepancies were resolved through discussion and consensus, ensuring While the significantly expanded sample size lends greater depth and credibility to the findings, certain limitations remain – notably the potential effects of self-selection and the limited representation of non-formal educational contexts.

This was assessed during the coding phase, as the last set of interview transcripts did not yield additional codes or insights beyond those already identified. The stability of thematic patterns across participants, regardless of background or context, further supported the conclusion that data saturation had been reached. This reinforces the reliability of the findings and ensures that the analysis captured the full range of perspectives relevant to the study objectives.

Triangulation was employed through cross-validation between the thematic codes of both researchers and comparison with insights from the literature review, enhancing the validity and robustness of the qualitative findings. In addition to methodological triangulation (via independent coding and thematic agreement), theoretical triangulation was applied by juxtaposing participant responses with established frameworks in digital pedagogy and AI ethics. For example, student references to personalized feedback were interpreted in light of self-determination theory (Ryan & Deci, 2000), while concerns about overreliance were discussed through the lens of heutagogy (Blaschke, 2012). Furthermore, data source triangulation was ensured by collecting perspectives from both students and teachers across varied educational contexts. This multi-level triangulation increases the credibility, coherence, and transferability of the study's findings. Analyst triangulation also contributed to the robustness of interpretations: both researchers brought complementary disciplinary perspectives – *education and digital ethics* – which enhanced thematic refinement. The convergence of themes across independently coded data and alignment with existing literature not only validated emergent patterns but also provided nuanced insight into divergences between stakeholder groups. Finally, environmental triangulation was partially addressed by including voices from urban and rural institutions, offering contextual depth and illustrating how institutional setting may mediate AI integration and perception.

2.4. Ethical considerations

The research complied with all principles of academic ethics: participation was voluntary, the data were anonymized, and informed consent was obtained prior to conducting the interviews. Additionally, special attention was paid to the protection of personal data, in line with GDPR regulations.

2.5. Results and interpretation

The results derived from the interview analysis were thematically grouped to ensure alignment with the research objectives. The data highlight several recurring trends and shared perceptions regarding the interaction between users and AI systems in educational settings.

2.5.1 Overall perception of AI in education

Most participants expressed a favourable view of AI, seeing it as an innovative, accessible, and motivating tool. Teachers emphasized AI's potential to provide instant feedback, encourage personalized learning, and reduce time spent on grading and formative assessment. Students particularly appreciated the interactive and "human-like" nature of the experience, especially when using conversational models such as ChatGPT: *"Sometimes it feels like you're talking to a super-smart classmate who never runs out of patience."* (Student, age 15) However, there were also critical perspectives, especially from teachers, who pointed to the risk of overreliance on automated responses and a diminishing capacity for critical thinking: *"Students no longer want to understand – they just want the perfect answer, instantly, with no effort."* (Romanian teacher, urban school)

2.5.2 Factors that influence effective human-AI communication

Several key factors were identified that facilitate smoother interaction with AI systems:

- **Digital literacy level:** Students with stronger tech skills were better able to ask clear questions and interpret AI-generated responses more effectively.
- **Clarity in natural language use:** Coherent and well-structured input resulted in more accurate and helpful answers, suggesting a strong link between linguistic skills and interaction quality.

- **Educational environment:** In schools where technology is systematically integrated into teaching, educators tended to demonstrate greater openness and trust in AI.

2.5.3 Algorithmic empathy – perception and limitations

An interesting aspect that emerged was the perception of "empathy" in AI systems. While participants acknowledged the artificial nature of these interactions, many highlighted the polite, calm, and encouraging tone of the responses: *"It never scolded me, no matter how weird my question was."* (Student, age 13) However, teachers emphasized that this type of "empathy" cannot replace the authentic teacher-student connection. This observation supports the idea that AI can serve as a supportive tool, but not as a substitute for human relationships in education.

2.5.4 Identified challenges

Among the main challenges reported were:

- Misunderstanding AI responses due to ambiguous phrasing;
- Lack of transparency regarding the source of the information provided;
- A tendency among some students to use AI to avoid cognitive effort.

These findings highlight the importance of fostering **critical digital literacy**, accompanied by an **ethical and reflective approach** to AI use in education.

3. Thematic Analysis and Interpretation of Results

Based on a focused thematic analysis of semi-structured interviews conducted with a sample of 57 teachers and 542 lower secondary students, the following key trends were identified regarding the perception and use of AI in educational communication.

One salient theme was that of **algorithmic empathy**, which emerged strongly among student responses. This concept of "algorithmic empathy" is central to the study's originality, capturing how simulated, polite responses can produce an affective, motivating experience for learners. While not equivalent to genuine empathy, this type of interaction has tangible educational value. These insights warrant deeper exploration into how algorithmic empathy could be harnessed ethically to support inclusive pedagogical practices. Connecting these findings to the theoretical framework, algorithmic empathy can be interpreted through the lens of socio-constructivist pedagogy, where learning is mediated by dialogue, emotional scaffolding, and relational trust. Although simulated, the empathetic behaviour of AI may serve as a proxy for peer or teacher interaction, reinforcing engagement and reducing anxiety – particularly for students less inclined to participate in traditional formats. This supports the claim by Daugherty and Wilson (2018) that AI should augment, not replace, human educators, and aligns with Istrate et al. (2025), who advocate for emotionally responsive digital pedagogy rooted in human values.

3.1. Key themes identified

Through the coding of participants' responses, the following central themes were identified:

a. Perceived usefulness of AI – Frequently cited by both teachers and students, this theme highlights the appreciation for AI's clarity, efficiency, and practical utility in educational contexts. AI is viewed as a valuable aid for writing, explanations, and test preparation.

b. Ethics and responsibility – The second most common theme reflects concerns about using AI responsibly and with integrity. Participants drew a clear line between leveraging AI as a learning support tool and using it to cheat or avoid intellectual effort.

c. Risk of dependence / Academic dishonesty – This theme was especially prevalent among student responses, suggesting that the temptation to rely on AI for quick answers is significant. Teachers expressed concern that this trend could hinder students' critical thinking development.

d. Support for personalized learning – AI is praised for its capacity to adapt explanations to the user's level of understanding, offering a more personalized and flexible learning environment, especially for students who require additional guidance.

e. Empathy – Students commented on the polite and calm tone of AI responses, which made interactions feel emotionally supportive. Even though they understood the empathy was simulated, they still found it comforting and motivating.

f. Concerns about teacher replacement – While AI was generally seen as an ally, some teachers expressed valid fears that technology might gradually take over aspects of their instructional roles, particularly in content delivery.

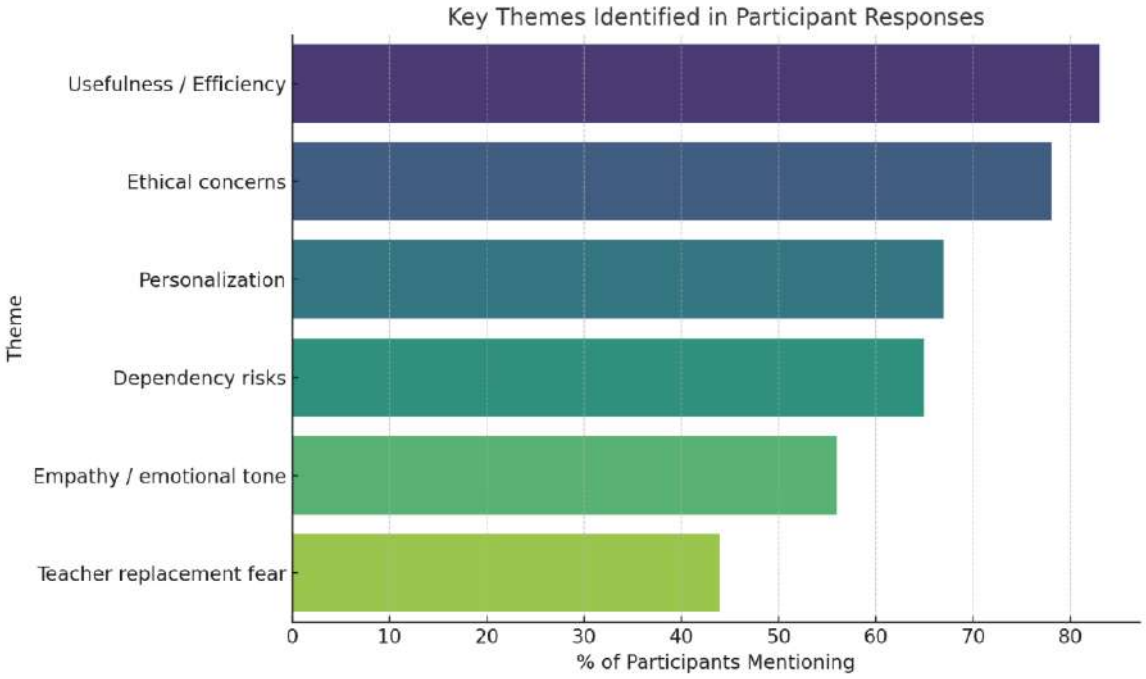
3.2. Overall interpretation

Based on the frequency of thematic references the infographic (Fig. 1) confirms that human-AI interaction is perceived as both valuable and challenging. There is a noticeable tension between usefulness and risk, between support and superficiality, between technology and humanity. These dualities shape a complex educational reality in which AI must be understood not merely as a technological tool, but as an interface for communication, co-creation, and responsibility.

The findings support the idea that integrating AI into education must be accompanied by the development of **digital conversational skills**, **critical literacy**, and a **redefinition of the teacher-student relationship** within the context of emerging technologies. Effective communication between humans and AI is not an end in itself, but a means to reinforce **learning, equity**, and **innovation** in the school of the future.

Figure 1

Key Themes in Human-AI Communication



The infographic above illustrates the most frequently mentioned themes from the interviews conducted with students and teachers about human-AI communication in education.

- **The perceived usefulness of AI** emerges as the most prominent theme, with 83% mentions. This reflects widespread appreciation for AI's clarity, speed of response, and practicality in tasks such as writing and explaining complex concepts.
- **Ethics and responsibility**, with 78% mentions, emphasize the importance of conscious and honest AI use, particularly in evaluation contexts and issues related to content originality.
- **Risk of dependency** and **support for personalized learning** are equally cited (65% and 67% mentions each), indicating a double-edged potential-AI can support learning, but may also encourage surface-level engagement when misused.
- **Empathy** (56%), and **concerns of teacher replacement** (44%) are recurrent concerns, especially among educators, suggesting that while AI is seen as a valuable tool, it cannot replace the relational core of education.

This visual synthesis offers a solid basis for shaping educational strategies focused on enhancing **digital communication skills**, **critically integrating AI into curricula**, and **preserving the essential role of the teacher** in a technology-rich learning environment.

Moreover, while the analysis confirms several positive aspects of AI integration in education, it also reveals a series of interpretative limitations, particularly regarding the contextualization of differences between participant groups. For instance, the study does not systematically distinguish between teachers' and students' perceptions, despite the fact that these two categories often articulate contrasting views on the utility, risks, and trustworthiness of AI-based systems. The lack of an explicit comparison diminishes the study's ability to capture the relational dynamics of human-AI interaction as shaped by the participants' educational roles. Future research would benefit from a more structured comparative analysis between these groups to highlight the influence of professional context, age, and digital experience on how AI is perceived and utilized in educational settings.

The thematic results are predominantly descriptive, focusing on what participants said rather than providing a critical interpretation of why they said it or how these perceptions relate to broader theoretical constructs. For instance, although empathy and personalization are frequently mentioned, the analysis does not sufficiently connect these themes with established pedagogical models or existing frameworks in digital education. This limitation reduces the explanatory power of the findings and suggests a need for deeper, theory-informed analytical engagement in future studies. For instance, the recurrence of personalization and autonomy in participant discourse could be better understood if linked to self-determination theory (Deci & Ryan, 2000), while concerns about cognitive passivity could be interpreted through the lens of heutagogy (Blaschke, 2012), which emphasizes self-directed learning and learner agency in digital environments. Further studies should encourage reflexive dialogue to better leverage qualitative insights.

4. Discussions

Recent literature underscores the transformative potential and complex challenges of AI integration in education. Holmes, Bialik, and Fadel (2022) emphasize the necessity of rethinking instructional design in light of AI's capability to support personalized learning and formative feedback. Similarly, Timms (2022) explores the potential of human–AI collaboration to enhance individualized education, but warns of the risk of displacing teacher roles if not ethically framed. Lockery and Gutteridge (2022) discuss the feasibility of scalable, self-paced learning environments mediated by AI, while highlighting the socio-technical barriers to equitable implementation. Zawacki-Richter et al. (2019) identify a gap in the involvement of educators in shaping AI tools, calling for stronger partnerships between developers and pedagogical experts. Tan et al. (2025) provide a comprehensive review of adaptive AI-enabled learning platforms, emphasizing their ability to dynamically respond to learner profiles, support differentiated instruction, and optimize content delivery based on real-time feedback data. These findings support the theoretical position of this article: that effective human-AI interaction in education must be guided by critical, ethical, and learner-centred approaches.

Another dimension only partially explored in this study relates to age and educational level, as well as the evolving role of *conversational digital literacy* in shaping user experience. Participants ranged from lower to upper secondary school, yet differences in developmental stage, cognitive maturity, and academic expectations were not systematically analysed. in this study relates to age and educational level. Participants ranged from lower to upper secondary school, yet differences in developmental stage, cognitive maturity, and academic expectations were not systematically analysed. Younger students (grades VII–VIII) often anthropomorphized AI systems and expressed higher emotional engagement with conversational agents, describing them as friendly, patient, or even "smart companions." In contrast, older students and teachers tended to assess AI through a more functional and critical lens, emphasizing aspects such as response accuracy, reliability, and ethical use. These divergences suggest that perceptions and uses of AI vary not only by role (teacher vs. student) but also by age-related psychological and pedagogical factors. Addressing these layers in future studies could enhance both theoretical insight and the design of differentiated AI-supported learning environments.

The integration of AI in education also raises specific curricular implications that remain underexplored. The findings of this study suggest that curricular frameworks must adapt to accommodate not only technological tools but also the development of transversal competencies such as critical thinking, digital literacy, and ethical reasoning. Incorporating AI tools like conversational agents or adaptive platforms necessitates a reconfiguration of instructional objectives to focus on process-oriented learning rather than mere content acquisition. Moreover, curriculum design should explicitly

address the risks of overdependence on AI by embedding metacognitive strategies that help students assess when and how to use such tools responsibly. For teachers, this requires sustained professional development and alignment with competence-based curricular standards that reflect the dynamic interplay between human agency and algorithmic assistance. Finally, curricular innovation should be supported by guidelines that ensure inclusivity, accessibility, and ethical sensitivity across different subjects and educational levels.

Digital pedagogy frameworks emphasize that meaningful integration of AI must go beyond access and infrastructure, embedding ethical reflection and inclusive design into instructional practices (Istrate, Velea, & Ceobanu, 2025). These frameworks also emphasize the pedagogical value of metacognition, feedback loops, and differentiated instruction – concepts mirrored in this study's findings on personalization, affective response, and *conversational digital literacy*. In particular, the importance of *conversational digital literacy* – understood as the ability to navigate, evaluate, and engage meaningfully with AI-mediated dialogue – is critical in preparing learners for emerging digital ecosystems. This type of literacy fosters not only technical competence but also critical awareness, enabling students to distinguish between simulated empathy and authentic human interaction, and to develop reflexive strategies for AI collaboration. The student preference for adaptive and dialogic tools aligns with Istrate et al.'s recommendation to restructure curriculum around digitally mediated learning pathways that support autonomy and inclusiveness.

Communication between AI and human intelligence is not merely a technological process, but also a profoundly human one, involving trust, mutual understanding, and adaptability. Beyond the exchange of data, this relationship must evolve into a type of co-creation, where AI not only assists but also learns from interaction with humans.

As AI becomes more sophisticated, human-machine interaction may develop into an authentic, personalized, and adaptive dialogue. For instance, systems based on deep learning can analyse users' communication styles and adjust the tone, pace, and level of detail in their responses. In education, this could support differentiated learning, while in healthcare, it could mean providing easy-to-understand explanations for complex medical decisions. Despite these developments, the study observed that some interview interpretations remained at a surface level. Citations were frequently used illustratively rather than analytically, indicating a need for deeper thematic engagement. This issue is visible throughout the article, where quotes from both students and teachers are presented largely as narrative reinforcement without being critically dissected or theoretically contextualized. For example, while a student's comment about AI feeling like a 'super-smart classmate' is evocative, it is not unpacked in relation to learner autonomy, agency, or constructivist theory. Similarly, teacher concerns about critical thinking erosion are mentioned but not analysed through pedagogical or psychological lenses. A deeper discourse analysis – situating such citations within broader epistemological or educational frameworks – would have enriched the interpretation and extended the scholarly contribution of the findings. In future studies, integrating a more layered and theory-informed analysis of participant discourse across all sections of the manuscript would enhance both depth and relevance.

A major challenge remains the balance between automation and human control. AI requires autonomy to respond efficiently and in real time, but this should not exclude human input. Another challenge is transparency: clearly communicating how AI makes decisions is essential for building user trust. The lack of explainability can lead to resistance in adoption, especially in sensitive sectors such as justice or medicine. Furthermore, the analysis did not explore potential differences in perception across different age groups or levels of education – an area that remains open for future inquiry.

An effective dialogue between humans and AI can open new spaces for innovative collaboration. Rather than competing, the two types of intelligence may join which AI optimizes processes, and humans contribute ethical, creative, and empathetic dimensions. In the future, we may speak of a new kind of "conversational digital literacy," where people learn not only to use AI, but also to communicate with it effectively and ethically.

The findings from the literature review highlight several important aspects concerning the communication between artificial intelligence and human intelligence. A key point is that the effectiveness of this interaction largely depends on the quality of AI system design, as well as the level of users' digital literacy. In other words, technological performance must be accompanied by adequate human preparation in order to maximize the benefits of the interaction.

Another significant aspect is the dynamics of trust: users are more likely to collaborate with an AI system when they perceive it as transparent, consistent, and adaptable. For instance, in the medical field, a patient's trust in the recommendations of an AI system is directly related to the clarity of its explanations and the transparency of its decision-making history. Thus, communication should not be limited to delivering an outcome but should also include accessible justifications of that outcome.

From an interdisciplinary perspective, differences in expectations emerge across various fields: in education, users seek empathy and personalized feedback, while in business, efficiency and response speed are often prioritized. This diversity underscores the need to develop flexible AI systems that can adapt to context-specific requirements.

Additionally, when it comes to the need for regulation and standardization – particularly in relation to data protection and the ethics of automated decision-making – there are indeed international initiatives in place. However, their applicability often remains uneven and, in some cases, lags behind the rapid pace of technological advancement. This highlights the need for closer collaboration between technology experts, ethicists, legal professionals, and policymakers to shape a coherent and sustainable framework.

Although numerous ethical guidelines for AI have been developed in recent years, Hagendorff (2020) emphasizes that many of them remain vague, inconsistent, or difficult to implement. This lack of normative coherence underscores the urgent need for clear and actionable standards, especially in sensitive domains such as education and healthcare, where the impact of AI directly affects human lives.

Moreover, genuine collaboration between AI and humans requires the development of "conversational intelligence" – not only on the part of machines, but also from human users, who must learn how to engage strategically with these systems to achieve optimal outcomes.

In this context, education becomes a crucial environment for cultivating AI interaction skills. The necessary competencies go beyond the technical use of applications or tools and include the ability to ask relevant questions, critically interpret AI-generated responses, and determine when it is appropriate to rely on automated systems. This process calls for a recalibration of the teacher's role – one that positions the educator as a facilitator of dialogue between the student and technology, rather than merely a transmitter of knowledge.

Another key point concerns the management of errors and uncertainty in human-AI interaction. Artificial intelligence systems are not infallible and may generate incorrect or inappropriate responses. Educating users to recognize and correct such errors is crucial for maintaining a functional and trustworthy relationship with technology. This necessity gives rise to a new type of literacy – one that is critical and reflective – emphasizing awareness of AI's limitations as well as its advantages.

The findings also suggest that human-AI interaction varies depending on factors such as age, digital experience, and cognitive style. Younger students tend to anthropomorphize AI more easily, attributing human traits to it, while teachers generally adopt a more rational, function-focused perspective. This contrast can significantly affect the quality of communication and the level of emotional engagement, which in turn influences motivation and receptiveness to learning.

Another issue addressed in the study is the risk of reinforcing cognitive or social biases through AI. When systems are trained on incomplete or biased datasets, they can perpetuate inequalities, stereotypes, or subtle types of discrimination. Effective communication requires more than just technological formatting of responses – it also demands the user's ability to critically evaluate the content provided. This reinforces the notion that AI should not be used in the absence of clear pedagogical and ethical thinking.

At the same time, a distinction has been observed between passive and active use of AI. Users who merely request "answers" miss out on the systems' co-creative potential. By contrast, those who use AI to explore ideas, rewrite texts, generate alternatives, or refine their thinking benefit from a more authentic and constructive dialogue. Therefore, fostering an exploratory attitude in human-AI communication is becoming a priority in educational environments.

Moreover, the emotional relationship between the user and the AI influences the level of engagement and the duration of interaction. Participants described experiences in which the AI's calm and supportive "voice" generated a sense of security, especially during moments of confusion or uncertainty. This phenomenon, known as affective computing, paves the way for developing systems capable of responding not only cognitively but also emotionally, in an adaptive manner.

Furthermore, the findings suggest that effective communication with AI can serve as a tool for educational inclusion. Students with verbal expression difficulties, social anxiety, or learning disabilities may benefit from a non-judgmental, consistent, and accessible interaction that allows them to progress at their own pace. Thus, AI is not only a tool for efficiency but also a potential enabler of equity.

Importantly, this study identifies a significant tension between the utility of AI tools and the growing risk of overdependence – especially among students who use AI to bypass effortful thinking. While this dynamic was acknowledged by both students and teachers, it calls for a more systematic curricular response to mitigate academic dishonesty and cognitive disengagement.

In conclusion, the discussion reflects a complex reality: human-AI communication is an emerging process that must be understood in all its multidimensionality. It is not enough for AI to learn how to respond accurately – humans must also learn how to ask the right questions, interpret critically, and collaborate ethically. In this ecology of interaction, responsibility is shared, and conversational literacy becomes an essential condition for the future of society.

To address these limitations, future work should incorporate a broader curricular analysis and include comparative studies of different AI platforms, as well as institutional practices related to AI integration. Although participants referenced tools such as ChatGPT, Google Bard, or adaptive learning environments, the study does not provide a systematic comparative analysis of their perceived strengths, limitations, or differential impacts on teaching and learning. A structured comparison reveals distinct functional profiles: ChatGPT is praised for its versatility, fluency, and contextual responsiveness in both student and teacher use, yet raises concerns about hallucinations and a lack of verifiable sources. Google Bard, while perceived as more concise and factual, was described as less engaging and less effective in sustaining dialogue. Adaptive platforms (e.g., Knewton, Smart Sparrow) were appreciated for personalized feedback and structured curriculum alignment but criticized for limited interaction and rigid content frameworks. In terms of ethical safeguards, institutional tools embedded in LMSs were deemed more compliant with privacy regulations, while commercial platforms offered greater flexibility at the cost of transparency. Preferences also varied by user profile: students favoured immediacy and tone (ChatGPT), whereas teachers valued content control and traceability (adaptive systems). This analysis suggests that platform choice should be aligned not only with pedagogical goals but also with user expectations and institutional values. A comparative matrix including usability, trust, personalization, and ethical compliance would guide more informed, context-specific decisions. This represents an opportunity for future research to guide evidence-informed decision-making regarding platform adoption in education.

5. Conclusions and Future Research Directions

Communication between artificial intelligence (AI) and human intelligence is a dynamic field, rich with both challenges and opportunities. The development of more intuitive and ethical AI systems has the potential to revolutionize human-machine interaction, generating significant benefits across multiple domains. However, it is essential that this process be guided by clear principles of ethics and responsibility. As technology continues to advance, it is imperative to ensure that AI remains a tool designed to support, rather than replace, human intelligence. In doing so, a harmonious collaboration between humans and AI can pave the way toward a more innovative and equitable society.

Effective communication between AI and human intelligence is crucial for harnessing the full potential of technology in a sustainable and fair manner. Beyond tools and algorithms, this interaction marks a paradigm shift in how we relate to technology. The relationship is no longer one of passive use but of active collaboration, where AI becomes a partner in learning, decision-making, and creativity.

It is vital that AI be developed within a well-defined ethical framework that safeguards fundamental human values such as privacy, fairness, and autonomy. Equally important is the education and training of users – whether students, professionals, or everyday citizens-as they play a critical role in fostering a healthy relationship with technology.

The future lies not in a competition between human and machine, but in a collaboration where both types of intelligence complement one another. Thus, communication between AI and human intelligence can become not only efficient but also meaningful-contributing to a society in which technology serves as a catalyst for human progress, not a replacement for it.

In this context, designing human-centred AI becomes a strategic imperative. AI systems must be built not only for efficiency but also for understanding, empathy, and social responsibility. Human-AI communication should reflect not only technological competence but also the values of the communities that use it. Achieving this vision requires interdisciplinary collaboration among educators, engineers, psychologists, and philosophers throughout the development process.

In the long run, the success of integrating AI into society will depend on our ability to cultivate informed and conscious citizens – individuals who can engage critically and constructively with technology. Education thus plays a crucial role in preparing a generation that not only understands how AI works but also recognizes why the way we communicate with it matters. Only through such an approach can we turn technological potential into meaningful human progress.

Tegmark (2017) envisions a bold future in which AI becomes an integral part of “Life 3.0” – an evolutionary stage where intelligence can reshape not only culture but also the biological structure of the human species. In such a

scenario, effective and ethical communication between humans and AI takes on a vital role in ensuring progress that is aligned with human values.

The interaction between artificial and human intelligence is an emerging field with deep pedagogical, social, and ethical implications. This study has demonstrated that this interaction is not a mere technological process, but a complex relationship shaped by factors such as digital literacy, trust, empathy, and the adaptability of both human and machine agents.

With this in mind, several future research directions are proposed:

- **Expanding the research sample** to include high school and university-level education, to capture variations in perception based on age and educational level;
- **Conducting longitudinal studies** to track how human – AI interaction evolves over time and how it affects academic performance and motivation;
- **Examining the impact of algorithmic empathy** in both educational and therapeutic contexts;
- **Exploring AI-mediated human-to-human communication**, to better understand how AI influences interactions between students or between teachers and parents;
- **Designing AI-enhanced pedagogical models** that leverage the adaptive capacity of intelligent systems without undermining student autonomy or the formative role of educators.

In a world undergoing rapid digital transformation, the integration of artificial intelligence must be accompanied by critical thinking, interdisciplinary dialogue, and a human-centred educational vision. Only by following this path can we ensure a balanced and sustainable relationship between the two types of intelligence – human and artificial.

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Generation X and Y Teachers' Perceptions of Digital Pedagogy: A Turkish Case Study

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Abstract: This study explores the perceptions of Generation X and Generation Y educators regarding digital pedagogy and its impact on teaching practices. Digital pedagogy, defined as the integration of technology into educational practices, is examined through the lens of two distinct generations, each with differing approaches to technology in education. Generation X approaches digital pedagogy cautiously, emphasizing the need to strike a balance between digital tools and face-to-face interactions. They view technology as a tool to enhance traditional teaching methods, with a strong focus on pedagogical alignment, security, and accessibility. In contrast, Generation Y embraces a more flexible, student-centred approach, seeing digital tools as integral to creating personalized and innovative learning environments. This generation is more comfortable with the rapid integration of technology and advocates for using digital tools to enhance engagement, adaptability, and individualized learning experiences. Both generations recognize the role of digital pedagogy in fostering 21st-century skills. However, both acknowledge the limitations of digital tools in promoting holistic personal development, emphasizing the importance of socio-emotional interactions and face-to-face learning experiences. Furthermore, the study examines the evolving roles of educators in the digital age, with Generation X envisioning teachers as guides and emotional connectors, and Generation Y viewing them as content designers and mentors. The findings highlight significant generational differences in integrating digital technologies into education, providing insight into the future of digital pedagogy and its implications for teaching practices.

Keywords: digital pedagogy, teachers, education, generations, qualitative research

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1. Introduction

The transformative power of digital advancements in education cannot be overstated. The increasing integration of technology into teaching and learning has challenged traditional instructional practices and opened new avenues for innovation. As schools embrace digital tools and platforms, educators are at the forefront of this transformation, focusing on ensuring quality, accessibility, and equity in education. Teachers' roles are constantly evolving to address contemporary educational challenges in a rapidly changing world. Expectations are placed on them to acquire new skills and stay up to date with emerging digital tools and pedagogies (Tan et al., 2024). Digital pedagogy combines technology with modern didactic methods, offering a flexible and adaptable framework for 21st-century learning (Voicu, 2025). In this context, digital pedagogy, which utilizes digital tools to enhance educational experiences, has become vital in shaping effective and inclusive learning environments in the digital age.

Digital pedagogy is a pedagogical approach that reveals the essence and structure of digital education, highlights the role of digitized educational processes in personal development, and develops practical methods and tools to enhance its effectiveness (Bećirović, 2023).

According to Istrate (2022), a more detailed and comprehensible definition was presented.

Digital pedagogy is the part of pedagogy that studies the design, implementation and evaluation of educational situations comprising a significant component of digital technologies, as well as the necessary conditions for their implementation – synchronous and asynchronous interactions in virtual and mixed learning environments, learning management platforms and tools, digital educational resources, educational usage of various digital applications and tools, virtual assistants for learning and teaching, digital competences of teachers, educational policies and specific programs (Istrate, 2022).

On the other hand, Voinea (2023) stated that today's society faces a new kind of generational diversity, which can be challenging to manage. The author argues that schools should serve as bridges between generations—open and inclusive spaces where learning, collaboration, and experimentation take place. In such environments, teachers from different generations can share perspectives and shape the values needed for personal growth and meaningful development. Additionally, according to Sözer (2021), generational differences can lead to mismatches in the group dynamics between students and teachers, highlighting the importance of generational theory in educational contexts. These differences shape communication styles, values, and expectations, influencing classroom interactions and collaborative behaviours.

As digital pedagogy becomes increasingly central to contemporary education, it is essential to acknowledge that teachers' engagement with these approaches may vary based on their generational backgrounds, professional experiences, and comfort level with technology. While younger teachers may exhibit greater fluency with digital tools due to growing up in a digital world, more experienced educators may approach digital pedagogy with different pedagogical priorities and technological competencies. By comparing the views, competencies, and teaching practices of teachers from different generations, this study aims to explore how generational differences impact the understanding, acceptance, and implementation of digital pedagogy in real educational contexts.

This study aims to examine the concept of digital pedagogy through a generational lens by examining the perceptions and practices of senior (X generation) and (Y generation) teachers. As part of this research, the following questions will be addressed:

1. What are the core elements that define digital pedagogy? How does this concept influence your understanding of teaching?
2. To what extent should digitalization be integrated into the learning process? In your opinion, is a fully digitalized educational process effective?
3. What is the role of digital courses in an education based on 21st-century skills? Do you think it is possible to foster personal development and attitudes solely through digital content?
4. What criteria do you consider when integrating digital technologies into your lessons?
5. How do teachers from different generations perceive digital pedagogy? Are there generational differences?
6. How would you assess your digital pedagogical competence? Are there areas in which you feel the need for improvement?
7. What direction will digital pedagogy evolve toward in the future? How will the role of teachers change?

2. Generations and Digital Pedagogy in Education

Pedagogy refers to the theory and practice of teaching and learning, encompassing the methods and strategies educators employ to facilitate student engagement and knowledge acquisition. It involves the content being taught and how it is delivered, considering students' diverse needs and learning styles. A key aspect of pedagogy is creating a learning environment that fosters meaningful learning, promoting critical thinking, creativity, and personal growth (Alexander, 2008). Additionally, Anderson (2020) defined effective pedagogy as a multifaceted approach that supports learners' intellectual, personal, and social development, preparing them for life. It involves engaging students with meaningful knowledge, ways of thinking, and discourse relevant to their contexts. Additionally, the author emphasized that effective pedagogy builds on learners' prior experiences and takes into account their personal and cultural backgrounds. It includes providing intellectual, social, and emotional support to facilitate progress, using formative and summative assessments aligned with learning outcomes, and promoting learner independence through diverse learning strategies.

In this regard, digital pedagogy has become an essential extension of traditional pedagogy, adapting age-old teaching methods to the digital age. This new approach emphasizes the integration of digital tools and technologies to enhance the learning experience (Coovadiaa & Ackermann, 2021). Moreover, digital pedagogy builds upon established pedagogical principles by incorporating technological innovations, encouraging active learning, student autonomy, and using digital resources to support cognitive and social development. (Dogan et al., 2024). The shift toward digital pedagogy began as educators recognized the potential of technology to enrich learning environments. By leveraging interactive tools and platforms, digital pedagogy enables more engaging and collaborative learning experiences (Lewin &Lundie, 2016). It allows educators to offer personalized learning paths, facilitate problem-solving activities, and create opportunities for students to engage in real-world applications. Through this dynamic approach, digital pedagogy provides a framework for evolving traditional teaching methods to meet the demands of the 21st-century classroom (Beetham & Sharpe, 2013). Additionally, research has also suggested that teachers' pedagogical beliefs are a significant predictor of their technology use (Ertmer et al., 2015).

A systematic review conducted by Tondeur et al. (2017) found a bidirectional relationship between teachers' pedagogical beliefs and the integration of technology. A teacher's belief can influence the type of technology they prefer and may be a barrier to technology integration. Conversely, integrating technology can also influence the teacher's pedagogical beliefs. Mishra and Koehler (2006) contended that it is not enough for teachers to possess technology-related competencies to teach effectively with technology. They highlighted that teachers need to understand and apply three knowledge domains (pedagogy, content, and technology) and the intersections of these knowledge domains. According to Tabesh (2018), a growth mindset is a key component of digital pedagogy. It encourages students to believe their abilities and talents can be developed through effort, effective learning, and perseverance. Digital pedagogy fosters such a mindset by creating a cognitively rich learning environment that emphasizes active engagement and exploration, utilizing various digital tools instead of relying on passive, one-directional instruction.

In today's rapidly evolving digital society, shaped by values such as dynamism, diversity, globalization, and increasing concern for sustainability and individual well-being (Voinea, 2023), education systems are under growing pressure to adapt. One key response to this transformation is the integration of digital technologies into teaching and learning environments. However, the effective implementation of digital pedagogy, a pedagogical approach that thoughtfully integrates digital tools and strategies, remains a complex and sometimes debated issue in educational technology (Tan et al., 2024). In this context, Akar (2020) defined the transformations in the learning and teaching approach as diversifying teachers' tasks and fields of responsibility and expanding them to include competencies such as utilizing technologies with pedagogical components, attending to students' differences, and teaching 21st-century skills to them.

This study is based on the generational classification by McCrindle and Wolfinger (2008), who developed a global generational framework. According to this classification, the generations are categorized as the Builders Generation, Baby Boomers, Generation X, Generation Y, Generation Z, and Generation Alpha. The study focuses on the general characteristics of Generations X and Y. Generation X includes people born between 1965 and 1979, following the Baby Boomer generation. This cohort experienced a period of relative peace and economic growth throughout their lives. They were the first generation to have access to computers both at home and in schools. They grew up in households where both parents were typically employed, resulting in less adult supervision (McCrindle, 2014). On the other hand, Generation Y, also known as Millennials, was born between 1980 and 1994. Unlike Generation X, Millennials grew up in

a diverse society and have not experienced economic recessions (Strauss & Howe, 2000). They were also part of the digital revolution during their formative years. Millennials are often seen as less focused on traditional career development, instead valuing flexibility, independence, management support, and engaging learning environments. They are often characterized by their idealism, optimism, self-reliance, and confidence, and are not afraid to embrace and drive change (Kraus, 2017).

Figure 1

Comparison of Generation X and Generation Y Teachers (Source: McCrindle, 2014)

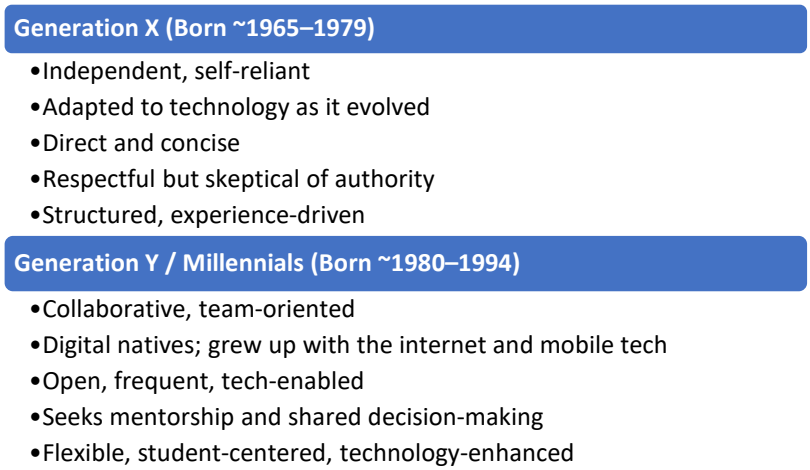

Figure 1 compares Generation X and Generation Y (Millennial) teachers in terms of their professional preferences and work styles. Generation X teachers are typically independent, value structure, and prefer formal communication and practical learning. They prioritize job security and maintain clear boundaries between their work and personal life. Generation Y teachers, on the other hand, are more collaborative, tech-savvy, and open to flexible, student-centred approaches. They seek purpose in their work, prefer immediate feedback, and thrive in digital, interactive learning environments. These differences suggest that educational leaders should recognize and address the diverse needs of each generation. By combining Generation X's experience with Generation Y's innovation, schools can create more effective and adaptive teaching environments (Polat et al., 2019).

3. Methodology

Research Design

This study employed a phenomenological design, a qualitative research approach. The primary aim of qualitative research is to focus on participants' experiences and perspectives, aiming to uncover their perceptions deeply and lived experiences regarding a particular phenomenon (Creswell, 2013; Denzin & Lincoln, 2011). As a qualitative research method, phenomenology describes the essence of a phenomenon through individuals' lived experiences (Patton, 2014).

In this context, the phenomenon addressed in the study is digital pedagogy. The study aims to reveal how teachers from different generations, based on their professional experiences, understand and conceptualize digital pedagogy, as well as how they integrate digital technologies into their learning processes. Phenomenological research emphasizes participants' perceptions and perspectives regarding a specific phenomenon, focusing on how they make sense of, experience, and describe it. Therefore, this study focuses on understanding how teachers experience digital pedagogy and how they interpret and express these experiences.

Study Group

The study group consisted of 30 teachers working in public schools within a large metropolitan province in Turkey during the 2024–2025 academic year. All participants were actively employed in urban public schools, an important contextual factor given the typically greater access to technological infrastructure, professional development opportunities, and policy implementations related to digital education in urban areas compared to rural settings.

Participants were selected using purposeful sampling, based on generational criteria. Teachers aged 40 and above were categorized as Generation X, while those under 40 were classified as Generation Y. Interview questions were initially sent via email, and participation in the study was entirely voluntary. Teachers who responded positively and

agreed to participate were included in the sample. Efforts were made to ensure equal representation from both generations, resulting in 15 teachers from Generation X and 15 from Generation Y.

Table 1

Demographic Characteristics of The Participant Teachers

Variable	Category	Generation X (*n* = 15)	Generation Y (*n* = 15)	Total (*n* = 30)
Gender	Female	8	9	17
	Male	7	6	13
Seniority	16-20	0	7	7
	21-25	7	0	7
Age	45-60 years	15	0	15
	30-44 years	0	15	15
Branch	English teacher	5	7	12
	Primary school Teacher	5	5	10
	Mathematics Teacher	3	0	3
	Science Teacher	0	3	3

As seen in Table 1, the data reveal notable generational differences between Generation X (ages 45-60) and Generation Y (ages 30-44) in terms of gender, seniority, age, and teaching specialization. In terms of gender, Generation X has 8 women and 7 men, while Generation Y has 9 women and 6 men, resulting in a total of 17 women and 13 men across both generations. Regarding seniority, Generation X members have an average of 21 to 25 years of experience (7 participants), while Generation Y members have an average of 16 to 20 years of experience (7 participants). Age is another distinguishing factor: all members of Generation X are in the 45–60 age group, while all members of Generation Y are in the 30–44 age group, creating a clear age division between the two generations. Regarding teaching specializations, English teaching is the most common for both generations, with 12 individuals (5 from Generation X and 7 from Generation Y) opting for this field. Primary school teaching involves 10 individuals (5 from each generation). Generation X is stronger in mathematics teaching (3 individuals), while Generation Y is notable in science teaching (3 individuals).

Data Collection

The data for this study were collected using two qualitative methods: semi-structured focus group interviews and open-ended questionnaires, both of which were designed to explore teachers' perceptions and experiences regarding digital pedagogy. A total of 30 teachers participated, including 15 from Generation X and 15 from Generation Y. Participants were initially grouped according to their generational affiliation to facilitate comparative analysis.

The focus group interviews were conducted first. Participants were organized into six focus groups, each consisting of five teachers, with a balanced representation from both generations. Each session lasted approximately 35 to 45 minutes. The interviews were scheduled based on participants' availability. Before each session, the researcher contacted participants individually to arrange appointments at mutually convenient times. This approach ensured voluntary participation and minimized disruption to their professional responsibilities. All interviews were recorded digitally, with the informed consent of participants obtained in advance. Data collection continued until thematic saturation was reached. By the fifth session, no new codes or themes emerged from the discussions. A sixth session was conducted to verify the consistency of recurring themes and to ensure the robustness of the findings.

Following the focus group sessions, participants were invited to complete open-ended questionnaires, which provided an opportunity to elaborate on their perspectives in written form. These questionnaires allowed for deeper individual reflection beyond the group setting. All responses were recorded in writing, and direct quotations from Participants 1 to 30 were preserved to reflect their authentic views accurately.

Data Analysis

The data analysis process was carried out using a combination of descriptive and content analysis, selected based on the nature and structure of the collected data. Descriptive analysis was employed for the focus group interview data, with responses organized under themes guided by the research questions (Yıldırım & Şimşek, 2018). A deductive approach was used, particularly in addressing the first sub-problem, to interpret the data by narrowing the content toward specific core concepts (Creswell, 2013). Content analysis was applied to the data obtained through open-ended questionnaires, following an inductive strategy in which codes and categories were derived from the participants' narratives rather than being predefined. The coding process began with the identification of meaningful data units,

which were then labelled as codes. These codes were grouped into sub-themes and overarching themes through the process of categorization and constant comparison, allowing patterns to emerge across responses. This approach is consistent with the principles of thematic coding, where coding and categorization provide a structured understanding of complex qualitative data (Gibbs, 2007). A preliminary coding framework, based on the theoretical background of the study, was refined during analysis better to reflect emergent data-driven insights (Patton, 2014). To ensure reliability and trustworthiness, coding was conducted independently by two researchers, with consensus achieved through a collaborative review and refinement process.

4. Findings and Discussion

In this section, the findings obtained within the research scope are thematically discussed and interpreted in light of the existing literature. The ways in which teachers from different generations perceive digital pedagogy, the strategies they adopt in practice, and their future projections are examined in a structured manner.

Table 2

Themes, Sub-themes, and Codes for Generation X and Y Teachers

Questions	Theme	Sub-theme	Codes (X Generation)	Codes (Y Generations)
Q 1.		Core Elements	Instrumental approach, guidance, controlled integration	Holistic approach, flexibility, student-centeredness
	Definition of Digital Pedagogy	Impact on Teaching Perception	Transformation from traditional, cautious progress	Role change, content designer, continuous learner
Q2.		Perceived Effectiveness	Face-to-face is indispensable, a hybrid model suggestion	Emphasis on flexibility, individualization, and a balanced model
	Degree of Digitalization	Digitalization Limits	Distance from full digitalization	Learning blended with technology
Q3.		Role of Digital Courses	Supports knowledge transfer, but not sufficient	Integrated teaching with skills and development of digital literacy
	21st Century Skills	Personal Development and Attitudes	Socio-emotional contact is necessary, and face-to-face interaction is required.	Digitally supported content, but interaction is necessary for empathy.
Q4.		Implementation Standards	Accessibility, security, and pedagogical alignment	Interaction, user experience, and student needs
	Technology Integration Criteria	Tool Selection	Functionality prioritized	Balance of innovation and pedagogical benefit
Q5.		Perception Differences	Cautious, experience-based, critical	Quick adaptation, bridge with digital natives
	Intergenerational Differences	Experience Growing Up with Technology	Met technology later, the effort to adapt	Digital youth, early adaptation
Q6.		Self-Assessment	Basic level proficiency, open to development	Intermediate/advanced level, need to stay up to date
	Digital Competence	Development Areas	Artificial intelligence, analytical tools	Gamification, data analysis, and digital ethics
Q7.		Evolution of Digital Pedagogy	Individualization, impact of AI	VR, AI, adaptive systems
	Outlook on the Future	Teacher Roles	Guide, facilitator, emotional connector	Content designer, data interpreter, mentor

As seen in Table 2, the teachers' views from Generations X and Y were analysed based on the themes, sub-themes, and codes derived from the research questions. These themes represent key focus areas, while the sub-themes provide more specific insights within each theme. The codes for each generation (Generation X and Generation Y) reflect the patterns and differences observed in their perspectives.

Q1. What are the core elements that define digital pedagogy? How does this concept influence your understanding of teaching?

According to the findings, digital pedagogy encompasses the tools used in digital learning environments and the underlying educational philosophies that support them. Generation X approaches digital pedagogy instrumentally, seeing it as a tool to enhance teaching with a focus on control and guidance.

The findings of this study reveal distinct generational approaches to digital pedagogy, which can be meaningfully interpreted through the lens of the TPACK framework (Technological Pedagogical Content Knowledge; Mishra & Koehler, 2006). Generation X teachers, who define digital pedagogy through an instrumental and guidance-based lens, tend to integrate technology in controlled and structured ways, aligning primarily with Pedagogical Knowledge (PK) and Content Knowledge (CK). Their cautious transformation of traditional roles into more technologically aware practices reflects a foundational level of Technological Pedagogical Knowledge (TPK), where technology is used to enhance, rather than redefine, teaching. In contrast, Generation Y teachers conceptualize digital pedagogy more holistically, embracing flexibility and student-centeredness, which illustrates a more developed TPK; they not only use technology but also redesign pedagogical strategies around it.

Polat et al. (2019) noted that Generation X teachers are more dedicated to lifelong learning and demonstrate a strong ability to adapt to new conditions. They are often open to collaboration with colleagues and receptive to feedback and guidance from school administrators and peer teachers. Mikušková (2023) found that while higher age alone is associated with a stricter interaction style and a focus on knowledge transmission and teaching goals, increased age combined with teaching experience leads to a preference for more interactive leadership and shared student-teacher responsibility. Additionally, a managerial teaching style becomes more common, and overall didactic competencies improve, except for a decline in uncertain and oppositional interaction styles. In contrast, Generation Y adopts a more holistic and flexible view, emphasizing student-centred approaches and adaptability. Gen X educators, influenced by traditional pedagogical practices, perceive the digital shift cautiously, requiring step-by-step integration. Gen Y, however, is more comfortable reimagining educators' roles as content designers and lifelong learners, reflecting the evolving demands of digital environments. Polat et al. (2019) also noted that Generation X teachers tend to be more flexible in professional environments, value practical experience, and are motivated to engage in continuous professional development, which contributes positively to school improvement and student outcomes. The participants expressed their views on the first question as follows:

Digital pedagogy can be defined as the integration of technological tools into education and their proper use. This concept is central to my understanding of teaching and is something I incorporate into my teaching process. I utilize digital technology in my profession to stay current and benefit from its features, such as visualization and appealing to multiple senses - Participant 5 (Generation Y, Math Teacher, 15 years of experience, urban public school)

With many years of experience in the classroom, I believe that teaching methods play a crucial role in achieving learning objectives. Traditional lecture-based methods have always formed an indispensable foundation; however, over time, I have started to incorporate some technological tools into my lessons. Rather than placing technology at the centre, I use it as a supportive tool when needed- Participant 1 (Generation X, English Teacher, 25 years of experience, urban public school)

Q2. To what extent should digitalization be integrated into the learning process? Is a fully digitalized educational process effective?

Both generations recognize the value of digitalization but advocate for different extents. Generation X supports hybrid models, viewing face-to-face interaction as indispensable for building rapport and ensuring clarity. Their cautious approach avoids complete digitalization, emphasizing balance. Generation Y recognizes the importance of balance but is more open to individualization and flexibility afforded by digital tools. They stress that a fully digital model may lack essential human elements, but appreciate how digital tools can be tailored to individual learning needs. In terms of perceived effectiveness, Generation X emphasizes the irreplaceable value of face-to-face interaction and favours hybrid models, indicating a pragmatic TPK application where technology supplements core pedagogical practices. Generation Y, however, views flexibility and personalization as essential, employing TPK to tailor instruction and respond dynamically to individual learner needs. On the limits of digitalization, Generation X resists complete digitalization, revealing limited integration of Technological Pedagogical Knowledge (TPK), whereas Generation Y balances digital tools with pedagogy, suggesting a more adaptive TPK usage (Koehler et al., 2013).

According to Coklar and Tatlı (2021), the X generation witnessed the emergence of digital technologies and experienced firsthand the transformation these innovations brought to social life. From their perspective, there is a

degree of scepticism toward the use of digital tools. As digitalization became widespread after their formative years, they adapted to it later. So, they tend to rely less on various digital technologies, including smartphones. Huang et al. (2024) stated that digital pedagogy is a teaching approach that transforms the entire learning process through digital technology, focusing on both teachers' abilities to deliver digital instruction and students' skills in communication, collaboration, and exploration. They emphasized that adopting new technologies should be driven by pedagogical needs that cannot be met without the use of technology. One of the participants expressed their view on the second question as follows:

Digitalization should be an important part of the learning process. Digital tools offer numerous advantages, including ease of access, the ability to learn independently of time and place, and support through visual and interactive content. They enable students to progress at their own learning pace, allowing teachers to monitor the learning process. However, a fully digitalized education process may lead to shortcomings, especially in socio-emotional development, face-to-face communication skills, and classroom interaction. Therefore, it is not entirely effective. A hybrid model that balances digital and traditional methods can be more effective. In this way, the benefits of technology are leveraged to support the student's holistic development - Participant 10 (Generation Y, Science Teacher, 17 years of experience, urban public school)

As an experienced teacher, I consider digital tools and applications to play a supportive role in enhancing the effectiveness of teaching and learning. When used appropriately and in the right context, these tools can improve learning outcomes; however, they are neither sufficient on their own nor suitable in every situation. Therefore, I believe that the use of technology should be shaped according to the intended learning outcomes, the students' age group and profiles, as well as social and regional conditions. Integrating digital tools into both in-class and extracurricular activities can be beneficial. However, a fully digitalized educational process may pose certain risks, particularly in terms of students' social and emotional development. I believe that for values such as face-to-face communication, empathy, and collaboration to flourish in students, a healthy balance must be established between technology and traditional teaching methods. As a teacher, my priority is to base my instruction on methods that allow for direct interaction with students and help me get to know them better, while using technology as a complementary tool to support this foundation- Participant 2 (Generation X, English Teacher, 23 years of experience, urban public school)

Q3. What is the role of digital courses in an education based on 21st-century skills? Can personal development and attitudes be fostered solely through digital content?

There is a consensus that digital courses play a significant role in transmitting knowledge and supporting skill development, but both generations acknowledge their limitations in fostering holistic personal development. Generation X emphasizes the significance of socio-emotional contact and face-to-face interactions in fostering empathy and positive attitudes. Digital tools alone are seen as insufficient. While Generation Y is more accepting of digital content, it agrees that interpersonal interactions are essential for emotional and ethical development. It advocates for digitally supported content that complements rather than replaces face-to-face experiences. Generation X teachers may occasionally contribute to challenging situations within the school environment. Positioned between older and younger generations, they can experience generational tensions, which may result in a sense of being caught in the middle.

When discussing the role of digital courses and 21st-century skills, Generation X emphasizes the importance of digital support for knowledge transfer while valuing socio-emotional contact as an indication of TPK awareness; however, with boundaries rooted in PK. Generation Y, by contrast, integrates digital literacy, empathy, and interactive content more fully, leveraging TPK to construct emotionally intelligent and technologically rich learning environments (Misha & Koehler, 2006).

Polat et al. (2019) emphasized that this feeling of "in-betweenness" can impact their professional dynamics and interactions. Regarding the outcomes reported by teachers, it can be said that their experiences with technology integration align with their pedagogical understanding and encourage the continuation of this understanding. It is also noted that technology can potentially change teachers' educational beliefs (Tondeur et al., 2017). Participants expressed their views on the third question as follows:

Digital courses are powerful tools for developing 21st-century skills, including critical thinking, problem-solving, and collaboration. Leveraging advanced technologies like interactive platforms, virtual simulations, and collaborative software, digital learning environments offer unparalleled opportunities for personalized and flexible education — Participant 25 (Generation Y, English Teacher, 23 years of experience, urban public school).

In 21st-century skill-based education, digital lessons provide students with unlimited access to information and opportunities to collaborate with different groups hold an important place. However, as a Generation X teacher, I believe that digital content alone falls short in fostering personal growth and development of attitudes. Therefore, it must be supported by face-to-face, active, and interactive practices. Technology should serve as a tool that supports teaching; maintaining balance is essential-Participant 12 (Generation X, Primary School Teacher, 24 years of experience, urban public school)

Q4. What criteria do you consider when integrating digital technologies into your lessons?

The integration criteria vary by generation. Generation X focuses on accessibility, security, and pedagogical alignment, prioritizing reliable tools that enhance existing teaching without compromising quality or equity. They tend to be more function-focused in their tool selection. Generation Y, however, prioritizes student experience, interactivity, and innovation. They strive to balance pedagogical impact and technological novelty, prioritizing tools that enhance engagement and meet students' needs. This generational distinction highlights the importance of contextualizing Technological Knowledge within teachers' values and expectations when integrating digital pedagogy. According to Kohler et al. (2013), the Technological Knowledge (TK) component of the TPACK framework encompasses teachers' ability to use technology to support digital pedagogy effectively. This includes selecting and implementing tools that align with instructional goals, enhancing student engagement and improving academic outcomes. Participants expressed their response to the fourth question as follows:

First and foremost, I consider the pedagogical objectives and learning goals. My most important criterion is that every digital tool I use genuinely supports student learning and aligns with the course content. I consciously try to choose technology not just for novelty, but to enrich the learning process and enhance student engagement—Participant 30 (Generation Y, Math Teacher, 18 years of experience, urban public school).

When integrating digital technologies into my lessons, I prioritize applications that support the lesson content, teaching methods, and learning objectives. Additionally, I focus on tools that increase classroom interaction, capture students' attention, and encourage their active participation in a fun and engaging way. I use technology as a supportive tool to facilitate teaching and involve students more deeply in the learning process- Participant 20 (Generation X, Science Teacher, 24 years of experience, urban public school).

Q5. How do teachers from different generations perceive digital pedagogy? Are there generational differences?

The differences are significant. Generation X tends to be cautious and critically reflective, relying on personal experience and emphasizing the challenges of adapting to newer technologies. Their approach is often grounded in proven practices. One possible explanation is that, as traditional teaching methods become less effective in meeting modern demands, learners need effective communication, critical thinking, creativity, innovation, problem-solving, negotiation, and collaboration skills. However, integrating digital technology into education remains a significant challenge. Many educators lack sufficient knowledge and confidence in using digital tools, which limits their ability to support students in acquiring the technical skills necessary for 21st-century learning (Viberg et al., 2023). Generation Y, having grown up with technology, displays faster adaptation and fluency in digital environments. They serve as bridges between older educators and digital-native students, leveraging their comfort with technology to innovate in pedagogical practice. Digital technology is an integral part of their daily lives, and they are accustomed to using screens. However, they were not born into the digital world; they migrated from the analog to the digital world. (Coklar & Tatlı, 2021). Participants expressed their views on the fifth question as follows:

Yes, there are significant differences. As members of Generation X, we adapted to digitalization later in life. Therefore, we sometimes experience hesitations and difficulties in learning. Generations Y and Z, on the other hand, have internalized technology more deeply; the digital world is a natural environment for them. We tend to approach it more cautiously and critically, but this also helps us to question the pedagogical value of digital tools more carefully. - Participant 15 (Generation X, Primary School Teacher, 25 years of experience, urban public school).

There are significant generational differences in the use of digital technologies. Older teachers often stick to traditional methods and use technology in limited ways, such as slides or digital textbooks. Younger teachers, like myself, are more comfortable with digital tools and tend to design interactive lessons that support 21st-century skills. We also try to carry these practices into our out-of-class learning activities- Participant 28 (Generation Y, English Teacher, 16 years of experience, urban public school).

Q6. How would you assess your digital pedagogical competence? Are there areas in which you feel the need for improvement?

Generation X self-assesses their digital competence at a basic level, though they are open to development. Their primary areas for growth include mastering artificial intelligence tools and analytical platforms to enhance learning analytics and decision-making. Positive or negative experiences with digital technologies may have influenced teachers' attitudes toward the use of technology in teaching. Bad experiences may result from low self-efficacy, a lack of knowledge, or inadequate peer collaboration (Väätäjä & Ruokamo, 2021). Generation Y rates themselves intermediate or advanced but emphasizes the importance of continual learning. They seek to deepen skills in gamification, data analysis, and digital ethics, reflecting an understanding of the evolving landscape of educational technology. Huang et al. (2024) defined digital pedagogy as having changed the way people acquire, interact with, and process knowledge, emphasizing that participation in the generation and construction of knowledge has become more significant than the knowledge itself. The participants expressed their views on the sixth question as follows:

I consider myself open to development. I have basic-level proficiency and knowledge of online platforms, video tools, and digital assessment systems. However, I need more training in AI-supported applications and data analysis. Staying current in this constantly evolving digital world is challenging but essential- Participant 29 (Generation X, Science Teacher, 22 years of experience, urban public school).

I make a conscious effort to use educational digital tools and platforms effectively, enhancing my course content, activities, and teaching methods through them. I also work on improving these skills by attending various programs and training. However, I see the need to develop further areas, such as creating personalized content and methods to support individual learning based on classroom interaction data, ensuring cybersecurity, and engaging with digital communities — Participant 24 (Generation Y, Primary School Teacher, 14 years of experience, urban public school).

Q7. What direction will digital pedagogy evolve toward in the future? How will the role of teachers change?

Future trends in digital pedagogy are pointing toward increased personalization and the integration of AI, VR, and adaptive learning systems. Generation X envisions teachers as guides and emotional connectors, focusing on maintaining the human element amidst technological change. Generation Y sees educators evolving into content designers, data interpreters, and mentors who use digital tools to create dynamic, responsive, and personalized learning environments. Both generations agree that emotional intelligence and adaptability will remain crucial in the future. Heard (2025) highlights that teachers face ongoing challenges balancing traditional and digital pedagogy. The report highlights concerns about the overuse of digital tools, which may limit human interaction, hinder non-verbal communication, emotional support, and social learning. One of the participants expressed their view on the seventh question as follows:

I expect digital pedagogy to move toward more personalized, adaptive, and AI-supported systems. The role of teachers will shift more toward mentoring, guidance, digital content design, and ethical responsibilities. Teachers will no longer be just lecturers but will become multidimensional educational leaders who manage the digital learning process. Adapting to this change is not easy, but we, as Generation X, are ready to take our place in this transformation. — Participant 28 (Generation Y, English Teacher, 13 years of experience, urban public school).

I believe that digital pedagogy, the human touch in education, will remain essential. As teachers, we will shift more into the role of a coach and guide, supporting students not just academically but also emotionally. To fulfil this role, we will need to adapt by improving our digital skills while maintaining the values that define meaningful teaching: connection, empathy, and presence. - Participant 6 (Generation X, Math Teacher, 25 years of experience, urban public school).

5. Conclusion

In conclusion, digital pedagogy represents a multifaceted approach that merges technology with educational philosophy, reshaping both teaching methods and learning environments. Generation X tends to perceive digital tools as enhancements to traditional teaching, valuing structure and face-to-face interactions. In contrast, Generation Y adopts a more student-centred and flexible approach, viewing technology as essential to personalized and innovative learning. Despite these generational differences, both groups recognize the importance of maintaining human connection in education, emphasizing the role of interpersonal relationships in promoting personal development and socio-emotional growth.

As digitalization continues to advance, both generations agree on the necessity of ongoing professional development. While Generation X focuses on strengthening their digital competencies, particularly in areas such as artificial intelligence and data analytics, Generation Y is more inclined to explore emerging technologies and innovative

applications in education. The future of digital pedagogy will likely be characterized by greater personalization, with AI and adaptive learning systems transforming how content is delivered. Teachers will continue to play a vital role as emotional connectors and mentors, while also evolving into content designers who utilize technology to create engaging and responsive learning experiences.

Limitations and Future Directions

This study has several limitations that warrant consideration. First, the small sample size of 30 teachers from Generation X and Y limits the generalizability of the findings. As a qualitative study focused on public schools in urban areas within a single province of Turkey, the results may not reflect the experiences of teachers in rural settings or other national contexts. Additionally, Generation Z teachers were not included due to their limited presence in the current teaching workforce in Turkey. Future research should aim to include a broader range of participants from diverse regions, cultures, and generations to gain a deeper understanding of the evolving digital pedagogical practices. Longitudinal and cross-cultural studies could further explore how generational and contextual factors shape digital teaching over time.

Despite these limitations, the findings offer practical implications for teacher education and professional development. Programs should address generational differences in digital fluency, learning preferences, and pedagogical approaches to support effective learning. Structured, hands-on training may better support Generation X teachers, while Generation Y may benefit from collaborative, tech-integrated formats. Intergenerational mentoring can enhance mutual learning and bridge digital competence gaps between generations. Professional development should be continuous, flexible, and aligned with frameworks such as TPACK to promote the meaningful integration of technology.

In this regard, teacher education programs within Turkey's higher education system should systematically embed digital literacy and generational awareness into their curricula. Tailoring course content to the distinct needs and learning styles of different generations can enhance engagement and effectiveness. Curriculum design should include modules on digital pedagogy, adaptive technology use, and generational communication strategies, supported by practical applications and micro-credentialing opportunities. Moreover, national education policies should promote institutional capacity-building to ensure that future teachers, regardless of their generational background, are equipped with the skills necessary to thrive in digitally mediated classrooms.

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Beyond Automation: A Conceptual Framework for AI in Educational Assessment

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Abstract: This paper synthesizes the main applications of artificial intelligence in educational assessment through a systematic review following PRISMA guidelines. Our comprehensive analysis yielded 60 studies that revealed five key areas of AI-assisted educational assessment: assessment design, automatic grading, data analysis, performance prediction, and feedback provision. Based on identified patterns and implementation challenges, we pro-pose a novel three-dimensional pedagogical framework for AI in educational assessment. Within this framework, we develop the Processual Assessment Integration Model (P-AI-M) to address the first dimension, distinguishing between assessment de-sign/development and implementation/utilization phases. The complete framework integrates: (1) this processual dimension operationalized through P-AI-M; (2) a stakeholder dimension mapping the distinct roles and responsibilities of researchers, policy makers, school leaders, teachers, and students; and (3) a cognitive-taxonomic dimension aligning AI capabilities with revised Bloom's Taxonomy levels. The model is grounded in established educational theories including assessment for learning, constructive alignment, and sociocultural perspectives on evaluation. By addressing recurring gaps between technological capabilities and pedagogical integration, our multidimensional approach provides educators and researchers with a structured framework for understanding where AI can most effectively enhance assessment while preserving essential human

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expertise. The framework offers both theoretical grounding and practical guidance for implementing AI assessment tools in pedagogically sound, ethically responsible, and equitable ways across diverse educational contexts.

Keywords: artificial intelligence in education, educational assessment, item construction, automatic grading, data analysis, learning analytics, performance prediction, feedback, AI-supported assessment, Bloom's Taxonomy

1. Introduction

Assessment is a cornerstone of effective educational practice, providing insights into student learning that inform instructional decisions and practices, enabling a more comprehensive examination of effective pedagogies (Zou et al. 2024; Black & Wiliam, 2018; Earl, 2013; Hattie & Gan, 2011). When thoughtfully embedded within the educational process, especially through sustainable feedback, assessment transforms from a mere measurement tool into a dynamic catalyst that guides teaching strategies and empowers students to claim ownership of their learning journey (Boud & Soler, 2016; Carless, 2019). This approach aligns with contemporary educational theories that emphasize the formative potential of assessment to cultivate an active and autonomous learning (Panadero et al., 2018). The capacity for self-directed learning is an imperative acquisition for lifelong learners navigating increasingly complex informational ecosystems.

Artificial intelligence is revolutionising industries worldwide (Rashid & Kausik, 2024; Boulay et al., 2023) and it has emerged as a transformative force in the educational assessment area. It offers unprecedented opportunities to enhance evaluation practices, especially in understanding some of the currently considered "black boxes" of educational processes, such as the increased difficulty of developing and testing theories about learning mechanisms (Luckin et al., 2016; Zawacki-Richter et al., 2019). AI-powered assessment tools can analyse vast quantities of student data with remarkable speed and precision, enabling more dynamic, detailed, and personalized feedback than traditional methods allow, scaling current methods to substantially increased capacities, while also inspiring new ones (Cope & Kalantzis, 2019). New technologies can support important pedagogical aspects as identifying patterns in student performance that might escape human observation, potentially uncovering learning gaps and misconceptions that require targeted intervention (Kellogg et al., 2010), and providing specific support in offering meaningful and individualised feedback to our students (Hattie & Gan, 2011).

Additionally, AI systems can adapt assessment parameters in real-time based on student needs, creating more equitable evaluation experiences that accurately reflect individual capabilities (Holstein et al., 2019). The integration of AI in assessment also presents possibilities for expanding what can be measured in educational contexts. Beyond traditional knowledge recall, AI can facilitate complex competencies such as critical thinking, problem-solving, and creative expression through sophisticated analysis of student work processes and outputs (Chen et al., 2020; Hamada & Hassan, 2017). This capability aligns with contemporary educational goals that emphasize higher-order thinking skills and application of knowledge in authentic contexts.

Furthermore, AI can reduce administrative burdens on educators by automating routine assessment tasks, potentially allowing teachers to devote more attention to instructional design and meaningful student interactions (Larusson & White, 2014).

Thus, researching the intersection of AI and assessment is imperative given both the rapid technological advancement in this domain and the profound implications for educational practice (Holmes et al., 2019; Reich & Ito, 2017). There is an increasing need for guidance and support for educators and learners in the applicative realm of AI-supported assessment, given the growing complexity of assessment practices and the unprecedented development of technology (Boulay et al. 2023). The current study strives to overview the important areas and provide a novel three-dimensional pedagogical framework of practical orientation, embedded in theory, for AI use in educational assessment.

The study followed an analytical process guided by the PRISMA methodology (Gough et al., 2017; Page et al., 2021). A comprehensive search conducted across five major databases (Scopus, Web of Science, ERIC, IEEE Xplore, and Google Scholar) using the search string "(artificial intelligence OR AI OR machine learning) AND (education* assessment OR learning evaluation OR academic measurement)." Initial screening of 542 publications (2019-2024) yielded 155 relevant studies after applying inclusion criteria requiring empirical findings, peer-review, and explicit focus on AI applications in educational assessment. The final analysis included 60 studies after full-text evaluation, coding each study for AI application areas, theoretical foundations, implementation challenges, and reported outcomes.

Analysis of the selected literature revealed five promising areas of AI-assisted educational assessment: assessment design (23%), automatic grading (31%), data analysis (17%), performance prediction (14%), and feedback provision (15%). Key findings included: (1) a consistent bifurcation between pre-assessment and post-assessment AI applications; (2) recurring implementation gaps between technological capabilities and pedagogical integration; (3) varied stakeholder perspectives on AI assessment adoption; and (4) uneven distribution of AI applications across cognitive domains. These five identified areas of AI-assisted educational assessment—assessment design, automatic grading, data analysis, performance prediction, and feedback provision—directly informed our three-dimensional framework. The processual dimension emerged from the bifurcation between pre-assessment and assessment implementation activities, the stakeholder dimension addresses the varied perspectives on AI adoption across educational roles, and the cognitive-taxonomic dimension responds to the uneven distribution of AI applications across different levels of cognitive complexity.

This analysis revealed three distinct but interconnected dimensions that collectively addressed the challenges and opportunities of AI in educational assessment: a process-oriented dimension that distinguishes between different phases of assessment, a stakeholder-oriented dimension that clarifies roles and responsibilities, and a cognitive dimension that maps AI capabilities to established taxonomies of learning. We then iteratively refined this framework through theoretical validation, ensuring alignment with established educational principles including assessment for learning, constructive alignment, and sociocultural perspectives on evaluation. This methodological approach ensured that our framework is grounded in both empirical evidence from current research and theoretical perspectives that have shaped our understanding of effective assessment practices.

The remainder of this paper elaborates on our three-dimensional framework (Section 2), followed by in-depth exploration of assessment design and development (Section 3) and assessment implementation and utilization (Section 4), concluding with implications for practice and future research (Section 5).

This study uses existing literature to support, exemplify, and contextualize the proposed framework. Literature is drawn on to clarify key dimensions, highlight practical implications, and connect emerging AI capabilities to enduring pedagogical concerns. This constructive and integrative approach enables a theory-building orientation, aimed at supporting educators, researchers, and policy makers in navigating the complex and rapidly evolving intersection of AI and assessment. The framework does not claim comprehensive synthesis of all research in the field, nor does it assume within its scope to provide a critical analysis of the methodologies employed and findings re-ported by the evidence-based literature referenced across the article (a section considering limitations will still be discussed, however). Nonetheless, the relevance of this article is drawn from the need for a normative theoretical framework, orienting the practical applications and usage of AI tools in education. It offers a structured, theoretically-informed model to guide future development and implementation efforts, based on a descriptive overview of the current state of AI's integration in the field of education.

The paper introduces a three-dimensional conceptual framework designed to guide the pedagogically grounded integration of artificial intelligence in educational assessment. This model, the Processual Assessment Integration Model (P-AI-M), brings together three intersecting dimensions:

- the process (addressing how assessment is designed, implemented, and utilized),
- the stakeholder (clarifying the roles and responsibilities of actors across the educational ecosystem), and
- the cognitive-taxonomic (mapping AI capabilities to levels of Bloom's revised taxonomy).

Together, these dimensions provide a normative structure for identifying, organizing, and interpreting the ways in which AI technologies can enhance assessment while maintaining pedagogical coherence and ethical integrity.

The P-AI-M framework did not emerge from a traditional systematic review based on inclusion/exclusion criteria or formal bibliometric validation. Instead, it is the product of a constructive, practice-informed synthesis that foregrounds relevance and real-world applicability. The model was built by analysing a wide range of current AI-supported assessment practices already in use – regardless of the level of validation or evidence-based endorsement they may currently hold. This deliberate choice reflects recognition that educators, institutions, and developers are already engaging in meaningful experimentation and instrumentation. By examining what is actively being used, piloted, or proposed in educational settings, the model aims to reflect the lived complexity of practice while offering a structured lens through which those practices can be critically examined, organized, and improved.

2. A Pedagogical Multidimensional Framework for AI in Assessment

When discussing artificial intelligence in educational evaluation, it is essential to establish a clear conceptual framework that situates technological capabilities within sound pedagogical principles. To this end, we propose **a three-dimensional framework – the Processual Assessment Integration Model (P-AI-M)** – that captures the multifaceted nature of AI integration in assessment. This model comprises: (1) a processual dimension, which distinguishes between the design/ development and implementation/ utilization phases of assessment; (2) a stakeholder dimension, which clarifies the distinct roles and responsibilities of re-searchers, policy makers, school leaders, teachers, and students; and (3) a cognitive-taxonomic dimension, which maps AI-supported assessment applications to levels of revised Bloom's Taxonomy. Together, these three dimensions offer a comprehensive structure for conceptualizing how AI can be meaningfully and ethically embedded into assessment practices. In the sections that follow, we elaborate on each dimension, dis-cussing both established practices and emerging possibilities.

2.1. A focus on the process

Our systematic review revealed a clear pattern in how AI applications in educational assessment naturally cluster into two distinct phases of the assessment lifecycle. The first phase encompasses preparatory activities before student engagement, while the second involves the execution and utilization of assessment data during and after student participation. This bifurcation emerged consistently across the literature, with AI tools and approaches aligning distinctly with either (1) Assessment design and development or (2) Assessment implementation and utilization. This process-oriented conceptualization directly responds to calls in the literature for more integrated assessment approaches that view evaluation as a continuous cycle rather than isolated events (Boud & Soler, 2016; Carless, 2019). Each facet contains specific components that articulate how AI can enhance assessment while maintaining pedagogical primacy.

The first facet – *assessment design and development* – encompasses the preparatory activities that occur before students engage with assessment tasks. Here, AI can assist in strategic planning by analysing curriculum standards and learning outcomes to suggest appropriate assessment approaches. It can support item construction through automated generation of questions, problems, and tasks aligned with specific learning outcomes and offer specific suggestions for personalised tasks. Additionally, AI can enhance quality assurance by identifying potential biases, predicting item difficulty, and ensuring alignment with educational standards (Boulay et al., 2023).

The second facet – *assessment implementation and utilization* – focuses on the activities that occur during and after student engagement with assessment tasks. This includes administration and adaptive delivery, where AI can personalize assessment experiences based on real-time performance. It extends to response analysis and scoring, where AI can evaluate complex student outputs such as essays, projects, and problem-solving approaches. Furthermore, it encompasses interpretation and feedback systems that translate assessment results into actionable insights for both educators and learners. Finally, it addresses learning enhancement, where assessment data drives personalized learning pathways and addresses underperformance through targeted remediation strategies, inspired by the assessment as/for learning paradigm (Schellekens et al., 2021).

Table 1

The two-facets AI-supported assessment framework (on the processual dimension)

Facet 1: **Assessment design and development**	**Facet 2:** **Assessment implementation and utilization**
• Strategic planning of assessment • Item construction and validation • Assessment assembly and quality assurance	• Administration and adaptive delivery • Scoring and response analysis • Interpretation and feedback • Learning enhancement

This dual-facet framework provides a comprehensive structure for examining the most prominent aspects identified across the research literature: AI for automated assessment and personalized feedback. These themes appear consistently across different studies and contexts, making them the central focus of research in AI for educational assessment. Additionally, our framework incorporates emerging applications and critical considerations to provide a comprehensive understanding of the field, addressed in the next chapters of this article.

Table 1 denotes an integrated approach acknowledging assessment not as an isolated evaluative event but as an integral component of the educational process that both informs instruction and enhances learning. The merits of this approach are related to the comprehensive understanding of the institutional assessment providing a measure of a student's performance and status at a particular moment in time and intended for a specific use (i.e. judgment of ability, advancement, placement, etc).

Our process-focused framework draws on three key theoretical perspectives:

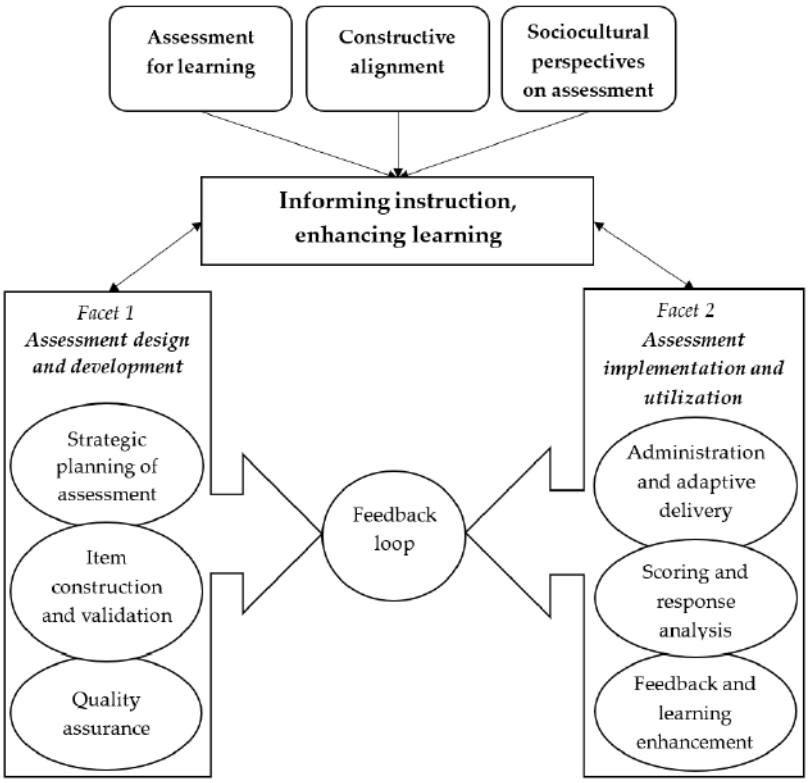
1. *Assessment for learning*: The processual dimension prioritizes formative functions of assessment, emphasizing how evaluation data can guide instruction and support student learning (Black & Wiliam, 2018; Schellekens et al., 2021). AI amplifies this approach by providing more detailed, timely, relevant and actionable information to support the dynamic features of learning. This perspective goes beyond the common understanding that assessments carry mainly a specific "stake" or consequence for students, offering educators an opportunity to exert influence and control through attainment pressure (Elmore, 2019)
2. *Constructive alignment*: Following Biggs' (2014) principles, the framework ensures that assessment methods are aligned from the curriculum perspective – in particular in relation with the learning outcomes foreseen and instructional learning activities recommended. AI tools enhance this alignment by offering sophisticated means to assess complex learning outcomes, ensure a comprehensive assessment and avoid gaps in coverage.
3. *Sociocultural dimension of assessment*: The framework recognizes assessment as a culturally situated practice (Gipps, 1999) and emphasizes the importance of considering diverse learner backgrounds and needs. AI applications must be designed and implemented with cultural responsiveness in mind, for example by controlling the questions' difficulty in relation to diverse students' cultural backgrounds. In this way, we could better acknowledge how current assessment systems have a deep embedded social and cultural purpose and not always serve as useful information about the development of learners' capabilities (Elmore, 2019).

These theoretical foundations ensure that technological innovations serve pedagogical purposes rather than allowing technology to drive assessment practices. This way, our *Processual Assessment Integration Model (P-AI-M)* emerges as a novel prescriptive framework for the AI use in education assessment. This top-down model uses the three theoretical key perspectives described above as a system of normative orientation for the processes underlying both facets. At the same time, the model concludes in an iterative feedback loop, informing instruction and enhancing learning (see Figure 1).

The processual dimension of our framework is directly informed by three theoretical perspectives identified in our literature review as essential for effective AI-enhanced assessment. Assessment for learning theory (Black & Wiliam, 2018) emphasizes the formative potential of evaluation, which our dual-facet approach captures by connecting design decisions with implementation outcomes. Constructive alignment principles (Biggs, 2014) necessitate viewing assessment as part of an integrated educational system, reflected in our framework's emphasis on linking assessment processes to curriculum and instruction. The sociocultural dimension of assessment (Gibbs, 1999) highlights how evaluation practices are culturally situated, which our process model acknowledges by emphasizing contextual adaptation in both design and implementation phases. Together, these theoretical foundations necessitate a process-oriented approach that views assessment not as a static event but as a dynamic component of the educational journey, with AI enhancing different phases while preserving educational integrity.

Figure 1

The illustration of the Processual Assessment Integration Model (P-AI-M)



Current studies and evidence will be subsequently utilized in Chapter 3 for illustrating instantiations of the two facets in practice, highlighting current capabilities and instrumentations that could justify the convergence towards the overarching processual dimension.

2.2. A focus on the roles

Our systematic review consistently highlighted implementation challenges stemming from misalignments between different educational actors in AI assessment integration. Successful implementations, by contrast, demonstrated clear role definition and cross-stakeholder collaboration (Tsai et al., 2019; Holstein et al., 2019). This finding aligns with distributed cognition theory and socio-technical systems perspectives, which emphasize how technological implementation requires coordination across multiple actors in complex educational settings (Buckingham Shum et al., 2019).

Drawing on these insights, we developed a stakeholder dimension that maps the ecosystem of AI assessment implementation by identifying five key stakeholder groups—researchers, policy makers, school leaders, teachers, and students—each with distinct responsibilities, concerns, and areas of expertise essential to successful AI integration. For each stakeholder, the table presents three dimensions: primary focus areas that demand their attention, key responsibilities that fall within their purview, and implementation considerations that should guide their decision-making.

Table 2

Stakeholder roles in educational AI assessment

Stakeholder	Primary focus areas	Key responsibilities	Implementation considerations
Researchers	Validity evidence; Ethical frameworks; Longitudinal impacts	Developing assessment models; Investigating bias; Validating effectiveness	Balance innovation with methodological rigor; Consider educational theory alongside technical capabilities
Policy makers	Governance structures; Equity safeguards; System integration	Creating regulatory frameworks; Ensuring fair implementation; Resource allocation	Develop policies based on evidence; Balance innovation with protection; Support capacity building
School leaders	Professional development; Institutional adoption; Data systems	Leading organizational change; Building assessment culture; Resource management	Prioritize pedagogical purpose; Create collaborative implementation teams; Develop assessment literacy
Teachers	Pedagogical integration; Feedback utilization; Student support	Designing assessments; Interpreting results; Guiding learning	Maintain professional judgment; Focus on formative potential; Connect assessment to instruction
Students	Feedback engagement; Self-regulation; Learning pathways	Self-assessment; Setting goals; Using feedback	Develop assessment literacy; Maintain agency in process; Connect assessment to personal growth

The stakeholder matrix emerged from our analysis of implementation studies that revealed how disconnects between different educational actors often undermined AI assessment initiatives. For example, many studies documented researcher-developed tools that failed to gain traction because they were designed without adequate teacher input (Knox et al., 2019; Selwyn, 2019), or policy frameworks that lacked sufficient guidance for classroom-level implementation (Reich & Ito, 2017). By explicitly mapping the complementary roles and responsibilities across the educational ecosystem, our framework addresses this recurring gap in the literature while acknowledging that successful AI integration depends not just on technological sophistication but on thoughtful human oversight distributed across organizational levels. This dimension prevents technological determinism by distributing accountability and agency across the educational community, a concern frequently raised in our reviewed literature (Holmes et al., 2019).

This framework recognizes that **successful AI assessment integration depends not only on technological capabilities but also on thoughtful human oversight across organizational levels**. By clarifying these complementary roles, the table provides a roadmap for collaborative implementation that balances innovation with ethical considerations, technical capabilities with pedagogical needs, and system-level changes with individual learning experiences. Understanding these varied perspectives is essential for developing AI assessment systems that are not only technically sound but also educationally valuable and equitably implemented.

2.3. A focus on the evaluative tasks

While the stakeholder matrix establishes who should be involved in AI assessment integration and their respective responsibilities, it is equally important to understand what specific assessment functions AI can support within established pedagogical frameworks. Instructional design and, consequently, the educational assessment have long been guided by Bloom's Taxonomy, which provides a hierarchical classification of cognitive processes from basic recall to complex creation. This taxonomy serves as an ideal structure for mapping AI capabilities to specific assessment needs across different levels of cognitive complexity. Therefore, a third and last cognitive-taxonomic dimension is presented.

Our review revealed that current AI assessment tools tend to cluster either at lower cognitive levels (focused on knowledge retrieval and basic understanding) or at advanced levels (supporting complex analysis and creation), with

limited integration across the full spectrum of cognitive processes. This finding highlighted the need for a comprehensive framework that maps AI capabilities to the entire range of cognitive operations. The following table addresses this gap by illustrating how artificial intelligence can complement human skills at each taxonomic level while supporting assessment functions linked to specific learning outcomes. This perspective is deeply rooted in Vygotsky's sociocultural theory of learning, particularly the concept of scaffolding within the zone of proximal development, where AI tools can provide the appropriate level of support needed for learners to progress to higher cognitive levels (Vygotsky, 1997). This theoretical lens informed our understanding of how AI can serve not just as an evaluation tool but as a supportive mechanism that facilitates cognitive development across multiple dimensions.

Furthermore, this approach reflects contemporary assessment theories emphasizing the need for multidimensional evaluation methods that capture the full spectrum of learning outcomes embedded in various national education systems' curricula. Often defined as general and specific competences, these learning outcomes cover a complex array of knowledge, skills and attitudes, defined both at a specific subject level, but also at a wider level. Our approach is therefore relevant to map not only the individual performance of a student at one subject, but also how the learners/graduate competence profiles are met.

By connecting stakeholder roles with taxonomically-organized assessment applications, we establish a comprehensive model that bridges organizational considerations with classroom-level pedagogical practices to ensure AI assessment tools are both theoretically grounded and practically applicable. The framework presented in Table 3 integrates a revised Bloom's Taxonomy with emerging AI capabilities to provide a comprehensive view of how human skills and artificial intelligence can complement each other in educational assessment. It is built based on the Oregon State University Ecampus resource for the teaching staff (the first three columns of the table), to which we added a fourth column dedicated to AI-supported assessment.

Table 3

AI assessment applications mapped to Bloom's taxonomy framework

Level	Distinctive human skills*	How GenAI can supplement learning*	How AI can support assessment/ evaluative tasks**
CREATE	Engage in both creative and cognitive processes that leverage human lived experiences, social-emotional interactions, intuition, reflection, and judgment to formulate original solutions	Support brainstorming processes; suggest a range of alternatives; enumerate potential drawbacks and advantages; describe successful real-world cases; create a tangible deliverable based on human inputs	Assess originality by comparing student work against corpus knowledge/ state of the art; provide constructive feedback on creative products; generate alternative solutions for comparison; evaluate alignment with provided criteria/ rubrics; support portfolio-based assessment
EVALUATE	Engage in metacognitive reflection; holistically appraise ethical consequences of other courses of action; identify significance or situate within a full historical or disciplinary context	Identify pros and cons of various courses of action; develop and check against evaluation rubrics	Analyse evaluation justifications for depth and coherence; provide multi-perspective feedback on ethical reasoning; assess the comprehensiveness of critical reviews; benchmark evaluations against expert examples; generate counterarguments to test robustness of student evaluations
ANALYZE	Critically think and reason within the cognitive and affective domains; justify analysis in depth and with clarity	Compare and contrast data, infer trends and themes in a narrowly - defined context; compute; predict; interpret and relate to real-world problems, decisions, and choices	Identify logical gaps in student analyses; provide immediate feedback on analytical processes; suggest additional analytical perspectives; evaluate the quality of evidence used in arguments; create customized analytical challenges based on student performance patterns

APPLY	Operate, implement, conduct, execute, experiment, and test in the real world; apply human creativity and imagination to idea and solution development	Make use of a process, model, or method to solve a quantitative or qualitative inquiry; assist students in determining where they went wrong while solving a problem	Imagine hypothetical problem situations that the student must solve using particular knowledge and skills; simulate real-world environments for authentic assessment (also possible within VR settings); automate assessment of procedural knowledge through step tracking; provide scaffolded support during application tasks; generate variations of practice scenarios with adaptive difficulty
UNDERSTAND	Contextualize answers within emotional, moral, or ethical considerations; select relevant information; explain significance	Accurately describe a concept in different words; recognize a related example; translate to another language	Automatically grade essays based on given (general) criteria; give knowledge-based hints to support demonstration of understanding; provide ongoing contextual support and supplementary questions (while taking the test) to gauge focused/ deep understanding; analyse concept maps for comprehension assessment; identify misconceptions in student explanations; personalize assessment based on learning pathways
REMEMBER	Recall information in situations where technology is not readily accessible	Retrieve factual information; list possible answers; define a term; construct a basic chronology or timeline	Indicate the most significant information to be included in a test/ exam; organise the flow of knowledge-based items in adaptive tests; generate personalized retrieval practice exercises; implement spaced repetition testing algorithms; create customized flashcards based on individual learning gaps; track knowledge retention over time

** Bloom's Taxonomy Revisited – by Oregon State University Ecampus, 2024 – based on MAGE framework (Zaphir & al, 2024).*

*** Assessment extension – a proposal for the taxonomy's AI-based assessment dimension; it mostly refers to digital exams.*

Organized hierarchically from foundational remembering to complex creation, the table delineates three essential dimensions. The second column identifies distinctive human skills that remain vital in an AI-augmented world, highlighting the irreplaceable aspects of human cognition at each taxonomic level. The third column outlines how generative AI can supplement student learning processes, serving as a tool that enhances rather than replaces human thinking (Oregon State University Ecampus, 2024).

In the last column, we propose a structured list of examples of how AI can support assessment and/or evaluative tasks, providing concrete applications for educational measurement from basic knowledge verification to sophisticated creative evaluation. Moreover, across all distinctive human skills, AI could provide immediate thorough feedback during various stages of assessment, supporting real-time amelioration. **The cognitive-taxonomic dimension** responds directly to recurring calls in the literature for assessment approaches that capture the full spectrum of learning outcomes embedded in contemporary curricula (Cope & Kalantzis, 2019; Chen et al., 2020). By mapping AI capabilities to Bloom's Taxonomy, our framework offers educators a structured approach to understanding where artificial intelligence can most effectively enhance assessment while preserving human expertise in areas requiring judgment, creativity, and ethical reasoning. This dimension addresses the tension identified in our review between technological capabilities and pedagogical needs by illustrating how AI and human assessment approaches can complement rather than replace each other, with each playing distinct roles across different cognitive domains. It further responds to concerns about AI potentially narrowing assessment focus to easily measurable outcomes by explicitly mapping how AI can support evaluation across the full range of cognitive processes, from basic recall to complex creation.

Together, these dimensions offer educators a structured approach to understanding how AI tools can most effectively strengthen assessment practices, while preserving the central role of uniquely human capabilities in learning and evaluation. Subsequently, an overview of the current research landscape will be explored in relation to the present framework, and connections to literature will serve as an illustration of practical options for each element comprised by the processual, stakeholder and taxonomical dimensions.

2.4. Integration of the Three Dimensions

The three dimensions of our P-AI-M framework—processual, stakeholder-oriented, and cognitive-taxonomic—emerged not as isolated components but as an integrated response to the multifaceted challenges of AI integration in educational assessment identified in our systematic review. Each dimension addresses distinct but interconnected aspects of assessment: the 'what' (processual), the 'who' (stakeholder), and the 'how' (cognitive-taxonomic). Together, they form a comprehensive framework that bridges theoretical foundations with practical applications.

The integration of these dimensions creates a dynamic model that reflects the complexity of educational assessment while offering practical guidance for implementation. For example, the processual dimension's distinction between assessment design and implementation is directly linked to the stakeholder dimension's differentiation of roles, with researchers and policy makers typically more involved in design aspects while teachers and students engage more with implementation. Similarly, the cognitive-taxonomic dimension intersects with both the processual dimension (different assessment phases may target different cognitive levels) and the stakeholder dimension (various stakeholders may prioritize different cognitive aspects of assessment).

Our review of the literature highlighted that existing approaches to AI in educational assessment often address only one of these dimensions in isolation, leading to implementation challenges and limited adoption. By integrating these three perspectives, our framework provides a more holistic approach that acknowledges the multidimensional nature of assessment and the complex interplay between processes, stakeholders, and cognitive domains in effective AI integration.

3. Assessment Design and Development

Having established our comprehensive three-dimensional framework—encompassing processual, stakeholder, and cognitive-taxonomic dimensions—we now delve deeper into the first facet of the processual dimension: assessment design and development. While the stakeholder roles (from researchers to students) and cognitive levels (across Bloom's Taxonomy) remain integral considerations throughout, this section examines how AI can enhance the preparatory phases of assessment, from strategic planning and item construction to assembly and quality assurance, providing practical applications that bridge theory with implementation.

3.1. Strategic Planning of Assessment

Artificial intelligence can significantly enhance how educators and institutions conceptualize and develop comprehensive evaluation strategies, moving beyond just automating the grading of completed assessments. This application focuses on using AI to shape the entire assessment framework from conceptualization to implementation.

In test purpose determination and specification, the application of AI in analysing curriculum content effectively identifies key assessment targets (Owan et al., 2023). Large language models demonstrate significant utility in test specification by processing extensive course-related text data, identifying essential themes and concepts, and generating appropriate test item recommendations. AI systems contribute to assessment design through several modalities: identification of critical knowledge and competencies from curriculum materials, recommendation of assessment frameworks that align with established learning objectives, thus ensuring a calibration of the assessment to the class content.

Another important aspect in assessment planning and calibration is the comprehensive coverage of the specified areas of the assessment domain, thus providing content validity. LLMs can analyse content areas and instructional objectives in the cognitive domain, and therefore, they can help educators design assessment methods exhaustively representing

it (Owan et al., 2023). This can be achieved by ensuring appropriate weighting of topics based on curriculum emphasis, align assessment difficulty with intended learning outcomes and include different item types for complementary skill assessment.

AI can also help obtain other validation evidence by analysing response processes of students (processing validity), internal structure of assessments (internal validity), as well as relationships to other relevant variables (criterion validity), all being important for the quality and accuracy of the assessment results, as well as the subsequent confidence in the derived learning goals (Kaldaras et al., 2024).

3.2. Item Construction and Validation

3.2.1. Item Construction

Item construction and validation represent two interconnected areas where AI technologies are making substantial contributions to educational assessment. These applications leverage natural language processing, machine learning, and large language models to enhance both the creation and evaluation of assessment items.

AI has significantly enhanced the process of building assessment items, particularly in high-stakes exams. Traditional methods of item generation often rely on human expertise, which can be time-consuming and prone to bias. AI technologies, such as Natural Language Processing (NLP) and Machine Learning (ML), have introduced automated item generation (AIG) as a viable alternative (Circi et al., 2023). This option allows for increased item production capabilities, especially useful for large-scale assessment. Allowing various types of input, ranging from templates to strong theories, its accessibility creates considerable opportunities for educators. Organized in multiple stages, the automatic item generation process can prepare and understand text for subsequent item production, as well determining usefulness of the generated items (Tan et al., 2024).

Beyond powerful capacities of production, LLMs underlying AIG also have the ability of generating highly structured items with unambiguous prompts and solutions. Exceeding frequently practiced traditional memory-recall questions, AI systems can provide multiple-choice items (with stem, correct answer and possible distractors), essay prompts, short-answer questions, and problem-based items, with the main advantage of increasing accessibility of a diverse plethora of assessment options corresponding to a complementary ability evaluation. There is practical evidence of questions constructed through AI, considered clear and relevant with regard to the assessment subject (Owan et al., 2023).

The power and speed with which these tools can build proposals for assessment items make AI-assisted assessment creation an increasingly valuable option in the perspective of scaling assessment education. AI systems also provide, beyond versatility and accessibility, unprecedented possibilities in large-scale testing, by offering exponentially more resources, as well as by combining AI technologies and psychometric methods to produce substantial joint developments in reliability and validity of assessment.

3.2.2. Item Validation

Research evidence indicates the potential use of neural networks in estimating both person and item parameters from Item Response Theory (IRT), such as item difficulty and item discrimination (the ability of an item to distinguish between increments of respondents' ability level) (Zhang & Chen, 2024). Moreso, AI systems can offer meaningful explanations of parameters across different cognitive domains as well as performance prediction (Su et al., 2021). AI's ability to estimate item parameters at incredibly high precision also allows for applications in more complex methods of cognitive diagnostics (Li et al., 2022).

AI derived options can also provide necessary complementarity for traditional methods that can be difficult to implement in practice, due to their sensitivity to many assumptions. In certain situations, AI systems could be preferred to classical Factor Analysis in studying the item-factor relationship, by being more accurate and adaptable (Milano et al., 2024).

3.3. Assessment Assembly and Quality Assurance

Once individual items have been constructed and validated, they must be assembled into coherent assessment instruments. AI supports this process through sophisticated assembly algorithms and quality control mechanisms.

As iterated earlier, AI supports the strategic selection of items to create cohesive assessments. It can interpret relevant materials and texts, identify redundant or overlapping items, ensure appropriate difficulty distribution and maintain internal consistency, thus providing support in identifying the appropriate items and ensuring convergent validity (Owan et al., 2023).

In terms of validity for the resulting assessment instrument, AI systems provide different support possibilities. Content validity measures using AI are developed for paralleling human evaluation, adding another layer of verification for the complete coverage of the assessment factors' domain by the selected items of the (Milano et al., 2025). Also, powerful options for validating the internal structure in large-scale assessment that use AI are available (Urban & Bauer, 2021). Specifically, algorithms of deep learning provide new performance possibilities in learning how the structural organization of items reflect the latent traits intended for assessment. Spectacular new developments attack some of the hitherto considered "black-boxes" of assessment challenges, namely the response processes. Research using biometrics and machine-learning enables insight in strategies and specific behaviours (Yaneva et al., 2022). These systems can also analyse student behaviour during assessments, offering a more comprehensive understanding of their cognitive and affective states (Liu et al., 2024). For instance, AI-powered platforms can track engagement levels, detect emotional states, and provide real-time interventions to support student well-being (Saputra et al., 2024; Apetorgbor et al., 2024).

These are just a few of the overwhelming tools and methods enabled by AI systems, dedicated for evaluating assessment quality.

AI also allows for important features with respect to the superordinate principle of cultural sensitivity and correction for bias and threats to fairness. AI systems can identify multiple sources of potential bias in assessment materials by analysing the content of test items and signalling specific issues (Owan et al., 2023). These tools can highlight cultural or linguistic barriers that may disadvantage certain students. Also, they can identify stereotypical representations in item contexts. Moreso, the AI systems have the potential to detect interference with item clarity leading to inaccuracies in interpretation by analysing language usage that may create construct-irrelevant variance and noise. Also, it can check assumptions about assessment content that relies on prior knowledge, not covered by the curriculum. AI-powered tools like Finetune (*Generate* and *Catalog*) have been used to align educational content with various standards and frameworks, reducing subjectivity and improving precision (Bolender et al., 2024).

4. Assessment Implementation and Utilization

Building upon our exploration of assessment design and development, we now turn to the second facet of the processual dimension within our three-dimensional framework: assessment implementation and utilization. This section examines how AI transforms the execution, analysis, and educational application of assessments while still acknowledging the distinct roles of various stakeholders and the cognitive processes being evaluated. The implementation phase represents the critical juncture where theoretical design principles meet practical classroom realities, creating opportunities for more responsive, equitable, and pedagogically sound assessment practices.

4.1. Administration and Adaptive Delivery

The second dimension of our framework addresses how AI can enhance the administration, scoring, interpretation, and educational use of assessments. This dimension focuses on the functional aspects of assessment as an integral component of the teaching and learning process.

4.1.1. Testing Environment Monitoring

AI systems can enhance assessment integrity through proctoring capabilities that detect suspicious behaviours, authentication methods to verify test-taker identity, environmental monitoring to ensure testing conditions, anomaly detection in response patterns or testing behaviours (Young, 2024).

4.1.2. Adaptive Assessment Delivery

One of the most innovative contingencies of AI usage in assessment implementation refers to the adaptive testing systems used to adjust the difficulty of questions based on a student's performance, providing a more accurate measure of their abilities (Msayer et al., 2024; Khlaif et al., 2024). Some of the most important advantages refer to precision in dynamically matching item difficulty to estimated student's ability to maintain optimal mental challenge, reduced testing time and test items while preserving measurement precision, and customized assessment pathways based on response patterns.

4.2. Response Analysis and Scoring

Traditional assessment methods often involve manual scoring, which can be time-consuming and prone to human error, or formulaic evaluation, excessively template-driven evaluation struggling with generalization and context.

Answering problems related to resource optimality AI-based systems offer automated grading and real-time feedback, enabling educators to quickly identify areas where students may need additional support. Recently, AI-powered tools started being successfully used in essay scoring, demonstrating high accuracy and consistency (Hartmann, 2023; Mahamuni et al., 2024). Recent studies emphasize the utility of AI tools for automatic grading of assessments, showcasing how AI can streamline the evaluation process. This includes the development of algorithms capable of effectively assessing student performance on various types of assessments, such as essays, quizzes, and practical assignments (Hrich et al., 2024).

For example, AI systems specialised on automated essay scoring (AES) evaluate written essays on dimensions including content relevance and accuracy, organization and coherence, grammar and mechanics, vocabulary usage and style, argument development. Major systems include e-rater (ETS), Intelligent Essay Assessor (Pearson), and features in platforms like Turnitin.

Apart from resource efficiency, the use of AI could also deliver serious contributions to the problem of lack of flexibility and rigid use of templates and answer keys instead of contextual meaning and understanding of the evaluation criteria. For instance, Richardson and Clesham (2021) describe how Pearson's Intelligent Essay Assessor uses latent semantic analysis (LSA), which uses words as vectors projected in a multidimensional semantic space. Words and sentences can be compared on similarity of meaning based on the contexts of the words used (relation to the rest of the text), allowing AI to evaluate meaning rather than merely matching keywords. Evidence of reliability comes in support for their practical use (Richardson & Clesham, 2021). Also, the possibility of evaluating scoring process transparency brings potential interest for educators, due to the capacity of grasping an understanding over the decisions made by the system by interrogating the "reasoning" behind the scoring process (Kaldaras et al., 2024).

4.3. Interpretation and Feedback Systems

AI enhances the interpretation of assessment results by offering comprehensive data analysis, personalized feedback, predictive analytics, and valuable insights for educators. This capability allows for a more responsive educational environment that can quickly adapt to students' needs.

4.3.1. Comprehensive Data Analysis

AI systems can process large volumes of assessment data quickly and efficiently, including both quantitative data (like scores and completion times) and qualitative data (like student-written responses). Machine learning algorithms can identify patterns, trends, and anomalies in student performance that may not be evident through traditional assessment methods.

AI systems excel at identifying patterns in large datasets that might be invisible to human analysts. As Owan et al. (2023) explain, AI can:

- Analyse student response patterns across multiple assessments to identify conceptual misunderstandings.
- Detect correlations between performance on different question types or topics.
- Identify anomalies that may indicate unusual learning challenges or strengths.
- Recognize trends in performance over time that suggest learning progression or regression.

4.3.2. Performance Prediction

AI can use historical assessment data to predict future performance. For example, it can evaluate how students' scores in formative assessments might relate to their expected scores in summative assessments. This predictive analysis can guide teachers in implementing early interventions for students who may be at risk of falling behind (Owan et al., 2023).

Key predictive capabilities include:

- Early identification of students at risk of academic difficulties;
- Projection of learning trajectories based on current performance;
- Estimation of knowledge acquisition rates over time;
- Prediction of performance on future assessments based on current patterns.

4.3.3. Multi-Level Feedback Systems in Learning Enhancement

AI-powered systems can generate detailed reports automatically, providing administrators with actionable insights into student performance (Bolender et al., 2024; Apetorgbor et al., 2024). These reports can include system-wide performance analytics, achievement gap identification, curriculum effectiveness indicators, and resource allocation recommendations, among many others.

AI-based assessment systems enable the identification of learning gaps, allowing educators to tailor instruction to individual needs based on indices of class-level performance patterns, topic-specific mastery levels, instructional effectiveness indicators, and even explicitly recommended teaching interventions.

The role of AI is also recognized in providing real-time feedback for students (Owan et al., 2023). AI can provide immediate feedback based on their assessment performance:

- Specific knowledge and skill gaps;
- Personalized learning recommendations;
- Progress tracking against learning goals;
- Metacognitive guidance on learning strategies.

Teachers and educators could guide intelligent tutoring systems and use collected data for monitoring how performance improvement recommendations are implemented and how effective they are.

5. Concluding Thoughts

The integration of artificial intelligence into educational assessment could represent a major transformation in how we conceptualize, design, and implement evaluative practices. Our systematic review reveals that AI's potential extends far beyond mere automation of existing processes – it offers unprecedented opportunities to reconceptualize assessment as an integral, dynamic component of the educational journey rather than an isolated evaluative event.

Our article explored current developments in AI use for enhancing learning, focussing on education assessment, as one of the most important and promising areas of ap-plication. The model proposed assumes that despite the current limitations in rigorously understanding how brains work, the theoretical advances are offering a promising perspective (Churchland and Abbot, 2016). AI tools still have documented limitations from the technological perspective and the areas explored in our normative model accurately follow these limitations. However, we highlight the limitations of our model when considering its real-life applications. The lack of enabling factors (for example, a systemic policy support, an enhanced accessibility, adequate training of teachers), as well as specific contexts (for example, rigid educational cultures and resistance to change, limited funding, insufficient cooperation between key stakeholders) could reduce

the practical value of this model, despite its normative nature. Also, at list at this stage, AI systems are **tools with no inherent moral agency**, trained on available data with its correspondent bias and error. Thus, uses of AI always pose the risk of circular reproduction of error, and their applications are always bound to the quality of its training data.

The *Processual Assessment Integration Model (P-AI-M)* proposed in this paper provides a comprehensive framework that bridges theoretical foundations with practical applications across three critical dimensions that work in synergy:

1. **The processual dimension**: Our dual-facet approach to assessment processes—distinguishing between design/development and implementation/utilization—creates a dynamic framework that recognizes assessment as a continuous cycle rather than a static event. This processual understanding demonstrates how AI can enhance different phases of assessment while maintaining pedagogical integrity. The iterative feedback loops embedded in this dimension ensure that assessment continuously informs instruction and enhances learning in a virtuous cycle.

2. **The stakeholder dimension**: By explicitly mapping the roles, responsibilities, and concerns of researchers, policy makers, school leaders, teachers, and students, our framework acknowledges that successful AI integration depends on coordinated efforts across the educational ecosystem. This multi-stakeholder approach ensures that AI implementation balances innovation with ethical considerations, technical capabilities with pedagogical needs, and system-level changes with individual learning experiences. The stakeholder dimension prevents technological determinism by distributing accountability and agency across the educational community.

3. **The cognitive-taxonomic dimension**: By aligning AI capabilities with Bloom's Taxonomy levels, our framework provides educators with a structured approach to understanding where AI can most effectively enhance assessment while preserving human expertise. This dimension illustrates how artificial intelligence can complement human skills across the spectrum from basic recall to complex creation, maintaining the centrality of uniquely human capabilities in areas requiring judgment, creativity, and ethical reasoning.

The integration of these three dimensions creates **a comprehensive model** that provides both theoretical grounding and practical guidance. When implemented together, they address persistent challenges in educational assessment: resource constraints, scalability limitations, and the need for more nuanced, timely feedback, while preserving the human elements essential to meaningful education.

From a **theoretical perspective**, the P-AI-M framework is grounded in established educational principles including assessment for learning, constructive alignment, and the sociocultural dimensions of assessment. This theoretical grounding ensures that technological innovations serve educational objectives rather than directing or constraining pedagogical practices. The model acknowledges that assessment is not merely a measurement tool but a catalyst that informs teaching strategies and empowers students in their learning journey.

The **practical implications** of our framework are substantial. In assessment design and development, AI offers capabilities ranging from strategic planning and item construction to quality assurance and bias detection. In implementation and utilization, AI enhances administration through adaptive delivery, sophisticated response analysis, comprehensive interpretation of results, and personalized feedback mechanisms. These applications collectively address persistent challenges in educational assessment: resource constraints, scalability limitations, and the need for more nuanced, timely feedback.

We acknowledge both the promise and limitations of our framework. Despite the current technical limitations in AI, the normative model we propose accurately identifies areas where AI can enhance educational assessment while remaining cognizant of its boundaries. However, successful implementation requires enabling factors including systemic policy support, enhanced accessibility, adequate teacher training, and collaborative stakeholder engagement. Moreover, the ethical implications of AI in assessment demand ongoing vigilance regarding data privacy, algorithmic transparency, and equity considerations.

The P-AI-M framework ultimately represents **a balanced approach to AI integration** that neither uncritically embraces technological determinism nor dismisses innovation due to resistance to change. Instead, it offers a structured pathway for thoughtful implementation that enhances assessment practices while preserving educational values. By situating AI capabilities within sound pedagogical principles, the framework helps educators and institutions to meaningfully employ assessment innovation while ensuring that technology serves as a tool for educational empowerment rather than a mechanism that reduces learning to data points.

Important challenges remain in determining how these technologies can be implemented ethically and effectively across diverse educational contexts, ensuring they enhance rather than undermine pedagogical objectives (Knox et al.,

2019; Selwyn, 2019). Vigilance in understanding algorithmic processes and sensitivity to error or inequity is imperative for ensuring principles of fairness, inclusivity and equality of chance (Kizilcec & Lee, 2020). Important research also addresses whether AI assessments produce valid and reliable evaluations across different student populations, addressing concerns about methodological integrity and accuracy of measurement (Saadati, 2023). Additionally, research should explore how educators can best integrate AI assessment tools into their practice while maintaining their professional judgment and pedagogical authority (Tsai et al., 2019). There is also focus on the broader ethical dimensions of AI in assessment, including data privacy, transparency of algorithmic decision-making, and student agency (Buckingham Shum et al., 2019). As educational systems increasingly adopt these technologies, evidence-based guidelines are essential to ensure that AI serves as a tool for educational empowerment rather than a mechanism that narrows curriculum or reduces students to data points or becomes blindly governed by technocentric systems (Selwyn, 2019). By systematically examining both the affordances and limitations of AI in assessment, researchers can contribute vital knowledge that informs policy and practice, ultimately ensuring that technological innovation serves genuine educational advancement (Holmes et al., 2019).

As AI continues to evolve, this framework provides both theoretical grounding and practical guidance for implementing assessment tools in pedagogically sound, ethically responsible, and equitably distributed ways – ensuring that technological advancement serves genuine educational enhancement rather than narrowing curricular focus or diminishing the rich complexity of human learning.

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Abbreviations

The following abbreviations are used in this manuscript:

P-AI-M	Processual Assessment Integration Model
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses

Author Information and Declarations

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Olimpius Istrate, PhD in education sciences, brings over 20 years of experience in the areas of digital pedagogy, education programmes evaluation, and teacher training. Since 2004, he has taught specialized courses at the University of Bucharest's Faculty of Psychology and Education Sciences, Teacher Training Department – at both bachelor's and master's levels – including *Computer Assisted Instruction, Virtual Learning Environments, New Media in Education and Training, AI in education*. Currently, Dr. Istrate works as an e-assessment specialist on secondment to the Office of the Secretary General of the European Schools in Brussels. His notable achievements include co-founding Academia Online (2003), founding Elearning.Romania (2005), serving as regional education manager at Intel (2007-2010), founding iTeach.ro (2010), coordinating eTwinning nationally (2011-2012), working as senior education officer at the International Federation of RCRC in Geneva (2013-2016), and co-founding digitaledu.ro (2015). Dr. Istrate has authored several books, chapters, and articles in the field of digital pedagogy, including his influential 2022 paper ”Digital Pedagogy. Definition and Conceptual Area”, published in the Journal of Digital Pedagogy. His latest assignments include collaboration with UNESCO IBE, the European Commission, the World Bank, and various national working groups for innovation in education.

Ciprian Fartușnic, PhD in education sciences, has over 25 years of experience in education research, policy analysis, curriculum, program and project assessment and teacher training. Former director of the Institute of Education Sciences in Romania (2014-2018), Dr. Ciprian Fartușnic is currently working as Head of the Pedagogical Development Unit, Office of the Secretary General of the European Schools. He held the position of an associated professor at the University of Bucharest, University of Iasi, and National School of Political Sciences and Public Administration - Bucharest, teaching courses at both bachelor's and master's level, including Didactics of Social Sciences, Theories of Learning, Education Policies. Dr. Ciprian Fartușnic co-ordinated the competence based curriculum reform and was involved in the design and delivery of a national continuous training program for teachers to support this reform, with an important online component. He is a member of national and international research teams on various topics. He worked as an expert for UNICEF, the European Commission, UNESCO (International Bureau of Education) and the World Bank. Dr. Ciprian Fartușnic was involved in the development of the Romanian Digital Competence Framework and he is a member of the EPAN (Council of Europe), REFERNET (CEDEFOP), International Research Network on Equity in Youth Education and Training (IRNEYET), and the Learning and Teaching, Bologna Follow-Up Group (European Commission).

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Text as a Tool. The Effects of Using Image-Generating AI in German University Contexts

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Abstract: This article investigates how German university students learn to use image-generating artificial intelligence and its implications for educational practice. Using semi-structured interviews and think-aloud protocols, twelve students (aged 18-26) from media and social science programs at three German universities created personal and academic images using Midjourney. Through descriptive thematic analysis, findings reveal that image-generating AI creates initial excitement and motivation while fostering soft skills including persistence, precise communication, and openness to new experiences. However, some students experienced frustration when attempting to realize specific visual concepts and showed susceptibility to distraction. Notably, students with broader general knowledge in art history and technical terminology achieved more successful outcomes. Further, the study identifies a fundamental shift in university learning paradigms: whereas academic work traditionally progresses from images to textual analysis, image-generating AI reverses this process, positioning text as a tool for visual creation. This has implications for curriculum designs, suggesting the need for enhanced visual literacy, expanded general education requirements, and explicit instruction in AI bias recognition. For educational practice, image-generating AI can serve as a valuable pedagogical tool for increasing engagement while requiring careful scaffolding to prevent distraction and ensure critical evaluation of outputs. The study contributes foundational insights for developing pedagogical frameworks that harness the potential of image-generating technologies in education.

Keywords: artificial intelligence, image generation, qualitative research, German higher education, digital technologies, visual literacy, general knowledge

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Introduction

Learning and researching with artificial intelligence (AI) are topics that are currently being hotly debated at universities, schools, and other institutions worldwide. This article would like to contribute to the debate, but unlike most (Baidoo-Anu & Owusu Ansah 2023, Meyer et al. 2023), focuses on image-generating AI and the way students appropriate the technique for their personal and university work. Further, it analyses the implications of this appropriation.

In 2023, Zhai published a paper on AI that has been mostly written by AI – which may not have been obvious if he had not clearly stated it. The same applies to pictures. The output of image-generating AI may look like paintings or drawings, and also already comes very close to photographic images, causing confusion, fascination, but along with it the necessity to discuss how to deal with this technology in the future. It could be seen as even more important, as pictures have a strong influence on our emotions. Further, seeing is, even after all the doubts created by picture manipulation starting basically with the invention of photography itself, equalled to believing (Cohen & Meskin 2010: 70), which may lead to image-generating AI being an even more touchy subject – be it with regard to rather documentary or artistically motivated topics (Guadamuz 2023, Sato 2023, Roza 2019).

1. Prompting

Image-generating AI works with prompts which are usually written instructions for the AI, describing what should be seen in the picture. In this article, we refer to diffusion models. This is a technology able to interpret natural language instructions or "prompts" and generate images from this interpretation. These models are made possible by the availability of large image corpora such as ImageNet (Deng et al. 2009) and LAION-2B (Schumann et al. 2022), which contain image pairs and associated human annotations, the advancement of natural language models such as Transformers and the GPT-2 architecture (Radford et al. 2019), which are able to represent real-world concepts in a mathematical vector space, and by using neural latent diffusion models that continuously refine images depending on the input text (Rombach et al. 2022). Starting from pure noise, a diffusion model iteratively refines its input according to patterns learned from the training data and the prompt text until it reaches a final image after a series of steps. It is also possible to start from an existing image and use this as a prompt, possibly with further text specifications. If the original image is still recognizable at the end, the result is referred to as a style transfer (Gatys et al. 2016).

Even though it is possible to create attractive and complex works with very simple prompts, writing good prompts has now even become a professional field that may be interesting for students of media science, social sciences, art etc. but also in the field of scientific illustrations. However, this article is not about particularly complex prompts, but about how people approach prompting from the very beginning.

2. The Sample, the Set-Up, and Perspective

To find out more about this topic, twelve volunteers, university students between the ages of 18 and 26, were selected, eight women and four men from three different institutions in Germany. All gave their informed consent to the study, allowing me to quote their statements. Apart from this, anonymity was granted.

The students had a middle- or upper-middle-class background and shared, as they were studying subjects connected to society and/or media, a general interest in the field. In addition, all of them have intensively used digital media at university and in their leisure time, e.g. dealt with photography, filmmaking, web design, or computer games, but not yet with image-generating AI. All of them had already tried ChatGPT for text generation in their private or students' lives.

Before letting them use the AI, the subjects were briefly interviewed for demographic data and about their attitudes towards image-generating AI, asking questions like "are you interested in the current developments regarding AI?," "for which purpose did you use AI so far?," "in general, do you think AI has a positive or negative impact on humanity?," "which aspects of AI do you see positively, which negatively?" After the semi-structured interviews, the responses to which were transcribed during the process, the students were introduced to the prompting process on

Midjourney. Then, they were asked to come up with a) a picture they would put on their wall in their home and b) a picture that would illustrate a topic they work on in their university courses. Thus, they would first try to create a picture that reflects their personal interests and aesthetics, and then create a more professional picture, both covering various ways how image-generating AI can be used. They were also asked to articulate how they felt about the AI-process using the think-aloud-method. This often resulted in a small dialog where I was asked what I thought of the results or if I could help improve the results. Although I held back, I provided support where necessary, which could be seen as an external influence, just as my presence itself.

The students' statements were then sorted into categories following an ethnographic content analysis. To ensure that these categories were not only seen by me, a specialist in computational linguistics was asked to review the transcriptions and sort the answers, which led to an almost identical result, thus to categories that covered the same content. Together, we then discussed the naming of the categories and decided on their titles.

In the present context, the constructivist and cultural anthropological perspective on learning, in which knowledge is related to questions of active construction of meaning, seems a suitable way to approach the topic. The formation of knowledge depends on the personal learning biography but is also embedded in cultural contexts (Reinmann 2015: 140). Here, it is important that both in the specific subject areas of the students, but also in the culture, there is a stress on creativity: so-called "Western cultures tend to endorse creativity – supporting values or practice" (Kwan et al. 2018).

Of course, the study has some limitations to it: the sample is rather small and homogenous, yet it may represent an avantgarde and could be prototypical of later generations of students. However, the situations of students from a lower-class, less privileged background will probably have to be analysed separately, as the digital divide probably plays an important role in the context. Then, since I, the author and interviewer, was obviously interested in AI and some students probably knew that I had already published on this topic, it is conceivable that an interviewer effect may have occurred, i.e., that the students for example rated their interest in or experience with AI higher. However, the subjects taught at their institutions would encourage students to adopt a reflective attitude, so my presence may not have influenced their answers in such a way that they were overly positive. Again, the results could be different with students who study subjects that do not foster a differentiated perspective on the socio-cultural environment, but rather focus on technical aspects, for example. Furthermore, there was no long familiarisation phase for the students with the AI and as it is not a longitudinal study, it is hard to say how things would develop if students continued using the AI.

3. Experiences with AI

It turned out that all subjects were interested in AI, some were quite cautious about it, others were somewhat to very open-minded. Their major concerns were that AI, also imagine-generating AI could cost jobs and that the possibility for deep fakes would make it harder to trust in media information.

In the following, we will look at how the participants described their experiences with image-generating AI via the method of thinking aloud. The categories are derived from an ethnographic content analysis.

3.1. Excitement and Fun

All participants, even those who had previously been sceptical, quickly took over after the introduction and started to generate images on their own. All were initially enthusiastic about how a selection of images emerges out of nowhere after entering the prompt. Several emotions were mentioned in this context: the feeling of magic, surprise, and flow, obvious in quotes like "it is really fun, I am so excited about the outcome that is slowly building up right now" or "I feel excited and relaxed at the same time, I am in the flow right now". Thus, the image generation is similar to instant photography: "You can compare the image with the development process, a small film is playing in front of your own eyes in which the image slowly takes shape. Its emergence out of nothing, out of whiteness, has almost metaphysical traits" (Jerrentrup 2020: 22).

The feeling of "flow" has been mentioned or paraphrased several times by those interviewed so far. The term, coined by Mihály Csíkszentmihályi (see 1996/2010), refers to a specific type of intrinsic motivation for activities (see Fischer &

Wiswede 2009: 100) in which one is neither underchallenged nor overwhelmed, in which one can "get absorbed" and it may be one of the major strong sides of image generating AI – that it gets people in this positively-experienced state.

Anticipation also plays an important role in this – "I am so excited if I get what I envisioned" – , but at the same time the inability to predict the results accurately, in fact, one can even use prompts for which one has no visual idea oneself – "let's see if such a crazy combination leads to anything at all". The resulting images are therefore nearly always more or less surprising – at least for those who are new to working with image-generating AI. Yet, this may change somewhat over time when one notices that very similar results often emerge that are related to the well-known biases.

3.2. Recognition of Biases

After several prompts, more than half of the participants tested if the software was biased, using prompts like "beautiful woman", "beauty", or "intelligent person" up to "myself" to see how the software would imagine the underlying concepts. Even without any guidance, the students were aware of eventual biases, which they also articulated. The biases were linked to social biases that persist: "Pretty women all look the same or what?", "So typical old white guys, why does it [the software] think I am one of them?" (a female student prompting "I" resulting in an image selection of mostly white men), "it is all very white" (a white female student after looking at her results with a prompt that used "woman" but did not specify the appearance). However, taken the specific nature of the sample, it is not clear if students typically would have detected such biases by themselves. Further, there are some biases they hardly noticed, e.g. the preference of the medium of photography over other forms of visual representation (mentioned by only one student), with typical image structures perceived as harmonious or artistic (regulated by the parameter "Stylize", mentioned by none).

Biases, e.g. the aforementioned racial biases or the preference of the so-called Western cultural context (Sterne 2000: 191, Turk 2023) have a long history in visual media: for a long time, films for analogue cameras were not good at representing dark skin tones, instead using "Shirley cards" with a Caucasian model as reference, and until today, face detection does not work as well with dark skin tones as with light tones (AIM Media House 2024). Even though, looking at their technical foundations, it is not surprising that image-generating AI continues such biases, it is important to recognize and circumvent them with appropriate prompts. By blindly accepting AI-generated images, biases would be replicated over and over again. However, it can be noticed that newer software versions, e.g. of Midjourney, map the biases somewhat lower, but they still exist.

3.3. Communication Training

If the initial enthusiasm gave way to the desire to present concrete things, most participants quickly reached their limits. All of them said that, to a significant extent, the images could not be implemented according to the idea. This was especially true for the images that were to be shown in a more professional context. Consequently, different strategies were used: some participants tried new formulations over and over again, others relied more on many iterations until an image came closer to the idea, sometimes stating "it [the AI] doesn't understand me", "we both [the AI and I] have issues" (smilingly).

The prompts were usually written according to the trial-and-error principle. Some participants suspected that this can promote endurance: "One prompts until something satisfying is created", "I will just go on until I like it and work on my patience". In fact, studies have shown that perseverance can be an important communicative skill and condition for creative work (Lucas & Nordgren 2015). Thus, it may not only be promising to teach prompting for success in fields related to image-generating AI, but also for more general soft skills such as learning to reframe ideas, present them differently to different audiences, and practice patience.

Related to this context, it is important to also consider students with special needs. It has been shown that such students also benefit from many kinds of AI (Yang et al. 2024) and it may be particularly interesting for students with dyslexia.

3.4. Openness

Several participants deliberately stated their actual image goal and said that the image provided by the AI did not correspond to what they had imagined but was still interesting: “This is not what I wanted, but why not change my goal, this one is nice,” “okay, interesting, I will follow this path now”. Accordingly, the image goal was occasionally modified or abandoned in favour of a completely new direction, which could be characterized as a “chance of serendipitous discovery” (Byrne 2023: 2). This suggests that openness, one of the “Big Five” personality traits, is being trained here as an important prerequisite for creativity (McCrae & Greenberg 2014: 222) but also for encounters with other people and mutual understanding.

On the other hand, one can also assume that the image-generating AI with its visually interesting results leads to deviating from actual goals. The participants confirmed both assumptions when thinking aloud – some got very distracted and especially in the first exercise lost sight of their initial goal and ended up just playing around. This indicates that there is a potential of image-generating AI to distract people from their actual goals, eventually leading to a scattered and even addictive behaviour.

However, it should be mentioned that for the participants, it has been their first encounter with image-generating AI, thus, it may be the appeal of the new and the fun in experimenting that made some of them getting a bit lost. Furthermore, the tendency to diverge from the actual goal was more obvious in the first exercise, which also allowed for more variation. On the other hand, taken into account the experimental situation and social desirability, the effect may be even stronger under real-life circumstances.

3.5. Importance of General Knowledge

As students of media- and/or society-related subjects, the students had quite a broad general knowledge with respect to visual looks, current trends, historical epochs etc. Thus, after few trials that did not match the participants’ expectations, most specified the look not only by mentioning e.g. the desired colours but also giving more detailed information: art styles such as “art déco” or “bauhaus”, but also names of specific artists like “da Vinci” and “Yayoi Kusama” were used as prompts. When it came to technical aspects they e.g. wrote “open aperture”, “crossed processed look”, “WB 2700”, or “candy filter”. All concluded that a good general knowledge on aesthetics may lead to more appropriate pictures, stating e.g. “you can get a good result by chance, but it works faster and more reliably if you know what you are doing” or, more specifically “now I know why it wasn’t a waste of time to study design history.”

Still, some instructions were not followed by the software, for example, instructions concerning the white balance did often not lead to the expected results. In some cases, the AI apparently could not put together concepts that felt too far apart, e.g. the attempt to develop a Bauhaus inspired sport via AI did not work out and just led to pictures of gyms in Bauhaus style. Yet, overall general knowledge proved to be very important to receive adequate images.

4. The Relationship between Words and Image

Working with AI image generation challenges the relationship between images and words. Despite the pictorial turn which gives more weight to images, learning, especially learning at university is still primarily associated with words. This was confirmed by the participants of the study, e.g. stating that “it is fun to finally work with pictures”. Visual mnemonics sometimes help, for example to link text elements with a visual map. Ultimately, however, it is words that are learned, remembered and used for analyses.

In the so-called Western cultural context, logos, understood not only as a science, but in its primary sense as a “word”, is usually seen as superior to the image: “Images only depict the world through passively receiving organs of perception, language, on the other hand, produces the world through actively formed concepts” (Geiger 2021: 24) or “’sensual impressions' as ultimately physically mediated stimuli are often subordinated to intellect-guided cognition” (Blank 2021: 96). Mitchell describes this as a distinction “between words and images [...], whereby the word is associated with law, literacy and elite rule, while the image is associated with popular superstition, ignorance and debauchery” (Mitchell 2009: 321).

At the same time, of course, it was noted that we live in an increasingly “visual age" (Bleiker 2018: 14) and “the relative importance of pictorial information is [even] steadily increasing” (Sarapik 2009: 277). In the meantime, images are being taken up more in many disciplines (e.g. Roeck 2003, Stolleis 2004, Heekeren 2021). However, the examination of the visual still takes place primarily in the medium of language and images are rarely allowed to speak for themselves. When pictures play a role, the order is usually: looking at a picture and then describing and analysing it with words.

With image-generating AI, the path is the other way around leading from words to images. Learning how to deal with words to evoke images plays a central role – so far quite similar to poetry, which is often used to create images in people’s heads. However, with image-generating artificial intelligence it is usually a much more technical approach. In this context, eloquence does not necessary means very elaborate and metaphoric language but a rather instructive use of language, especially if there are clear image goals. Precision on the one hand and empathy – trying to understand how the AI functions and eventually rephrase or deconstruct the original idea – on the other are central here.

In addition, the competence in dealing with image-generating AI also consists of a purely visual activity: judging and selecting images according to one’s goal, thus deciding on the ability of images to convey the desired messages respectively lead to the desired results. This includes aspects based on general visual studies, such as those outlined in *Gestalt* theory. However, in most cases, the socio-cultural background of the recipients plays a fundamental role, including something as simple as the reading direction from left to right or vice versa, which can be associated with different directional vectors, to more complex culture-specific habits and metaphors. Thus, capacities to assess images with regard to different presentations contexts, i.e. sociocultural groups, becomes a key qualification, a discipline that could be integrated into a *studium generale*.

Conclusion and Implications

Working with image-generating AI is a new learning experience that creates excitement and motivation, thus, is a good tool to integrate in classwork not only because it may be a key qualification in the future but also because it could facilitate learning. Further, it trains soft skills as it could provide a significant motivation for students to train differentiated and precise expressions, to formulate instructions clearly and/or to find work-arounds – abilities that may be useful in many occupational fields. It can also allow for the practice of patience, frustration tolerance, and openness to new experiences, thus, important soft skills. Unexpected results offered by the AI can lead students to discover new perspectives and thus broaden their horizon as well as practice their tolerance of dissonance, and even their interactive skills by learning to empathize and see things from different angles. However, “getting lost” in new, interesting perspectives could also distract them from their actual goal leaving them scattered, especially, if the exercises are quite open. Eventual addictive behaviours should be controlled in university environments; however, this aspect needs further research, especially longitudinal studies. Biases inherent in the software are often recognized by students familiar with social topics, however, it is important to point out to them and to teach how to circumvent them.

With regard to these biases, it becomes obvious that knowledge about social aspects plays an important role in image-generation with AI. In addition, a substantial level of general education is beneficial for the use of the software as appropriate descriptions are necessary for the prompts, as well as knowledge on the right look of something to select the right pictures. Further, knowledge on visual aspects and cultural contexts is key for successful image generation, i.e. conveying the intended meanings.

However, this knowledge does not have to be taught independently of image-generating AI. The connection between knowledge and good image results itself can create more motivation to accumulate more general knowledge. On the organizational level, this could lead to a reconsideration of curricula in a direction that promotes not only the continuously growing specialized knowledge but also stresses the study of general knowledge which can be combined with teaching image-generating AI. Some universities already offer optional or compulsory courses in “studium generale” which would be a good way to lead students to use image-generating AI as effective as possible.

The goal of image-generating AI is, unlike in most parts of university learning not referring to the use of words but to creating images. Thus, it resembles some artistic activities, but differs from others, as it works through language – language, however, is the tool, not the goal. This sets it apart from e.g. from the common use of ChatGPT in university contexts and this uncommon way alone may broaden the horizon and have the appeal of getting into something new

and innovative. It also seems like a second level visual turn that does not only acknowledge the importance of images but sees them as an ultimate goal – which makes it the more important to learn how to understand images. This, however, is not possible without regard to the sociocultural contexts and again emphasizes the importance of general studies.

In all this, the role of the author in the creation stays relatively vague (see Jerrentrup 2024: 818f.). Therefore, it may become a practice to publish prompts along with images so that the creative and conceptual potential of the pictures can be assessed. Still, this would create a weird way of setting AI-generated images apart from other (visually maybe very similar) images, as paintings or graphics often do not carry much more text than their title. Therefore, one of the most important aspects to be addressed in the future will be the question of authorship, credits, the relation between images created by respectively with the help of AI and other images, and ultimately a further exploration of the interplay between text and image.

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