International Studies in

EDUCATIONAL SCIENCES

June 2025

EDITOR
PROF. DR. DENİZ BESTE ÇEVİKKILIÇ

SERÜVEN YAYINEVİ

Genel Yayın Yönetmeni / Editor in Chief • Eda Altunel

Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi

Birinci Basım / First Edition • © Haziran 2025

ISBN • 978-625-5897-24-4

Serüven Yayınevi / Serüven Publishing
Türkiye Adres / Turkey Address: Kızılay Mah. Fevzi Çakmak 1. Sokak
Ümit Apt No: 22/A Çankaya/ANKARA
Telefon / Phone: 05437675765

web: www.seruvenyayinevi.com
e-mail: seruvenyayinevi@gmail.com

Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 42488

INTERNATIONAL STUDIES *in* EDUCATIONAL SCIENCES

EDITOR

PROF. DR. DENİZ BESTE ÇEVİKKILIÇ

SERÜVEN
YAYINEVİ

CONTENTS

Chapter 1

THE CULTURAL DANCE OF WORDS: THE TRANSFORMING VALUE OF LANGUAGE TEACHING IN THE AGE OF AI

Bora BAŞARAN[1]

1 Assoc. Prof. Dr., Anadolu University, Faculty of Education, Department of Foreign Language Education, bbasran@anadolu.edu.tr, Orcid: 0000-0003-0251-5895

INTRODUCTION

With the emergence of AI for language learning, the field has arrived at a turning point. AI systems—such as machine translation, intelligent tutoring systems, and generative language models—now support real-time linguistic interaction and increasingly precise automated communications. Students use these resources, allowing them to challenge traditional assumptions about languages as teachable domains, and the relevance of human-assisted instruction. From a technical perspective, AI is capable of simulating a lot of language description in the technical domains (i.e., grammar, vocabulary, pronunciation) albeit several dimensions of language (e.g. emotional, contextual nuance, cultural meaning) are not automatable.

This bifurcation defines language education in a space of both threat and opportunity. From one perspective, the ubiquitous availability of AI tools threatens the perceived utility of formal language learning (Muñoz-Basols et al., 2023; Cohen et al., 2024). From another, it provides language educators with a unique chance to learn to redefine their own pedagogical identities. Instead of being viewed as simply product deliverers, teachers can be viewed as cultural mediators, collaborative facilitators, and guides in the ethical utility of educational technologies (i.e., Tutton & Cohen, 2025). This change in pedagogy necessitates a deep engagement with the affordances and limitations of tools and a well-thought-out process for acquiring, adapting, and utilizing technology for pedagogical purposes—all without succumbing to the devaluation of humanistic principles.

Certainly, while AI tools— such as natural language processing systems and chatbots—offer some interesting advantages; they also create important ethical, psychosocial, and pedagogical issues (Tafazoli, 2023). Examples of issues that have been raised range from learner overreliance on technology (Li et al., 2024), to enduring algorithmic biases, and intrinsic emotional resonance complexity in AI based feedback (Thorne, 2024). To date, a few scholars have suggested theoretical frameworks (e.g., IMI+ model, Critical Ecological Approach) to guide ethical integration of AI into language classrooms (Muñoz-Basols et al., 2023).

In light of these important considerations, it appears that a dual-anchored approach is emerging, which seeks to:

1) maximize AI potential and minimize-lost opportunity costs, and

2) enhance the inseparable value of in-person teaching, which is characterized by interpersonal communication, critical thinking, and cultural immersion. (Tutton & Cohen, 2025).

AI-assisted technology can certainly offer space for repetitive practice and individualized feedback (Handley, 2024; Tafazoli, 2024) to free educators to rely on more complicated aspects of instruction, such as leading reflective discussion or advancing a critical cultural self-awareness perspective.

Now that we have addressed the dual dynamics of educators and AI, the final step in progressing forward is to design banal learning ecosystems with integrated AI which support engaged, intelligent personalization (Zhong, 2024). Learning systems that encourage personalization, through the delivery of content tailored to the unique profiles of learning approaches, will ultimately enhance a learner's comprehension and retention of the learning outcomes being attempted. The infusion of AI literacy into language programs also develops multi-dimensional global competencies that learners can employ in simultaneous linguistic, cultural, and technological arenas (Zhong, 2024).

Yet, with this promise for innovation comes a responsibility for vigilance. Over-use of AI has the potential to compromise the developmental benefits of human interaction, including the use of emotional scaffolding and internalized motivation (Gao, 2024). Sustained teacher education and professional development are critical. Educators need to be prepared to not only use AI tools, but also to evaluating their impact, to create hybrid approaches, and preserve pedagogical integrity in increasingly technologically mediated context (Tafazoli, 2024; Li et al., 2024).

An ideal way to move forward is to develop a pedagogy that employs AI to process computational possibilities but position language learning based on its potentially transformative humanistic qualities. Instructional frameworks such as flipped learning, collaborative human-AI forms of interaction, and opportunities for feedback loops based on reflection are promising directions (Xue, 2021; Li et al., 2024). However, language interactions will always be more than technological processes and unlike even the most sophisticated "intelligent" algorithms, will focus on culture, empathy, and individual relationships (Gao, 2024).

In conclusion, the future of language education will require a pedagogical perspective merging technological capabilities with humanistic thinking—neither rejecting nor idealizing AI—but anchoring it within a reflexively adaptive sense of purpose. By systematically balancing technological affordances with humanistic values, the field can find a new purpose for meaning making that will continue to be relevant in an increasingly transitioning AI landscape.

From Knowledge Delivery to Cultural Mediation

Today's language teachers continue to evolve from the widely held long-standing picture of their traditional role as the replicators of language knowledge, which is becoming increasingly outdated as it fails to respond to technological disruptive change and new pedagogical imperatives in language education. Today with the arrival of artificial intelligence (AI) and digital technology in language education, there are new ways of being a teacher, specifically teachers as cultural mediators, or as technology navigators (Gao, 2024; Thorne, 2024). This evolution represents more than an affectation of the profession, but a reconceptualization of - and hence accountability - including a reimagining of their own agency and the socio-emotional and intercultural dimensions of learner development, in reference to pedagogical responsibility.

Over time, AI will be able to perform many transactional language tasks such as machine translation, grammar correction etc., while also exposing the behavioural limits of AI, e.g., not being affective, contextual or cultural (Handley, 2024; Yuan et al., 2024). Although AI tools such as Duolingo can offer consistent feedback and uninterrupted repeat practice on structures, processes, and models, they cannot remediate and rehearse pedagogical competence, empathy and engagement that take place in meaningful language learning. Hence, the continued need for real human teachers remains, and is more critical than ever, particularly in culturally and linguistically diverse contexts as a mediating guide for the individual learner to navigate the interplay of language, identity and culture in language learning (Handley, 2024).

Language teachers are increasingly conceptualizing their role as of mediators of intercultural understanding, which necessitates more than the technical language competence needed to fulfil that role in the first place. Educators and teachers are responsible for developing learners' intercultural communicative competence, a commitment to negotiating representations of a range of cultural contexts and values, in between the layers of reflective and reflexive practice (Kohler, 2020; Scarino, 2021). Hence, this reframing of who a language teacher is, challenges teachers to consider aspects which are often rendered invisible when thinking about working in an intercultural space - subjectivity, affectivity, ideology, and our ethical accountability towards others - and to revisit and reconsider their professional sense of self (Kohler, 2020).

Other studies illustrate how this commitment to re-framing self as a language teacher can take shape through lived experiences in practice. For example, Vietnamese EFL teachers changed their conceptions of their professional selves through becoming technological-learners, and technological-interested teachers, in order to respond to digital demands (Tham, 2024). Tham's findings echo broader studies, where language educators experience the complexity of different and overlapping professional identities as they navigate the space of traditional linguistic, intercultural, and technological identities, against the backdrop of changing institutions and sociocultural contexts (Gong et al., 2021). Far from diminishing the role of teacher, the incorporation of AI technology will require professionals to bridge technology systems with humanised and culturally situated forms of education.

The demands resulting from this change indicate that teacher education courses need to grow beyond offering technology-infused literacy learning, and include intercultural sensibilities and interpretive pedagogies. Pre-service teacher education and in-service teacher education courses should seek to develop teachers who can engage critically with emerging technologies while being able to maintain the inherent humanistic purposes of language education (Yazan & Lindhal, 2022; Yuan & Wang, 2024). Teacher or continuing professional development opportunities must support teachers to harmonise their instrumental goals of efficiency, access, and scalability, with integrative goals around empathy, intercultural growth and learner identity (Yuan et al., 2024).

The increasing incorporation of AI in education raises serious concerns about the further marginalization of human teachers and the deepening of digital divides and inequities (Gao, 2024; Handley, 2024). For those unable to navigate or control tool, they may find themselves at a pedagogical disadvantage, and this would only further entrench systemic inequities. Even though generative AI might improve some functional aspects of learning a language, it cannot and therefore does not replace an educator's role in building human connection and rapport, modeling intercultural engagement, and facilitating quality learning experiences (Davin, 2024).

In conclusion, language teachers' roles in the era of AI will not be eclipsed, but repositioned in a more compex, cognitive and emotional landscape, where human experience meets algorithms, as they are required to address not only linguistic competencies but also cultural accounts and ethical navigation. The reason why language educators will always remain relevant to a humanized learning experience is precisely that they are uniquely positioned to humanize learning-and this will always separate them from any machine (even the smartest ones).

Embracing Depth: The Non-Replicable Dimensions of Language

Despite considerable progress in artificial intelligence (AI) and its integration into educational settings, significant restrictions persist in the ability of AI to fully understand the nuance of human language. While AI has achieved a significant degree of success in emulating syntactic and lexical patterns, it continues to falter in the areas of inexplicable, poetic, and emotional aspects of language (Zhao & Sun, 2024). Specifically, metaphor, idiomatic expression, irony, and expressions that are culturally embedded continue to be a challenge for algorithmic interpretation because of the absence of both embodiment and contextual reasoning (Skrynnikova, 2024). Accordingly, a limitation can afford a pedagogical opportunity; thus, an ongoing human-centeredness in language education continues to be important. Most recently, studies have illustrated that cultural incongruencies in AI arise out of the specificity of cultural training data and settings. In essence, biases in representation exist because the AI tools do not represent the diversity of the global cultural context (Prabhakaran et al., 2022). This structural limitation is harmful, leaving out the intricacy of nuance in language, but additionally limits inclusive and equitable language instruction relative to different sociocultural contexts.

This structural limitation is having pedagogical impacts. New pedagogical choices can be described as "depth approaches" in terms of language teaching, where emotional connection, aesthetics, and cultural ethnography, appear to be inseparable from human experiences and interpretation. Unlike AI, human educators can facilitate the aforementioned, and prioritize empathy, vary scaffolding, and be culturally responsive (Gao, 2024; Umar, 2024). In a depth approach, language learning reflects more than a transactional and instrumental process; it is a holistic flux of identity development, intercultural bridging, and personal artifacts.

AI tools (e.g. intelligent tutoring systems, real time feedback) can augment the language learning process, [in particular,] because they increase access, agency, continuity, and efficiency (Eswaran et al., 2024; Konyrova, 2024). However, it is important to conclude AI as augmenting, and not replacing pedagogic functions of human instructors. Good language education is more than functional knowledge; it is about relationships, reflection, and being connected emotionally, all of which are beyond the operational capacity of AI (Handley, 2024; Gao, 2024). With changes to importance of navigating the challenges of being human, we must now ask educators to build the critical, human capabilities of intercultural communicative competence, critical thinking, and ethical judgment (Gao, 2024; Kovalenko & Baranivska, 2024). These are critical only when learners must demonstrate the ability to use AI in a critical and responsible manner. Therefore, teacher training must be centered around AI literacy and prompt engineering analysis given pedagogic frameworks that are ultimately humanistic in tone and substance (Walter, 2024; Yuan & Wang, 2024).

At the same time, it is right to be careful. Implementing AI in language education raises ethical issues related to privacy of data, algorithmic bias, and the environmental impact of massive AI systems (Umar, 2024; Selwyn, 2024). Also, if we do not proactively consider also the infrastructures and digital skills needed, disparities in education could be exacerbated by the inequity of access to language education (Kovalenko & Baranivska, 2024). Researchers recommend a guided use and the development of critical AI awareness in order for the tools to work for educational rather than corporate or ideological purposes (Urlaub & Dessein, 2024). Ultimately, the future of language education will not lie in AI replacing human teachers; it will lie in a careful design of human-AI collaboration, where AI takes over mundane or easily attended to tasks and provides learners significant opportunities for practice. The person educator is the one who situates, humanizes, and transforms these experiences into a learning opportunity. The more ambiguous the boundaries of what AI can do become, the more important we also retain and preserve the unique aspects of language teaching: innovation, emotion, ethical considerations, and intercultural understanding (Zhao & Sun, 2024; Urlaub & Dessein, 2024). For at least the near future, these will be human advancements only.

Measuring What Matters: Empirical Insights into AI's Pedagogical Impact

As the theoretical acknowledgement of AI in education becomes more established, it will be research that will ultimately provide the evidence of AI's value in practice. As a major feature of language education, the incorporation of artificial intelligence (AI) has expanded the role of language teaching in ways that are truly transformational with respect to its function within education. It will be enough to look back and question what was left behind. The introductions of features such as personalized and formative feedback, adaptive testing, intelligent assessments and real-time multilingual support (Kamalov et al., 2023; Owan et al., 2023), are altogether disruptive enough to change many of the traditions of language teaching. Nevertheless, whilst these features have educational affordances, we should exercise caution in letting our anecdotal optimism be the primary determiner educational value of any AI product. Educational change is derived from research, not assumptions or speculation. Absent an appropriate evaluation of the enacted intervention, AI products might simply be disregarded as speculative or enhancement add-ons instead of an educational change.

Measuring Learning Outcomes

Empirical research has started to document the quantifiable improvements to language abilities that can be attributed to AI-based mechanisms. For example, these researchers reported in a controlled experiment with 400 subjects that the experimental group that used AI assessed technologies saw a 45% change in language ability as opposed to a 13% change in the control group which followed the traditional language learning paradigm (Alzahrani, 2024). In another study, automated writing evaluation systems and intelligent tutoring mechanisms have been useful in providing improvements in the variables of language acquisition that included writing, reading, vocabulary, grammar, speaking, and listening (Huang et al., n.d.). AI-enabled learning provides accelerated skill acquisition rates combined with new scalable assessments, which can be continually improved using an automated and algorithmic method.

Tracking Motivational Trends

In addition to its impact on academic performance indicators, the effect of AI on learner motivation and engagement is gaining scholarly notice. AI tools are reported to enhance learner autonomy and motivation, as a result of personalisation in instruction modalities and adaptive learning systems (Turdaliyevna, 2024). When instructors have positioned AI-supported interventions strategically into the curriculum, they have noticed students increase their participative behaviours and engagement, regardless of infrastructure limitations or hindrances associated with technologies (Mananay, 2024). There is significant evidence to suggest that AI can enhance intrinsic motivation, as long as it is consistent with a learner's preferences and pathway for learning.

Analyzing Classroom Dynamics

The influence of AI on classroom dynamics is a contested issue that warrants careful exploration, especially the tensions between ABET for a brave new world and the human side of teaching and learning. Efforts like AI Working Groups, and the use of AI and chatbot-assisted tools can contribute to responsible pedagogical use (Cohen et al., 2024). However, the success of any use of these tools will depend on the degree of teacher preparation to harness this potential, situating the AI tool within a program of prescribed curricular intent, and the necessity of continued development (Madjid, 2022; Kovalenko & Baranivska, 2024). Because of the nature of hybrid pedagogies it is the human educator who orchestrates AI-supported instruction in ways that allow for learner-centered, human interchange and engagement.

Challenges and Ethical Considerations

Despite its potential, the use of AI in language education is accompanied by a myriad of ethical, practical, and infrastructure considerations. Chief among those issues are concerns around data privacy, algorithmic bias, and the potential loss of human interaction in learning (Sangkala & Mardonovna, 2024). Further, the potential for job loss and the over-dependence on AI services creates a need for careful consideration, planning, and implementation of ethical AI (Kussin et al., n.d.). The successful integration of AI will depend on the infrastructure, equity of access, and alignment with institutional learning goals (Kovalenko & Baranivska, 2024). It is also worth noting that the increased popularity of AI-supported writing tools - divided into four functional groups, likely - has already changed how students are engaging with writing and literacy practices (Alharbi, 2023).

Toward a Balanced and Responsible Integration

While early research has shown how AI can support parts of personalized learning and learner satisfaction (Sharadgah & Sa'di, 2022), the research field emphasizes the need for transparent processes within the methods and critical analysis of these systems to validate results. The literature suggests a collaborative effort between educators, researchers, policymakers, and technology companies to develop guidelines to manage the changing space of AI (Owan et al. 2023). This responsible process must include an empirical validation of AI, pedagogical continuation, and clearly defined commitment to learner agency, inclusivity, and educators as professionals.

In conclusion, AI presents a significant opportunity for language education through scalable personalized, data-informed teaching and learning opportunities. However, the success of AI depends on transparent evaluation, ethical consideration, and pedagogical alignment. AI cannot achieve its full enactment before the relational and complex endeavor of language teaching will only be evident through contributions made from a responsible consideration, while the appeal of AI as a tool will be dimmed, ideally.

Modularity in Motion: Structuring Language Learning Through AI

The use of artificial intelligence (AI) in language education represents a paradigm shift from fixed, one-size-fits-all programs to modular, learner centered instructional practices. The flexibility inherent within AI systems allows for short, purposeful learning units that can focus solely on a discrete communicative function (professional interviews, academic essays, travel related needs, etc.). These modular features not only support achieving relevance in instruction (i.e, addressing a learner's immediate needs and personal learning objectives), and providing pedagogical soundness and coherence into an established curriculum (Singha et al., 2024; J. & Rajakumari, 2024).

AI supported, modular instruction caters to the tenets of both pedagogy and andragogy. AI is able to accommodate individual cognitive profiles, preferences, and learning pathways for an individual learner (Goh & Rahman, 2024) through intelligent tutoring systems, natural language processing applications, and conversational agents. In this manner, it is possible to deliver a highly personalized learning journey that accommodates supportive self-directed and continuous learning, while also providing the opportunity for real time personalized feedback (Eswaran et al., 2024; Zhong, 2024). These create a greater level of autonomy and control in educating continuous learning for language learners, while still facilitating more authentic interaction with linguistic resources and content.

When combined with AI's facility for customised feedback and adaptation, modular learning holds many beneficial promises for supporting and strengthening lifelong learning messaging for upskilling. AI-based platforms can allow educators the ability to design modular units that can focus on the building blocks of discrete communicative competencies. Units can easily be sequenced and/or modified to support learners' own professional or academic responsibilities, thus providing more relevance and flexibility (Jain, 2024). This element of flexibility is essential today, given the historically fast change of linguistic and occupational environment, and connectivity and demand for practical and transferrable language knowledge and skills.

There are also clear research benefits to using AI-enhanced language learning to achieve measurable learning outcomes. AI tools have shown significant increases in proficiency where there is evidence of up to a 40% increase in fluency and a 30% savings in time saved to reach communicative competence (Rehman, 2024). Platforms with technologies such as automated speech recognition, and adaptive writing, also provide several positive estimates where improvements have been shown in pronunciation, grammar and accuracy in writing (Turdaliyevna, 2024; Rusmiyanto et al., 2023).

Feedback and engagement by learners are also positively correlated to personalized engagement using AI technology that supports learner and communicative competence (Zhumatayeva et al., 2024; Polamuri et al., 2024). Intelligent tutoring systems and adaptive feedback contribute to ongoing motivated engagement in interactive learning contexts, which are very important for sustaining successful language acquisition and transfer learning across the language macro skills as suggested (Polamuri et al., 2024; Rusmiyanto et al., 2023). This emphasizes the potential for future AI based teaching and learning contexts to continue to adapt and create learner-based instructional ecosystems which are scalable and relevant to context.

Nonetheless, the incorporation of AI in language education provides its own issues. Ethical issues involving data protection, bias in AI algorithms and learner monitoring need to be addressed to ensure fair and responsible use of AI technologies, (Zhumatayeva et al., 2024; J. & Rajakumari, 2024). Further, technological structures, pedagogy, and teacher training practice also remain the most significant features important to its establishment (Mananay, 2024; Kovalenko & Baranivska, 2024). The significance of teacher agency and purposeful curriculum is essential to their full potential (Yang & Kyun, 2022).

In this regard, future research should demonstrate the long-term effects of AI on teaching and learning in real educational contexts, and how they assist the productive dialogue and intercultural communication, as well as deeper learning (Yang & Kyun, 2022; Rusmiyanto et al, 2023). As the field develops, understanding how to strike a balance between the modular learning capabilities of AI, and the insights human pedagogical practices can uniquely provide becomes vital. The relationship between AI and human pedagogical practice would not only enhance the efficiency of the instruction, however would also constitute a new redesigned pedagogy and cultivate an alignment toward a high level of individualized and responsive instruction that depicts a personalized learning colonization of today's learner.

Learner Autonomy Through AI-Supported Self-Regulation

The decentralization of language education through artificial intelligence (AI) tools signals the change of the learner's role in education. Instructional models that relied heavily on the instructor are changing to a model where the learner is assumed more and more responsibility for their own learning. AI tools facilitate this pedagogical shift when they provide learners with individualized, self-paced learning options, continuous opportunities for metacognitive reflection, and real-time monitoring (Goh & Rahman, 2024; Umar, 2024). However, the innovation of such tools cannot exist in isolation; they cannot be just fancy technology (Hattie, 2009). It is important to ultimately develop the cognitive and ethical capacity in the learner to independently and reflectively use AI tools.

Intelligent tutoring systems, chatbots and automated feedback systems are demonstrated to positively influence learner engagement and self-regulated learning (Mohebbi, 2024; Eswaran et al., 2024). AI systems provide not only immediate and individualized feedback but instruction that accommodates different learning preferences based on cognitive styles, which ultimately constrain the learners' retention and language proficiency (Umar, 2024). Many emerging tools – like virtual reality apps or AI-based grammar and writing assistants – have fundamentally improved the students' speech, writing and grammatical accuracy demonstrated in speaking (Mohebbi, 2024; Krishnan & Zaini, n.d.)

The evidence continues to show that AI-mediated language education supports learners' ability to improve language competency and one of the more qualitative aspects of learning, motivation and self-regulated learning (Wei, 2023). Students exposed to AI-supported instruction appear more engaged and deliver stronger outcomes in L2 acquisition and self-regulated learning skills compared to learners in traditional language educational paradigms (Wei, 2023). This movement toward education that is personalized, student-directed is a shift in not only how we think pedagogically but also a movement that displaces the boundaries of the classroom.

Nonetheless, where technology is introduced, a range of ethical and practical challenges emerge. We should be concerned about issues of data privacy, algorithm bias, and human interaction with AI as we make ethical decisions about scheduling (Sangkala & Mardonovna, 2024; Al-Aqlobi et al., 2024) and we also need to be concerned about access to tools. Considerations of access to AI are all the more pressing given the unequal technological realities of so many, and the introduction of learning technologies may exacerbate these inequities (Krishnan & Zaini, n.d.; Umar, 2024). Our challenges of addressing equity in education requires working together as educators, administrators, policy makers and developers to maintain ethical practice and protect the ethics of inclusion (Kristiawan et al., 2024).

Teaching with AI in language education demands more from us than deploying technologies. We need to have pedagogical frameworks in place to ensure that AI education promotes learner agency, critical thinking, and emotional intelligence in learners. Educators must actively engage with students using these tools to help create contexts where learners use AI tools not in place of human engagement but an addition to the educational ecology of engagement options (Danilina & Pichon–Vorstman, 2023; Mananay, 2024). One of the considerations we need to address is the need to promote AI literacy and prompt-engineering skills if we want learners to remain present to both the cognitive elements and the social potential of language learning (Walter, 2024; Umar, 2024).

Integrating AI tools into pedagogies centered in practice, learner autonomy and critical ethical awareness, language education can be a more accessible and empowering space. While AI tools might create dependence, they can also provide a scaffold for learners to take charge of their learning and develop skills that are related to metacognitive and intercultural fluency besides linguistic abilities (Danilina & Pichon–Vorstman, 2023).

To summarize, AI has the capacity to be transformative for language education not because it can automate instruction, but because it can support learners. However, this requires a rather nuanced approach to pedagogies which balances innovation and technology with integrity. The language education field must engage with AI tools with attention to cooperative learning, learner autonomy, and respect for students' agency in line with values of learner-centered education, if it is to achieve its full potential to improve language proficiency, and educational equity in a generalized and mediated world.

Conclusion: Beyond Translation, Toward Transformation

The use of artificial intelligence in language education involves much more than just technology; it represents an epistemological and pedagogical shift that makes the field rethink what it means to teach, what it means to learn, and therefore, what it means to communicate. This chapter has illustrated that although AI is able to offer unprecedented affordances in scalability, personalization, and timely feedback, valuable and irreplaceable human aspects will remain in language education. In advancing toward using AI technologies, it is possible to consider a rearticulation of what language teaching is fundamentally about: developing intercultural competence, ethical agency, critical thinking, and emotional alignment.

The main argument that emerges here is not an either-or relationship between human and machine, as much as a call for symbiotic recalibration. There is no debate that AI advances adaptive, modular instruction and learner autonomy; yet, these features alone cannot foster the kind of deep, reflective, and transformative learning that amount to what language education strives to be. Therefore, educators can no longer simply be instructors, but also must be cultural interpreters, ethical navigators, and builders of hybrid and humanized learning spaces. They must humanize the digital; they must humanize the empathy, context, and meaning of algorithmically generated outputs.

There is empirical support for the argument that in relation to instructional design, AI can act as a medium that contributes to improved language acquisition outcomes, fluency, and learner motivation when incorporated into intentional pedagogical design. These outcomes depend fundamentally on the continuing presence of a human mediator to interpret, adapt, and critically analyze the data-based scaffolding that AI provides. Ultimately, this makes the case for strong teacher education, and ongoing and ongoing improvement that provides developers not with just technical fluency, but also reflective engagement with what AI produces and provides as affordances and limitations.

The argument for "depth approaches"—pedagogies that acknowledge emotional, aesthetic, and cultural aspects—has also been critical in providing a counter-balance to AI's largely instrumental orientation. Depth approaches have, at the same time, drawn attention to the experiential and affective layers of language learning that cannot be easily digitized. In times when linguistic interaction can be driven by efficiency, we must also maintain the student and the teacher as the primary sources of for nuance, irony, ambiguity, and cultural significance.

In addition, the ethical issues related to integrating AI in education have considerable implications ranging from data privacy and algorithms to algorithmic bias, and issues of inequality in access globally, requiring close and case-sensitive solutions. Although it is difficult to predict the rapid proliferation of AI in various learning contexts, we may have to reconcile our limited purpose in delving into inequitable classrooms rather than resolution—for action against inequalities. Especially, we cannot assume that the use of AI in the space of language education will equate with democratizing our access to language education. The process of democratizing in equity conscious, inclusive, participatory, and critical ways, cannot abandon this purpose to robotic design automation.

In summary, reading these findings in relation to the broader context and future of language education means that we are advocating for consciously navigating the anticipated convergence for better language education, not assuming technological determinism. In expanding away from limiting narratives in language education, AI, through aspects of humanistic, reflective and critical and adaptive pedagogies will not replace language education in any traditional form, but elevate language education to better reflect the realities of the complex communication world we now live in through responsive, and more inclusive methods.

In the end, what makes language teaching valuable when AI is infused into our lives is its resistance to be reduced to functionality. Language is not just an instrument for transmitting information; it is also an instrument for identity, culture, and imagination. If education is to be a humanizing force, language teaching must continue to engage at the crossroads of words and worlds—where algorithms can be a guide, but where only humans can evaluate, relate, and transform.

REFERENCES

Abdullah Sharadgah, T., & Abdulatif Sa'di, R. (2022). A Systematic Review of Research on the Use of Artificial Intelligence in English Language Teaching and Learning (2015-2021): What are the Current Effects? Journal of Information Technology Education: Research, 21, 337–377. https://doi.org/10.28945/4999

Al-Aqlobi, O., Alduais, A., Alasmari, M., & Qasem, F. (2024). Artificial Intelligence in Language Acquisition: A Balancing Act of Potential and Challenges. Forum for Linguistic Studies, 6(6), 1103–1122. https://doi.org/10.30564/fls.v6i6.7524

Alharbi, W. (2023). AI in the Foreign Language Classroom: A Pedagogical Overview of Automated Writing Assistance Tools. Education Research International, 2023, 1–15. https://doi.org/10.1155/2023/4253331

Alzahrani, S. (2024). The Future of AI in Language Education. Advances in Educational Marketing, Administration, and Leadership Book Series, 309–332. https://doi.org/10.4018/979-8-3693-7016-2.ch015

Cohen, S., Mompelat, L., Mann, A. M., & Connors, L. J. (2024). The linguistic leap: Understanding, evaluating, and integrating AI in language education. Journal of Language Teaching, 4(2), 23–31. https://doi.org/10.54475/jlt.2024.012

Danilina, E., & Le Pichon–Vorstman, E. (2023). Embracing Advances in AI-Based Language Tools in EAP Programs (pp. 88–107). IGI Global. https://doi.org/10.4018/978-1-6684-8761-7.ch005

Davin, K. J. (2024). The issue: New technologies and language education. The Modern Language Journal, 108(2), 513–514. https://doi.org/10.1111/modl.12925

Eswaran, U., Eswaran, V., Murali, K., & Eswaran, V. (2024). AI-Powered Language Teaching and Learning. Advances in Educational Technologies and Instructional Design Book Series, 55–92. https://doi.org/10.4018/979-8-3693-4310-4.ch002

Gao, X. (2024). Language education in a brave new world: A dialectical imagination. The Modern Language Journal. https://doi.org/10.1111/modl.12930

Goh, Y., & Abdul Rahman, N. A. (2024). Personalized Language Learning With AI for Pedagogical and Andragogical Approaches. Advances in Educational Technologies and Instructional Design Book Series, 153–174. https://doi.org/10.4018/979-8-3693-6130-6.ch007

Gong, Y. F., Lai, C., & Gao, X. A. (2021). Language teachers' identity in teaching intercultural communicative competence. Language, Culture and Curriculum, 35(2), 134–150. https://doi.org/10.1080/07908318.2021.1954938

Handley, Z. (2024). Has artificial intelligence rendered language teaching obsolete? The Modern Language Journal. https://doi.org/10.1111/modl.12929

Huang, X., Zou, D., Cheng, G., Chen, X., & Xie, H. (n.d.). Trends, Research Issues and Applications of Artificial Intelligence in Language Education. https://doi.org/10.30191/ets.202301_26(1).0009

Jain, I. (2024). Modular Learning and the Role of Teachers in Its Execution. International Journal For Multidisciplinary Research. https://doi.org/10.36948/ijfmr.2024.v06i01.11923

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. Sustainability, 15(16), 12451. https://doi.org/10.3390/su151612451

Kohler, M. (2020). Intercultural language teaching and learning in classroom practice (pp. 413–426). Routledge. https://doi.org/10.4324/9781003036210-32

Konyrova, L. (2024). The Evolution of Language Learning: Exploring AI's Impact on Teaching English as a Second Language. 2(2), 133–138. https://doi.org/10.63034/esr-42

Kovalenko, I., & Baranivska, N. (2024). Integrating artificial intelligence in english language teaching: exploring the potential and challenges of ai tools in enhancing language learning outcomes and personalized education. 1, 86–95. https://doi.org/10.61345/2734-8873.2024.1.9

Krishnan, V., & Zaini, H. (n.d.). A Systematic Literature Review on Artificial Intelligence in English Language Education. https://doi.org/10.47772/ijriss.2025.903sedu0002

Kussin, H. J., Khalid, P. Z. M., Sulaiman, S., Sufi, M. K. A., & Chaniago, R. H. (n.d.). Systematic Literature Review: Integrating Artificial Intelligence (AI) in Teaching and Learning of Language. https://doi.org/10.37134/ajelp.vol11.1.8.2023

Li, F., Cao, Z., & Li, X. (2024). College Translation Teaching in the Era of Artificial Intelligence: Challenges and Solutions. Journal of Higher Education, Theory, and Practice. https://doi.org/10.33423/jhetp.v23i19.6704

Madjid, Abd. (2022). Towards a new era of language learning: predicting trends and challenges of ai integration in the future. TRANSFORMATIONAL LANGUAGE LITERATURE AND TECHNOLOGY OVERVIEW IN LEARNING (TRANSTOOL), 2(1), 1–9. https://doi.org/10.55047/transtool.v2i1.1369

Mananay, J. A. (2024). Integrating Artificial Intelligence (AI) in Language Teaching: Effectiveness, Challenges, and Strategies. International Journal of Learning, Teaching and Educational Research, 23(9), 361–382. https://doi.org/10.26803/ijlter.23.9.19

Mohebbi, A. (2024). Enabling learner independence and self-regulation in language education using AI tools: a systematic review. Cogent Education, 12(1). https://doi.org/10.1080/2331186x.2024.2433814

Muñoz-Basols, J., Neville, C., Lafford, B. A., & Godev, C. (2023). Potentialities of Applied Translation for Language Learning in the Era of Artificial Intelligence. Hispania, 106(2), 171–194. https://doi.org/10.1353/hpn.2023.a899427

Owan, V. J., Abang, K. B., Idika, D. O., Etta, E. O., & Bassey, B. A. (2023). Exploring the potential of artificial intelligence tools in educational measurement and assessment. Eurasia Journal of Mathematics, Science and Technology Education, 19(8), em2307. https://doi.org/10.29333/ejmste/13428

Polamuri, S. R., Manikyamba, I. L., & Viswanath, D. G. (2024). Artificial Intellıgence-Driven Frameworks For Fostering Active Participation And Learning In Language Classrooms. International Journal of Interpreting Enigma Engineers, 01(03), 23–32. https://doi.org/10.62674/ijiee.2024.v1i03.004

Prabhakaran, V., Qadri, R., & Hutchinson, B. C. (2022). Cultural Incongruencies in Artificial Intelligence. arXiv.Org, abs/2211.13069. https://doi.org/10.48550/arXiv.2211.13069

Rajakumari, R., & J., A. (2024). Harnessing AI: Enhancing English Language Teaching through Innovative Tools. 1–7. https://doi.org/10.1109/iceeict61591.2024.10718399

Rehman, S. U. (2024). Adaptive Learning Systems for Personalized Language Instruction in Transnational Higher Education. Advances in Educational Marketing, Administration, and Leadership Book Series, 165–190. https://doi.org/10.4018/979-8-3693-7016-2.ch008

Rusmiyanto, R., Huriati, N., Fitriani, N., Tyas, N. K., Rofi'i, A., & Sari, M. N. (2023). The Role Of Artificial Intelligence (AI) In Developing English Language Learner's Communication Skills. Journal on Education, 6(1), 750–757. https://doi.org/10.31004/joe.v6i1.2990

Sangkala, I., & Sulaymanova Mardonovna, N. (2024). Artificial intelligence as a personalized tutor in language learning: a systematic review. Klasikal: Journal of Education, Language Teaching and Science, 6(2), 565–576. https://doi.org/10.52208/klasikal.v6i2.1193

Scarino, A. (2021). Language teacher education in diversity – a consideration of the mediating role of languages and cultures in student learning. Language and Education, 36(2), 152–169. https://doi.org/10.1080/09500782.2021.1991370

Selwyn, N. (2024). On the Limits of Artificial Intelligence (AI) in Education. Nordisk Tidsskrift for Pedagogikk Og Kritikk, 10(1). https://doi.org/10.23865/ntpk.v10.6062

Singha, S., Singha, R., & Jasmine, E. (2024). Enhancing Language Teaching Materials Through Artificial Intelligence (pp. 22–42). IGI Global. https://doi.org/10.4018/979-8-3693-0872-1.ch002

Skrynnikova, I. (2024). Interpreting Metaphorical Language: A Challenge to Artificial Intelligence. Vestnik Volgogradskogo Gosudarstvennogo Universiteta. Seriâ 2. Âzykoznanie, 23(5), 99–107. https://doi.org/10.15688/jvolsu2.2024.5.8

Tafazoli, D. (2023). Critical Appraisal of Artificial Intelligence-Mediated

Communication (Version 2). arXiv. https://doi.org/10.48550/ARXIV.2305.11897

Tafazoli, D. (2024). Critical Appraisal of Artificial Intelligence-Mediated Communication in Language Education (pp. 62–79). Auerbach Publications. https://doi.org/10.1201/9781003473916-5

Tham, C. T. H. (2024). Vietnamese EFL Teacher Identity Reconstruction under the Pressure of Technological Integration. International Journal of Current Science Research and Review, 07(10). https://doi.org/10.47191/ijcsrr/v7-i10-29

Thorne, S. L. (2024). Generative artificial intelligence, co-evolution, and language education. The Modern Language Journal. https://doi.org/10.1111/modl.12932

Turdaliyevna, B. B. (2024). Using artificial intelligence technologies in language teaching. International Journal Of Literature And Languages, 4(11), 35–39. https://doi.org/10.37547/ijll/volume04issue11-08

Tutton, M., & Cohen, D. (2025). Reconceptualizing the Role of the University Language Teacher in Light of Generative AI. Education Sciences, 15(1), 56. https://doi.org/10.3390/educsci15010056

Umar, U. (2024). Advancements in English Language Teaching: Harnessing the Power of Artificial Intelligence. Foreign Language Instruction Probe, 3(1), 29–42. https://doi.org/10.54213/flip.v3i1.402

Urlaub, P., & Dessein, E. (2024). When Disruptive Innovations drive Educational Transformation: Literacy, Pocket Calculator, Google Translate, ChatGPT. An MIT Exploration of Generative AI. https://doi.org/10.21428/e4baedd9.cb55d9a3

Walter, Y. (2024). Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education. International Journal of Educational Technology in Higher Education, 21(1). https://doi.org/10.1186/s41239-024-00448-3

Wei, L. (2023). Artificial intelligence in language instruction: impact on English learning achievement, L2 motivation, and self-regulated learning. Frontiers in Psychology, 14. https://doi.org/10.3389/fpsyg.2023.1261955

Xue, J. (2021). On the Innovation of Foreign Language Teaching in the Era of Artificial Intelligence. 140–144. https://doi.org/10.1145/3461353.3461355

Yang, H., & Kyun, S. (2022). The current research trend of artificial intelligence in language learning: A systematic empirical literature review from an activity theory perspective. Australasian Journal of Educational Technology, 180–210. https://doi.org/10.14742/ajet.7492

Yazan, B., & Lindahl, K. (2022). An Identity Approach to Teacher Education. In The TESOL Encyclopedia of English Language Teaching (pp. 1–7). Wiley. https://doi.org/10.1002/9781118784235.eelt1030

Yuan, C., Zheng, X., & Li, G. (2024). English Classroom in the Era of Artificial Intelligence: The Transformation and Reshaping of Teachers' Role. Region - Educational Research and Reviews, 6(10), 64. https://doi.org/10.32629/

rerr.v6i10.2701

Yuan, R., & Wang, K. (2024). "Passing the Torch" to Language Teachers: A Transformative, Action-Oriented Perspective on Language Teacher Identity Research. Journal of Language Identity and Education, 1–7. https://doi.org/10.1080/15348458.2024.2391334

Zhao, W., & Sun, Y. (2024). The Exploration of Emotional Aspects of Artificial Intelligence (AI) in Artistic Design. International Journal of Interdisciplinary Studies in Social Science, 1(1), 58–65. https://doi.org/10.62309/bk757m16

Zhong, W. (2024). Adaptive System of English-Speaking Learning Based on Artificial Intelligence. Journal of Electrical Systems. https://doi.org/10.52783/jes.2637

Zhong, X. (2024). Changes and Innovations in Teaching Language Programs in the Age of AI. Frontiers in Humanities and Social Sciences, 4(11), 227–238. https://doi.org/10.54691/jkr9an37

Zhumatayeva, Z. N., Mametkarim, Zh. M., & Dosanova, A. M. (2024). The Role of Artificial Intelligence In The Formation of Communicative Competence in Foreign Language Lessons. The Bulletin, 412(6). https://Doi.Org/10.32014/2024.2518-1467.858

Chapter 2

EFFECTIVE INTEGRATION OF AUGMENTED REALITY APPLICATIONS IN CONSTRUCTIVIST LEARNING ENVIRONMENTS

Mehmet Can ŞAHİN[1]

1 Asst.Prof. Çukurova University, Faculty of Education, ORCID ID: 0000-0002-3687-600X

Introduction

The landscape of education is continually evolving, driven by technological advancements that offer novel ways to engage learners and foster deeper understanding. Among these innovations, Augmented Reality (AR) has emerged as a particularly promising technology, capable of overlaying digital information onto the physical world, thereby creating enriched, interactive experiences. AR's potential lies in its ability to bridge the gap between abstract concepts and tangible reality, making learning more contextualized and engaging (Badilla-Quintana et al., 2020; Duh & Klopfer, 2013; Fidan & Tuncel, 2019; Gómez-Galán et al., 2020; Wang et al., 2013; Zhao et al., 2020). Simultaneously, constructivist learning theories, which emphasize active knowledge construction by learners through experience and social interaction, continue to provide a robust pedagogical foundation for effective education. Constructivism posits that learners are not passive recipients of information but active participants who build their own understanding by interacting with their environment and peers (Lester et al., 1999).

Augmented Reality (AR) can be more specifically defined as a technology that enhances the real-world environment by superimposing computer-generated information, including visual, auditory, haptic, or olfactory content, in real-time (Azuma et al., 2001; Carmigniani & Furht, 2011). Unlike Virtual Reality (VR), which creates a completely immersive digital environment, AR maintains the real-world context while enhancing it with digital elements (Milgram & Kishino, 1994). AR technologies can be classified into several types, each with distinct educational implications: (1) Marker-based AR, which uses visual markers or QR codes to trigger digital content, offering structured learning experiences with precise content placement (Cheng & Tsai, 2013); (2) Markerless or location-based AR, which utilizes GPS, digital compasses, and other sensors to overlay content based on the user's location, facilitating contextual learning in authentic environments (Dunleavy & Dede, 2014); (3) Projection-based AR, which projects digital interfaces onto physical surfaces, enabling collaborative interaction with digital content (Bimber & Raskar, 2005); and (4) Superimposition-based AR, which partially or completely replaces the view of an object with an augmented view, particularly valuable for demonstrating transformations or internal structures in subjects like anatomy or engineering (Wu et al., 2013). Each of these AR types offers unique affordances for constructivist learning and may address different pedagogical challenges, requiring thoughtful selection based on specific educational objectives and contexts (Bower et al., 2014).

The integration of AR technology within constructivist learning environments presents a powerful synergy. AR applications can provide the very tools and contexts that facilitate constructivist principles, enabling students to explore, experiment, and collaborate in ways previously impossible. By offering situated learning experiences, facilitating hands-on interaction with virtual objects superimposed on the real world, and supporting collaborative problem-solving, AR aligns naturally with the core tenets of constructivism (Arici & Yilmaz, 2022; Castellano Brasero & Santacruz Valencia, 2018; Hsu & Liu, 2023; Lai et al., 2019). The significance of exploring this integration lies in its potential to transform educational practices, enhance student motivation and learning outcomes, and prepare learners for an increasingly technologically complex world. Understanding the factors that enable the *effective* integration of AR is therefore crucial for educators, instructional designers, and policymakers seeking to leverage this technology responsibly and productively.

Despite the recognized potential, the successful implementation of AR in constructivist settings is not automatic. It requires careful consideration of various pedagogical, technological, learner, and contextual factors. Challenges related to usability, cognitive load, teacher training, and equitable access must be addressed to fully realize AR's educational benefits (Christopoulos et al., 2021; Delello et al., 2015; Lai et al., 2019). This chapter aims to provide a comprehensive review of the key factors influencing the effective integration of AR applications within constructivist learning environments. By synthesizing theoretical perspectives and empirical findings, this chapter seeks to illuminate the conditions under which AR can best support active, meaningful, and learner-centered educational experiences.

To achieve this objective, the chapter is structured as follows: First, it delves into the theoretical framework underpinning the integration, discussing constructivism and relevant technology acceptance models. Second, it presents an extensive literature review, analyzing existing research to identify and elaborate on the critical factors influencing successful AR integration. Third, it discusses potential future directions for research and practice in this rapidly evolving field. Finally, the chapter concludes by summarizing the key findings and reiterating the significance of thoughtfully integrating AR into constructivist learning paradigms.

Theoretical Framework

The effective integration of Augmented Reality (AR) into educational settings, particularly those grounded in constructivist principles, necessitates a robust theoretical foundation. This framework draws upon established learning theories, primarily constructivism, and incorporates models of technology acceptance and cognitive processing to understand how AR can best facilitate meaningful learning experiences. Constructivism, as a guiding pedagogy, emphasizes that learners actively construct their own knowledge and understanding through interaction with their environment, prior knowledge, and social exchanges, rather than passively receiving information (Lester et al., 1999). This perspective aligns strongly with the potential of AR to create immersive, interactive, and contextually relevant learning scenarios that encourage exploration and discovery (Badilla-Quintana et al., 2020; Cabero-Almenara et al., 2019; Wibowo, 2023; Yilmaz, 2021; Zhao et al., 2020).

Central to constructivism is the idea of active learning, where students engage in hands-on activities, problem-solving, and critical thinking. AR technologies can directly support this by enabling learners to manipulate virtual objects, conduct simulated experiments, and explore complex systems in three dimensions, often overlaid onto their physical surroundings. This interaction fosters a deeper engagement and allows learners to build mental models through direct experience (López-García et al., 2019; Macauda, 2018; Moreno Martínez et al., 2017). Furthermore, constructivism highlights the importance of situated learning, where knowledge is acquired and applied within authentic contexts. AR excels in providing such contexts by augmenting real-world environments with relevant digital information, making learning more applicable and transferable to real-life situations (Abdelmagid, 2018; Wang et al., 2013; Zhao et al., 2020).

Beyond the core tenets of constructivism, understanding user acceptance and interaction with AR technology is crucial for effective integration. Models like the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) provide valuable frameworks. TAM posits that perceived usefulness (PU) and perceived ease of use (PEOU) are primary determinants of users' intention to adopt a technology (Ghobadi et al., 2022). In the context of AR in education, this means that both students and educators must perceive AR applications as beneficial to learning goals and relatively straightforward to operate. Factors such as technical quality, perceived immersion, and enjoyment also significantly influence attitudes and adoption intentions, extending the basic TAM framework for AR-specific contexts (Alsomali, 2023; Ghobadi et al., 2022; Lin & Yu, 2023). User characteristics, self-efficacy with AR, and even potential resistance or fatigue towards the technology also play roles in its adoption within learning ecologies (Alsomali, 2023; Delello et al., 2015).

Cognitive Load Theory (CLT) offers another critical lens, suggesting that instructional design should minimize extraneous cognitive load (mental effort not contributing to learning) to maximize cognitive resources available for germane load (effort related to schema construction) (Lai et al., 2019; Yang et al., 2021). While AR's interactivity and richness can enhance engagement, poorly designed applications might overwhelm learners with excessive information or complex interfaces, hindering rather than helping learning. Therefore, effective AR integration requires careful design that aligns with CLT principles, presenting information clearly, guiding user interaction effectively, and ensuring that the technology supports, rather than distracts from, the learning objectives (Lai et al., 2019; Yang et al., 2021). The interplay between AR's immersive potential and the need to manage cognitive load is a key consideration for designing constructivist AR learning experiences. By integrating principles from constructivism, technology acceptance models, and cognitive load theory, educators and designers can create AR-enhanced learning environments that are not only engaging and interactive but also pedagogically sound and cognitively supportive, ultimately fostering effective knowledge construction.

The integration of constructivism with technology acceptance models creates a comprehensive framework for understanding AR implementation in educational settings. These theoretical perspectives both complement and challenge each other in several ways. Constructivism and technology acceptance models share a focus on user-centered design, with constructivism emphasizing learner-centered educational experiences and TAM/UTAUT highlighting user perceptions and needs in technology adoption. Both frameworks also recognize the importance of contextual factors, acknowledging that learning and technology adoption occur within specific social and environmental contexts. However, these frameworks may create tension in implementation approaches. Constructivism advocates for open-ended, exploratory learning with minimal externally imposed structure, while technology acceptance models often emphasize ease of use and clear utility, which might suggest more structured, guided interactions with technology. Additionally, constructivism prioritizes deep, meaningful learning processes, whereas technology acceptance models focus more on measurable outcomes and utility. Understanding these complementary aspects and potential tensions is crucial for designing AR learning experiences that are both pedagogically sound and likely to be adopted by users. An integrated approach acknowledges that successful AR implementation requires both constructivist design principles for effective learning and attention to factors that influence technology acceptance for sustainable adoption.

Literature Review

The integration of Augmented Reality (AR) into constructivist learning environments holds significant promise, but its effectiveness hinges on a complex interplay of various factors. This review synthesizes existing research to identify and analyze the key pedagogical, technological, learner, and contextual factors that influence the successful implementation of AR in these settings. By examining empirical studies, meta-analyses, and theoretical discussions, we can gain a deeper understanding of how to optimize AR-enhanced constructivist learning.

Pedagogical Factors

Pedagogical considerations are paramount for ensuring that AR technology serves educational goals rather than becoming a mere novelty. A primary factor is the alignment of AR activities with constructivist principles. Effective integration requires that AR tools are used to support learner-centered activities, promote active knowledge construction, facilitate inquiry-based learning, and encourage collaboration (Aiello et al., 2012; Baharuddin et al., 2020; Hirumi, 2002; Lester et al., 1999; Wasko, 2013). Simply overlaying digital information onto the physical world is insufficient; the design must prompt students to interact, explore, question, and build understanding actively. Studies integrating AR into problem-based learning (PBL) in physics, for instance, have shown positive effects on learning achievement and attitudes when the AR component is designed to support the PBL process (Arici & Yilmaz, 2022; Fidan & Tuncel, 2019).

Instructional design strategies play a critical role. Designing effective AR learning experiences involves more than just selecting an AR application; it requires careful planning of tasks, scaffolding of learning, and integration with other classroom activities (Abdelmagid, 2018; López-García et al., 2019; Macauda, 2018). The 3P model (Presentation, Practice, Production) has been proposed as a framework for designing AR teaching proposals, emphasizing structured progression in learning (López-García et al., 2019). Similarly, integrating AR with inquiry models like the EIA (Engage, Investigate, Articulate) model can enhance scientific literacy by structuring the learning process (Yang et al., 2021). The design must consider how AR facilitates specific learning objectives, whether it's understanding complex spatial relationships in architecture (Hajirasouli & Banihashemi, 2022; Hendricks, 2022), visualizing abstract scientific concepts (Yilmaz, 2021), or engaging with historical artifacts in social sciences.

Teacher training and pedagogical support are frequently cited as crucial yet often overlooked factors (Alsomali, 2023; Cabero-Almenara et al., 2019; Lasica et al., 2022; Wasko, 2013). Educators need not only technical proficiency but also pedagogical knowledge on how to effectively integrate AR into their constructivist teaching practices. They require training on designing AR-based lessons, facilitating student inquiry, managing classroom logistics, and assessing learning within AR environments. Lack of adequate training can lead to superficial use of the technology or resistance to adoption. Studies highlight the importance of professional development programs that focus on both the technology and its pedagogical application to build teacher confidence and competence (Nikimaleki & Rahimi, 2022; Wasko, 2013).

Beyond initial training, teachers' ongoing experiences with AR implementation reveal complex challenges and professional development needs. Studies examining teachers' lived experiences highlight concerns about classroom management during AR activities, balancing technology facilitation with content instruction, and developing new assessment competencies for AR-enhanced learning (Nikimaleki & Rahimi, 2022). Teachers often report anxiety about technical failures during lessons and uncertainties about their changing role in technology-rich environments. Teachers may experience role shifts as they move from content providers to facilitators of AR-enabled learning. Effective professional development approaches include communities of practice, mentorship programs, action research opportunities, and gradual implementation strategies that build confidence over time. Teachers particularly value input into AR selection, reliable technical support, and peer collaboration opportunities. Comprehensive, ongoing professional development is essential for successful AR integration.

Technological Factors

The characteristics of the AR technology itself significantly impact its integration. AR affordances, such as interactivity, visualization capabilities, and the potential for immersion, are key technological factors (Ghobadi et al., 2022; Lin & Yu, 2023). The ability to manipulate 3D models, interact with virtual elements in a real-world context, and experience phenomena not otherwise accessible can greatly enhance engagement and understanding (Baharuddin et al., 2020; Fidan & Tuncel, 2019; Zhao et al., 2020). However, the effectiveness of these affordances depends on their purposeful implementation within the learning design. Meta-analyses suggest that AR generally has positive effects on learning outcomes in interactive environments, but the magnitude of the effect can vary depending on the specific application and context (Lin & Yu, 2023; Abdul

Hanid et al., 2020).

The technological maturity of AR applications represents a key consideration for educational integration. AR technologies exist along a developmental spectrum, from simple single-purpose applications to sophisticated platforms supporting multiple interaction modalities. Early-stage AR applications often focus on visualization of static 3D models, offering limited interactivity but relatively straightforward implementation. Mid-range applications typically incorporate interactive elements and basic feedback mechanisms, enabling more dynamic engagement with content. Advanced AR systems may feature adaptive content presentation, multi-user interaction, and integration with other educational technologies. Understanding this maturity spectrum helps educators select AR tools that match both their pedagogical goals and implementation capabilities, while recognizing that simpler applications can sometimes be more effective than complex ones if they align closely with specific learning objectives.

The hardware requirements for AR applications introduce another significant technological consideration. Mobile device-based AR offers accessibility advantages through familiar interfaces and widespread availability but may provide limited immersion and interaction capabilities. Headset or glasses-based AR provides more immersive experiences and hands-free interaction but typically involves higher costs and potential comfort issues during extended use. Projection-based systems enable shared AR experiences without requiring individual devices but are usually restricted to fixed locations. Each hardware approach creates different affordances for collaborative learning, mobility, and integration into existing classroom practices. The selection of appropriate hardware must balance educational aspirations with practical constraints related to budgets, technical support, and physical learning environments.

Interoperability and content creation tools form a third crucial technological dimension. AR systems vary considerably in their ability to work with existing educational content, connect with learning management systems, or share data with assessment platforms. Similarly, content creation tools range from specialized programming environments requiring technical expertise to user-friendly authoring platforms enabling teacher and student content development. AR platforms that provide accessible content creation tools and seamless integration with existing educational systems reduce implementation barriers and support constructivist approaches where learners become creators rather than just consumers of AR experiences. The evolution of these tools toward greater accessibility and interoperability represents a critical factor in the widespread adoption of AR in constructivist learning environments.

Usability and technical quality are critical determinants of user acceptance and effectiveness (Ghobadi et al., 2022; Lasica et al., 2022). AR applications that are difficult to use, prone to technical glitches, or have poor registration (misalignment between virtual objects and the real world) can frustrate users and increase extraneous cognitive load, hindering learning (Lai et al., 2019). Factors such as intuitive interface design, reliable tracking, realistic rendering, and seamless interaction are essential for a positive user experience (Alzahrani, 2020; Ghobadi et al., 2022). The technical quality, including the accuracy and relevance of the augmented information, directly impacts the perceived usefulness and credibility of the AR tool.

Accessibility and device compatibility also pose significant challenges (Alzahrani, 2020; Hajirasouli & Banihashemi, 2022). Effective integration requires that students and teachers have access to appropriate hardware (smartphones, tablets, or AR headsets) and reliable internet connectivity. Disparities in access can exacerbate equity issues. Furthermore, the proliferation of different platforms and operating systems necessitates consideration of cross-platform compatibility or the selection of applications that work reliably on the available devices within the specific educational context (Wang et al., 2013). The cost associated with hardware and software development or procurement can also be a barrier for many institutions.

Learner Factors

Learner characteristics and responses significantly mediate the effectiveness of AR integration. Student engagement, motivation, and attitudes towards AR are consistently highlighted as important factors (Baharuddin et al., 2020; Fidan & Tuncel, 2019; Ghobadi et al., 2022; Wen, 2021). AR's novelty and interactive nature often lead to increased initial engagement and motivation. Studies show AR can enhance cognitive engagement by supporting collaborative activities (Wen, 2021) and improve attitudes towards subjects perceived as difficult, like physics (Fidan & Tuncel, 2019). However, maintaining engagement beyond the novelty effect requires pedagogically sound design and meaningful tasks. Perceived enjoyment and immersion are key contributors to positive attitudes and sustained use (Ghobadi et al., 2022).

Cognitive load management remains a critical learner factor (Lai et al., 2019; Yang et al., 2021). While AR can facilitate understanding by visualizing complex information, it can also impose high cognitive demands if not designed carefully. Balancing the intrinsic load (complexity of the material), extraneous load (related to interface design and irrelevant information), and germane load (related to learning and schema construction) is essential. AR applications should present information clearly, guide attention effectively, and avoid overwhelming the learner with simultaneous stimuli (Lai et al., 2019; Yang et al., 2021). Integrating AR with structured inquiry models can help manage cognitive load while promoting deeper learning (Yang et al., 2021).

Students' digital literacy and prior experience with technology, including AR, can influence their ability to effectively use AR tools (Alsomali, 2023; Delello et al., 2015). Learners unfamiliar with AR interfaces may require more scaffolding and support initially. Conversely, students with high digital literacy may adapt more quickly and be better equipped to leverage AR features for learning. Furthermore, individual differences in spatial abilities or learning preferences might affect how students benefit from AR experiences. Addressing potential inequalities in digital skills and providing adequate support are necessary for equitable integration (Badilla-Quintana et al., 2020).

Contextual Factors

The specific learning environment and broader context also shape AR integration. The characteristics of the physical learning space—be it a traditional classroom, a science laboratory, a museum, or an outdoor field trip—influence the types of AR applications that are feasible and effective (Cabero-Almenara et al., 2019). Ubiquitous learning games using AR, for example, leverage the physical environment for exploration and problem-solving. The integration must consider the practicalities of using AR devices within the specific space, including network availability, lighting conditions, and safety.

Beyond these immediate practical concerns, the temporal dimension of learning contexts also significantly influences AR integration. Educational settings operate within specific timeframes—from individual lesson periods to academic calendars—that create natural constraints and opportunities for AR implementation. Short class periods may limit the feasibility of complex AR setups, while project-based learning blocks or laboratory sessions may provide more appropriate timeframes for immersive AR experiences. The rhythm of academic schedules also necessitates consideration of when AR is most pedagogically valuable—whether for introducing new concepts, reinforcing previously taught material, or synthesizing learning across topics. Strategic timing of AR integration within broader instructional sequences can maximize its cognitive impact while respecting the practical limitations of educational timetables.

The social ecology of learning environments constitutes another critical contextual layer. Classroom dynamics, established norms of interaction, and existing collaborative structures all shape how AR experiences unfold. AR activities that require students to move freely around a space may challenge traditional classroom management approaches, while those that isolate individual learners in personal AR experiences may disrupt established patterns of peer interaction. The most effective AR integrations acknowledge and leverage existing social dynamics, incorporating strategies that maintain positive group interactions, balance individual and collaborative engagement, and create opportunities for meaningful discourse around AR-mediated experiences. The degree to which an educational setting already embraces constructivist approaches also influences receptiveness to AR integration, as environments steeped in transmissionist pedagogy may require more fundamental shifts in teaching and learning culture.

Administrative and policy contexts further frame AR implementation possibilities. School or institutional policies regarding technology use, data privacy, equitable access, and assessment requirements create enabling or limiting conditions for AR adoption. Digital use policies may need updating to accommodate AR's unique characteristics, while assessment systems may require modification to recognize and value the types of learning that AR facilitates. Funding mechanisms and resource allocation procedures influence sustainability of AR initiatives, determining whether they remain isolated experiments or become embedded in institutional practice. Successful AR integration therefore requires not only classroom-level considerations but also attention to these broader administrative and policy contexts, often necessitating advocacy and leadership to create supportive institutional frameworks.

Additionally, subject-specific applications demonstrate how AR's potential can be realized across different disciplines. In STEM fields, AR is used for visualizing molecular structures, simulating physics experiments, or exploring anatomical models (Arici & Yilmaz, 2022; Fidan & Tuncel, 2019; Lasica et al., 2022; Yilmaz, 2021). In architecture and construction, it aids in understanding complex designs and construction processes (Ghobadi et al., 2022; Hajirasouli & Banihashemi, 2022; Hendricks, 2022). In arts and humanities, AR can bring historical artifacts to life or enhance the understanding of artistic elements (Baharuddin et al., 2020). The effectiveness often depends on how well the AR application aligns with the specific learning objectives and conceptual challenges within that subject area (Castellano Brasero & Santacruz Valencia, 2018; Hsu & Liu, 2023).

Finally, institutional support and infrastructure are crucial enabling factors (Ghani et al., 2023; Gómez-Galán et al., 2020). Successful, sustainable integration requires more than individual teacher efforts. It necessitates institutional commitment in terms of funding for technology and training, technical support, curriculum flexibility, and a broader vision for integrating innovative technologies into the learning ecology (Gómez-Galán et al., 2020). Ethical considerations, such as data privacy and the potential for unequal impacts on learning, also need institutional attention and clear policies (Christopoulos et al., 2021; Radu et al., 2021).

Synthesis and Gaps

The literature consistently points towards a multi-faceted approach for effective AR integration in constructivist learning. Success is not solely dependent on the technology itself but on its thoughtful alignment with pedagogical principles, user-friendly design, consideration of learner needs and characteristics, and supportive contextual factors (Alzahrani, 2020; Duh & Klopfer, 2013; Moreno Martínez et al., 2017; Zhang et al., 2021). While many studies report positive outcomes regarding engagement, motivation, and learning achievement, challenges related to teacher readiness, technical issues, cost, accessibility, and cognitive overload persist. A significant gap remains in longitudinal studies investigating the long-term impact of AR on deep learning and knowledge retention. More research is also needed on effective assessment strategies within AR environments and on ensuring equitable access and outcomes for all learners, including those with special educational needs (Badilla-Quintana et al., 2020). Further exploration into the specific design features of AR that best support different constructivist learning activities (e.g., collaboration, reflection, argumentation) is also warranted.

The synthesis of literature on AR in constructivist environments reveals a mutually reinforcing relationship between AR technology and constructivist pedagogy. AR's capacity for visualization, interaction, and contextual embedding naturally complements constructivism's emphasis on experiential learning, active engagement, and social meaning-making. This synergy creates educational experiences that are difficult to achieve through traditional means, particularly for abstract concepts requiring spatial understanding or phenomena otherwise inaccessible in classroom settings. The most successful implementations appear to be those where AR is thoughtfully integrated into broader pedagogical frameworks rather than employed as a standalone technological novelty.

A notable pattern across studies is the progression from technology-focused to pedagogy-focused research questions as the field matures. Early

AR education research primarily examined technological feasibility and immediate engagement effects, whereas recent work increasingly addresses deeper questions about knowledge construction processes, pedagogical design principles, and implementation frameworks. This evolution suggests the field is moving beyond proving AR's potential toward developing sophisticated models for effective integration, though significant gaps remain in understanding the specific mechanisms through which AR experiences facilitate constructivist learning processes.

Interestingly, the challenges identified in AR implementation mirror broader educational technology integration issues, suggesting that successful AR integration depends not only on addressing AR-specific concerns but also on resolving persistent systemic challenges in educational technology adoption. These include balancing teacher autonomy with technical support needs, addressing institutional constraints like assessment requirements and curricular alignment, and navigating the tension between innovation and sustainability. The parallels suggest that lessons from broader educational technology implementation research may prove valuable for developing effective AR integration frameworks, while AR-specific findings may contribute to advancing technology integration theory more generally.

Future Directions

While the integration of Augmented Reality (AR) in constructivist learning environments shows considerable promise, the field is still evolving, and several avenues for future research and development remain crucial for optimizing its potential and addressing existing challenges. Building upon the gaps identified in the literature, this section outlines key areas where further investigation is needed, encompassing longitudinal effects, methodological approaches, technological advancements, assessment strategies, and equity considerations.

One significant area for future research is the investigation of the long-term effects of AR integration on student learning outcomes, engagement, and knowledge retention (Alzahrani, 2020; Baharuddin et al., 2020; Abdul Hanid et al., 2020). Most existing studies focus on short-term interventions, often measuring immediate effects on motivation or performance on specific tasks. Longitudinal studies, tracking students over extended periods, are necessary to understand whether the benefits observed in short-term studies translate into deeper, lasting conceptual understanding and transferable skills. Such studies could also shed light on how the novelty effect of AR diminishes over time and what strategies are effective for maintaining engagement in the long run.

Methodologically, there is a need for more rigorous and diverse research designs. While quasi-experimental studies and case studies provide valuable insights, employing mixed-methods approaches that combine quantitative data (e.g., learning gains, usage logs, physiological measures of cognitive load) with qualitative data (e.g., interviews, observations, think-aloud protocols) can offer a more holistic understanding of the complex interactions within AR-enhanced constructivist environments (Christopoulos et al., 2021; Hirumi, 2002; López-García et al., 2019; Yang et al., 2021). Design-based research (DBR) is particularly well-suited for this field, allowing researchers to iteratively develop and refine AR interventions in authentic educational contexts while simultaneously contributing to theory.

Further research should delve deeper into the specific design features of AR applications and their differential impacts on learning processes and outcomes within a constructivist framework. For example, investigating how different levels of interactivity, types of feedback, or modes of collaboration afforded by AR influence cognitive load, student agency, and collaborative knowledge building is essential (Lai et al., 2019; Yang et al., 2021; Zhang et al., 2021). Understanding the optimal ways to design AR experiences for specific learning goals (e.g., conceptual change, spatial reasoning, procedural skills) and different subject domains requires continued exploration (Hendricks, 2022; Wang et al., 2013).

Developing robust and valid assessment methods tailored for AR-enhanced learning environments is another critical future direction. Traditional assessment methods may not fully capture the situated, process-oriented learning that occurs within constructivist AR activities. Future research should explore innovative assessment techniques, potentially leveraging learning analytics captured from AR interactions, performance-based assessments within the AR environment, or portfolio-based approaches that document the learning process (Christopoulos et al., 2021; Ghani et al., 2023). Establishing ethical frameworks for collecting and using learning analytics data from AR environments is also paramount (Christopoulos et al., 2021).

Assessment within AR-enhanced constructivist environments presents unique challenges and opportunities that require specialized approaches aligned with constructivist principles. Traditional assessment methods often focus on content retention and discrete skills, which may not adequately capture the complex, process-oriented learning that occurs in AR environments. Constructivist assessment approaches that could be effectively integrated with AR include authentic assessment, where learners demonstrate understanding through real-world tasks; portfolio assessment, documenting the evolution of learners' thinking and artifact creation over time; performance-based assessment, evaluating learners' abilities to apply knowledge in simulated scenarios; and peer and self-assessment, fostering metacognitive skills and collaborative evaluation. AR technologies can enhance these approaches by capturing real-time data on learner interactions, enabling process visualization through replay features, facilitating immediate feedback through embedded assessment triggers, and supporting collaborative assessment through shared AR experiences. Future research should explore how these assessment approaches can be seamlessly integrated into AR experiences without disrupting immersion or increasing cognitive load, and how the data generated through AR interactions can inform both formative and summative assessment practices while maintaining alignment with constructivist learning goals.

Addressing issues of equity and accessibility remains a persistent challenge and a vital area for future work. Research should investigate how AR integration impacts diverse learners, including students with special educational needs, those from different socioeconomic backgrounds, or those with varying levels of digital literacy (Alzahrani, 2020). Studies are needed to identify potential barriers and develop strategies to ensure equitable access to AR technology and effective pedagogical support for all students. Exploring the potential of AR to personalize learning pathways based on individual needs within a constructivist paradigm is a promising, yet under-explored, avenue.

Finally, future research must keep pace with rapid technological advancements. Emerging AR technologies, such as more sophisticated headsets, improved tracking and rendering capabilities, integration with artificial intelligence (AI) for adaptive feedback, and the development of collaborative multi-user AR environments, offer new possibilities for constructivist learning. Investigating the pedagogical potential and practical challenges of these emerging technologies will be crucial for guiding future integration efforts effectively and responsibly.

Practical Implications for Educational Practice

The theoretical framework and literature review presented in this chapter yield several practical implications for educators, instructional designers, and educational leaders seeking to implement AR in constructivist learning environments. These implications span pedagogical approaches, technological considerations, and institutional strategies.

For classroom educators, effective AR integration begins with clear pedagogical intentionality rather than technological novelty. Teachers should first identify specific learning challenges that might benefit from AR's unique affordances, such as concepts requiring spatial visualization, phenomena that are too small, large, dangerous, or expensive to experience directly, or historical contexts that benefit from immersive exploration. Once these learning needs are identified, a graduated implementation approach is recommended: beginning with simple AR applications that require minimal technical expertise before progressing to more complex implementations. Collaborative planning with colleagues, particularly those with complementary technical and pedagogical expertise, can support effective design and troubleshooting. Teachers should also consider developing "technological backup plans" to address potential technical failures and establish clear classroom management protocols for AR activities, including device handling, transition procedures, and collaboration structures.

For instructional designers and educational technologists, developing AR experiences that support constructivist learning requires careful attention to both technological and pedagogical design principles. AR interfaces should be intuitive, minimizing extraneous cognitive load through clear navigation, consistent interaction patterns, and focused content presentation. Supporting materials such as introductory tutorials, reference guides, and troubleshooting resources enhance user self-efficacy and reduce implementation barriers. Designers should also incorporate scaffolded learning supports within AR experiences, such as contextual hints, guiding questions, progress indicators, and reflection prompts that gradually fade as learner expertise develops. Co-design approaches involving educators and even students in the design process can ensure that AR applications address authentic learning needs and align with classroom realities.

For educational leaders and administrators, sustainable AR implementation requires strategic institutional support. This includes developing technology infrastructure plans that address connectivity, device access, and maintenance considerations, while establishing clear policies regarding data privacy, acceptable use, and equity of access. Financial planning should account for not only initial hardware and software costs but also ongoing technical support, professional development, and eventual replacement or upgrading. Professional development strategies should evolve beyond one-time workshops to include coaching models, peer mentoring systems, and dedicated time for teachers to collaborate on AR implementation. Leaders should also consider establishing "early adopter" programs that allow motivated educators to pilot AR implementations and serve as internal champions and resources for colleagues.

Across all stakeholder groups, evaluation of AR implementation should be ongoing and multifaceted, examining not only learning outcomes but also engagement, accessibility, technical performance, and sustainability. By thoughtfully addressing these practical considerations, educators can move beyond the novelty effect of AR to leverage its affordances for creating meaningful, constructivist learning experiences.

Conclusion

This chapter has explored the critical factors influencing the effective integration of Augmented Reality (AR) applications within constructivist learning environments. Grounded in constructivist theory, which emphasizes active knowledge construction through experience and interaction, and informed by models of technology acceptance and cognitive load, the review highlights that successful AR integration is a multifaceted endeavor extending far beyond mere technological deployment. The potential of AR to transform learning by providing immersive, interactive, and situated experiences is significant, offering powerful tools to enact constructivist pedagogical principles in novel ways.

The literature review synthesized findings across pedagogical, technological, learner, and contextual domains. Effective integration necessitates careful pedagogical design that aligns AR activities with constructivist goals, promotes inquiry, and is supported by adequate teacher training. Technologically, factors such as usability, technical quality, appropriate affordances, and accessibility are crucial for ensuring AR tools enhance rather than hinder learning. Learner characteristics, including engagement, motivation, cognitive load management, and digital literacy, significantly mediate the effectiveness of AR interventions. Finally, the specific learning context, subject matter, and institutional support structures play vital roles in enabling or constraining successful implementation.

While the research demonstrates considerable enthusiasm and positive outcomes associated with AR in constructivist settings, challenges related to design complexity, cognitive overload, teacher readiness, assessment, and equity persist. Future research must focus on longitudinal impacts, employ robust methodologies, refine design principles for specific features and contexts, develop appropriate assessment strategies, and actively address equity concerns. Keeping pace with technological advancements while maintaining a focus on sound pedagogy will be essential.

In conclusion, the effective integration of AR in constructivist learning environments offers a compelling pathway towards more engaging, authentic, and learner-centered education. However, realizing this potential requires a deliberate, theoretically informed, and context-sensitive approach. By carefully considering the interplay of pedagogical strategies, technological capabilities, learner needs, and contextual factors, educators, designers, and researchers can harness the power of AR to foster meaningful knowledge construction and prepare learners for the complexities of the 21st century.

References

Abdul Hanid, M.F Mohd. Nihra Haruzuan Mohamad Said , Noraffandy Yahaya (2020). Learning Strategies Using Augmented Reality Technology in Education: Meta-Analysis. Universal Journal of Educational Research, 8(5A), 51 - 56. https://doi.org/10.13189/ujer.2020.081908

Abdelmagid, M. (2018). The pedagogical potentials of integrating augmented reality: Revisiting Gagné ISD framework. *Advances in Social Sciences Research Journal, 5*(11). https://doi.org/10.14738/assrj.511.5455

Aiello, P., D'Elia, F., Di Tore, S., & Sibilio, M. (2012). A constructivist approach to virtual reality for experiential learning. *E-Learning and Digital Media, 9*(3), 317–324. https://doi.org/10.2304/elea.2012.9.3.317

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences, 10*(16), 5660. https://doi.org/10.3390/app10165660

Arici, F., & Yilmaz, M. (2022). An examination of the effectiveness of problem-based learning method supported by augmented reality in science education. *Journal of Computer Assisted Learning, 39*(2), 446–476. https://doi.org/10.1111/jcal.12752

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. IEEE Computer Graphics and Applications, 21(6), 34-47. https://doi.org/10.1109/38.963459

Badilla-Quintana, M. G., Sepulveda-Valenzuela, E., & Salazar Arias, M. (2020). Augmented reality as a sustainable technology to improve academic achievement in students with and without special educational needs. *Sustainability, 12*(19), 8116. https://doi.org/10.3390/su12198116

Baharuddin, N. B., Rosli, H., & Juhan, M. S. (2020). Constructivism learning environment by using augmented reality in art history course. *The International Journal of Academic Research in Business and Social Sciences, 10*(8), 13–25. https://doi.org/10.6007/ijarbss/v10-i8/7497

Bimber, O., & Raskar, R. (2005). Spatial augmented reality: Merging real and virtual worlds. A K Peters/CRC Press. https://doi.org/10.1201/b10624

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented reality in education – cases, places and potentials. Educational Media International, 51(1), 1-15. https://doi.org/10.1080/09523987.2014.889400

Cabero-Almenara, J., Barroso-Osuna, J., Llorente-Cejudo, C., & Fernández Martínez, M. M. (2019). Educational uses of augmented reality (AR): Experiences in educational science. *Sustainability, 11*(18), 4990. https://doi.org/10.3390/su11184990

Carmigniani, J., & Furht, B. (2011). Augmented reality: An overview. In B. Furht (Ed.), Handbook of augmented reality (pp. 3-46). Springer. https://doi.org/10.1007/978-1-4614-0064-6_1

Castellano Brasero, T., & Santacruz Valencia, L. P. (2018). Enseñapp: Aplicación educativa de realidad aumentada para el primer ciclo de educación primaria. *Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología, 21*(1). https://doi.org/10.24215/18509959.21.e01

Cheng, K.-H., & Tsai, C.-C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. Journal of Science Education and Technology, 22(4), 449-462. https://doi.org/10.1007/s10956-012-9405-9

Christopoulos, A., Mystakidis, S., Pellas, N., & Laakso, M.-J. (2021). ARLEAN: An augmented reality learning analytics ethical framework. *Computers, 10*(8), 92. https://doi.org/10.3390/computers10080092

Delello, J. A., McWhorter, R. R., & Camp, K. M. (2015). Using social media as a tool for learning: A multi-disciplinary study. International Journal on E-Learning, 14(2), 163-180.

Duh, H. B.-L., & Klopfer, E. (2013). Augmented reality learning: New learning paradigm in co-space *Computers & Education, 68*(1), 534–535. https://doi.org/10.1016/j.compedu.2013.07.030

Dunleavy, M., & Dede, C. (2014). Augmented reality teaching and learning. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), Handbook of research on educational communications and technology (pp. 735-745). Springer. https://doi.org/10.1007/978-1-4614-3185-5_59

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. Computers & Education, 142, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Ghani, E. K., Muhammad, K., Mohd Ali, M., Johari, R. J., & Sukmadilaga, C. (2023). Factors influencing effective smart learning environment in Malaysian universities. *Journal of Asian Scientific Research*. https://doi.org/10.55493/5003.v13i4.4953

Ghobadi, M., Shirowzhan, S., Ghiai, M. M., Mohammad Ebrahimzadeh, F., & Tahmasebinia, F. (2022). Augmented reality applications in education and examining key factors affecting the users' behaviors. *Education Sciences, 13*(1), 10–10. https://doi.org/10.3390/educsci13010010

Gómez-Galán, J., Vázquez-Cano, E., Luque de la Rosa, A., & López-Meneses, E. (2020). Socio-educational impact of augmented reality (AR) in sustainable learning ecologies: A semantic modeling approach. *Sustainability, 12*(21), 9116. https://doi.org/10.3390/su12219116

Hajirasouli, A., & Banihashemi, S. (2022). Augmented reality in architecture and construction education: State of the field and opportunities. *International Journal of Educational Technology in Higher Education, 19*(1), 1–28. https://doi.org/10.1186/s41239-022-00343-9

Hendricks, D. (2022). Applications of augmented reality as a blended learning tool for architectural education. https://doi.org/10.36615/sotls.v6i1.247

Hirumi, A. (2002). Student-centered, technology-rich learning environments (SCenTRLE): Operationalizing constructivist approaches to teaching and learning. Journal of Technology and Teacher Education, 10(4), 497-537.

Hsu, K.-C., & Liu, G.-Z. (2023). The construction of a theory-based augmented reality-featured context-aware ubiquitous learning facilitation framework for oral communication development. *Journal of Computer Assisted Learning, 39*(3), 883–898. https://doi.org/10.1111/jcal.12792

Lai, A.-F., Chen, C.-H., & Lee, G.-Y. (2019). An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory. *British Journal of Educational Technology, 50*(1), 232–247. https://doi.org/10.1111/bjet.12716

Lasica, I.-E., Meletiou-Mavrotheris, M., & Katzis, K. (2022). How to effectively integrate augmented reality in secondary education in the fields of STEM. *EDULEARN Proceedings*. https://doi.org/10.21125/edulearn.2022.2110

Lester, J. C., Stone, B. A., & Stelling, G. D. (1999). Lifelike pedagogical agents for mixed-initiative problem solving in constructivist learning environments. *User Modeling and User-Adapted Interaction, 9*(1), 1–44. https://doi.org/10.1023/a:1008374607830

Lin, Y., & Yu, Z. (2023). A meta-analysis of the effects of augmented reality technologies in interactive learning environments (2012–2022). *Computer Applications in Engineering Education, 31,* 1111–1131. https://doi.org/10.1002/cae.22628

López-García, A., Miralles-Martínez, P., & Maquilón, J. (2019). Design, application and effectiveness of an innovative augmented reality teaching proposal through 3P model. *Applied Sciences, 9*(24), 5426. https://doi.org/10.3390/app9245426

Macauda, A. (2018). Augmented reality environments for teaching innovation. *Research on Education and Media, 10*(2), 17–25. https://doi.org/10.1515/rem-2018-0011

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE Transactions on Information and Systems, 77(12), 1321-1329.

Moreno Martínez, N. M., Leiva Olivencia, J. J., & López Meneses, E. (2017). La realidad aumentada como tecnología emergente para la innovación educativa. https://doi.org/10.4025/notandum.44.11

Nikimaleki, M. R., & Rahimi, M. (2022). Effects of a collaborative AR-enhanced learning environment on learning gains and technology implementation beliefs: Evidence from a graduate teacher training course. *Journal of Computer Assisted Learning, 38*(3), 758–769. https://doi.org/10.1111/jcal.12646

Radu, I., Hv, V., & Schneider, B. (2021). Unequal impacts of augmented reality on learning and collaboration during robot programming with peers. https://doi.org/10.1145/3432944

Alsomali, S. I. (2023). Exploring academics' perspectives related to the adoption of augmented reality applications within an e-learning environment in higher education institutions: The role of AR self-efficacy, innovation resistance, perceived AR fatigue and technology involve. https://doi.

org/10.33422/icmetl.v1i1.40

Wang, Y., Vincenti, G., Braman, J., & Dudley, A. (2013). The ARICE framework: Augmented reality in computing education. *International Journal of Emerging Technologies in Learning (iJET), 8*(6), 27–34. https://doi.org/10.3991/ijet.v8i6.2809

Wasko, C. (2013). What teachers need to know about augmented reality enhanced learning environments. *TechTrends, 57*(4), 17–21. https://doi.org/10.1007/s11528-013-0672-y

Wen, Y. (2021). Augmented reality enhanced cognitive engagement: Designing classroom-based collaborative learning activities for young language learners. *Educational Technology Research and Development, 69*(2), 843–860. https://doi.org/10.1007/s11423-020-09893-z

Wibowo, F. C. (2023). Effects of augmented reality integration (ARI) based model physics independent learning (MPIL) for facilitating 21st-century skills (21-CS). *Journal of Technology and Science Education, 13*(1), 178–178. https://doi.org/10.3926/jotse.1800

Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). Current status, opportunities and challenges of augmented reality in education. Computers & Education, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

Yang, Y., Cai, S., Wen, Y., Li, J., & Jiao, X. (2021). AR learning environment integrated with EIA inquiry model: Enhancing scientific literacy and reducing cognitive load of students. *Sustainability, 13*(22), 12787. https://doi.org/10.3390/su132212787

Yilmaz, O. (2021). Augmented reality in science education: An application in higher education. *Education 3-13, 9*(3), 136–148. https://doi.org/10.34293/education.v9i3.3907

Zhang, Z., Li, Z., Han, M., Su, Z., Li, W., Pan, Z., & Pan, Z. (2021). An augmented reality-based multimedia environment for experimental education. *Multimedia Tools and Applications, 80*(1), 575–590. https://doi.org/10.1007/s11042-020-09684-x

Zhao, X., Li, X., Wang, J., & Shi, C. (2020). Augmented reality (AR) learning application based on the perspective of situational learning: High efficiency study of combination of virtual and real. *Psychology, 11*(9), 1340–1348. https://doi.org/10.4236/psych.2020.119086

Chapter 3

EXAMINING THE ROLE OF CHATGPT IN SCIENCE AND CHEMISTRY EDUCATION RESEARCH

Doğan DOĞAN[1]

1 Assistant Professor, Bolu Abant İzzet Baysal University, Department of Mathematics and Science Education, ORCID 0000-0001-7889-329X, ddogan@ibu.edu.tr

INTRODUCTION

In recent years, the impact of Artificial Intelligence (AI) has been increasingly felt in science and chemistry education as well as in various other fields (Adeyele & Ramnarain, 2024; Chen & Chang, 2024; Feldman-Maggor et al., 2025; Park & Martin, 2024). AI is expected to play an important role in shaping the future especially with the introduction of large language models (LLMs) such as ChatGPT (Karakose, 2023). Its first version was built on the GPT-3.5 platform. It is an AI-powered chatbot that communicates with humans through natural language processing. It has been trained on a large amount of textual data to respond to queries spanning different domains in a conversational manner (Ameen et al., 2024). As a result, new models have emerged in a short period of time, such as GPT-4, GPT-4o, GPT-4.1 and GPT-4.5, which offer more advanced features (Mburu et al., 2025). The speed at which this technology has emerged has attracted the attention of researchers around the world, and debates about its use and implications in education have started in the research community (Bhullar et al., 2024). Understanding these impacts particularly on science and chemistry education research is essential to assist educators, researchers, and curriculum developers. In this regard, a systematic analysis is needed on the available literature regarding the application of ChatGPT in science and chemistry education.

It has been asserted that the integration of ChatGPT models into educational settings has the capacity to reshape learning, teaching and assessment processes (Salih et al., 2025). This is because ChatGPT have the capacity to mimic human intelligence and produce new outputs such as text and visuals on user prompts (Alabidi et al., 2023; Cooper, 2023). Therefore, it is emphasized that ChatGPT can facilitate the creation of comprehensive educational contexts, increase active student involvement, and provide individualized learning experiences in science and chemistry education. It can provide immediate feedback, generate accessible explanations and offer structured learning through step-by-step guidance (Liang et al., 2023; T.-T. Wu et al., 2025). This property makes it a useful and engaging tool for both students and teachers. It has also been argued that ChatGPT can be used as a virtual teaching assistant, promoting student success by helping them solve complex problems (Jang & Choi, 2025; Pawlak, 2024).

The integration of ChatGPT is particularly important for science and chemistry education which requires critical thinking, problem solving and managing complex information (Dewi et al., 2024; García-Carmona, 2025; Misbah et al., 2022; Stephenson & Sadler-McKnight, 2016). Some studies have shown that while ChatGPT offers some opportunities for individual and student-centered teaching, integrating ChatGPT in science and chemistry education is not without challenges (Choi, 2025; Clark, 2023; Dindorf et al., 2024). For example, in science education ChatGPT has been found to be effective in providing personalized feedback to students, helping them identify their strengths and weaknesses, adapting teaching methods for teachers, designing lesson plans and measurement and evaluation processes (Cooper, 2023; Peikos & Stavrou, 2025). In chemistry education it was found to be effective in helping students solve complex chemistry problems, design experiments and develop computational thinking (Ameen et al., 2024; Sallam et al., 2024; Scoggin & Smith, 2023). However, the quality, accuracy and reliability of the content generated by ChatGPT is a concern. Moreover, there is concern of over reliance of students on AI tools and AI increasing inequalities in education and reducing teacher influence if not managed properly (Ishmuradova et al., 2025; Jang & Choi, 2025). A systematic synthesis of these and similar studies in science and chemistry education will provide valuable information to educators, curriculum developers and policy makers by giving an update. Secondly this review will highlight the gaps in existing research and guide future research. Finally understanding teachers and students' perspectives on AI integration is crucial in tailoring teacher education degree programs and in-service training initiatives. This will ensure that prospective and current teachers are equipped with AI literacy and pedagogical content knowledge to manage this emerging situation.

When the available literature was assessed, two studies were found, one in the form of a review article and the other in the form of a conference paper, synthesizing research on the utlization of ChatGPT in science and chemistry education. Park and Martin (2024) systematically examined the studies on the applications of ChatGPT in science education between January and September 2023. They stated that there were mainly studies on chemistry and physics education in Europe and USA, that although ChatGPT was successful in writing tasks, it was insufficient in understanding scientific concepts, that this situation could be turned into an opportunity to develop critical thinking, that ethical rules should be determined and awareness should be raised, that positive attitudes can increase cooperation during the learning process, and that learners' gaining the ability to create effective prompts will enable them to make the most of ChatGPT. Cheung et al. (2025) systematically examined the studies in which AI technologies were applied in science education by using the family resemblance approach. They emphasized that AI technologies are increasingly used in science education at the K-12 level, but a framework for students' understanding of the epistemic connection between AI and science in the generation, evaluation and critique of scientific knowledge is lacking, and a systematic review revealed that few studies have assessed this relationship. Given the complex set of difficulties arising from the integration of ChatGPT into science and chemistry education, there is an urgent need for a comprehensive understanding of its current applications, potentials and limitations. Although the above literature review studies have investigated various aspects of this integration, a systematic and holistic synthesis of these findings is lacking. Therefore, the purpose of this study is to comprehensively analyze and synthesize the existing academic literature available in the Web of Science (WoS) database on the use of ChatGPT in science and chemistry education. WoS is selected because it is recognized as a leading scientometric database that indexes high-quality journals in the fields of science and chemistry education. To this end, the following research questions were identified:

RQ1. How are the reviewed papers distributed across different WoS indexes according to their year of publication?

RQ2. How are the reviewed papers distributed according to the journals?

RQ3. How are the reviewed papers distributed according to the countries?

RQ4. How are the reviewed papers distributed according to their research designs?

RQ5. What types of instruments were used for data collection in the reviewed papers?

RQ6. What conclusions can be drawn from a comparison of the objectives and key findings of the reviewed papers?

METHOD

Systematic literature review is a robust research method based on a planned, detailed and transparent review of existing literature within a particular field of inquiry (Adeyele & Ramnarain, 2024; Chen & Chang, 2024; Park & Martin, 2024). Unlike the traditional reviews, this method aims to minimize researchers bias based on well-defined inclusion and exclusion criteria and ensure replicability (Paul et al., 2021; P. Wang et al., 2025). To guide the review process in this study, the updated PRISMA approach, which is frequently used in systematic review studies, was adopted (Page et al., 2021). PRISMA is a widely recognized reporting protocol that provides a standardized approach to identifying, screening and synthesizing research studies (Moher et al., 2015). By employing this approach, the present study aims to provide a comprehensive and methodologically sound answer to the selected research questions. The PRISMA flow diagram of the study is illustrated in Figure 1.

Identification and Selection of Relevant Literature

The search strategy utilized in this study included all articles available through 24 May 2025 to ensure the use of recent references and current information. The WoS database was used for this systematic review due to its widely recognized credibility and multidisciplinary nature within the global research community (Birkle et al., 2020; Pranckutė, 2021). To this end, an advanced WoS search was carried out using the query TS= ((("ChatGPT" and "chem*") OR ("ChatGPT" and "science")) AND ((educ* OR Teach* OR Learn* OR instruc*))). The topic heading (TS) was particularly chosen to obtain the most relevant articles, as it includes the title, abstract, keyword plus, and author keywords fields. As a results, the search yielded a total of 667 documents covering the period from 1970 to 24 May 2025. Since this study is focused solely on full-text articles related to ChatGPT use in science education or chemistry education, applying the "Article" filter under the Document Type tab and removing Early Access entries resulted in 382 relevant articles. Since the categories 'Education Scientific Disciplines' and 'Education Educational Research' were considered the most relevant to science education or chemistry education within the WoS categories, the dataset was further refined by category, resulting 91 records. After excluding non-English records, 88 articles remained. These 88 articles were then rigorously screened by the author and another expert in science education to assess their suitability for inclusion in the study. Upon reviewing the full texts, it was found that 60 articles were related to fields other than science education or chemistry education, such as medical education, statistics and data science education, technology education, and engineering education. Therefore, these articles were removed from the dataset, leaving only 28 relevant articles. These articles were then subjected to systematic data analysis procedure.

Data Analysis

After the inclusion and exclusion standards were applied during the article selection process, the final dataset consisting of 28 articles retrieved from the WoS database was stored as full text PDF files on the computer hard disk. Then, for the systematic analysis of these articles, a comprehensive Excel spreadsheet was developed. This spreadsheet included several key columns related to the bibliographic and methodological characteristics of each study. For the bibliographic information, columns such as WoS index, author names, journal names and country names were established to provide an overview of each study. In addition to these descriptive elements, columns such as research objectives, research designs, instruments, and key findings were also established for a detailed comparison and synthesis of the selected studies. The full texts of all 28 articles were thoroughly reviewed, and the spreadsheet was populated accordingly by the author and another expert simultaneously. This final dataset in the Excel file was used to generate visual representations, including tables and graphs in the following section.

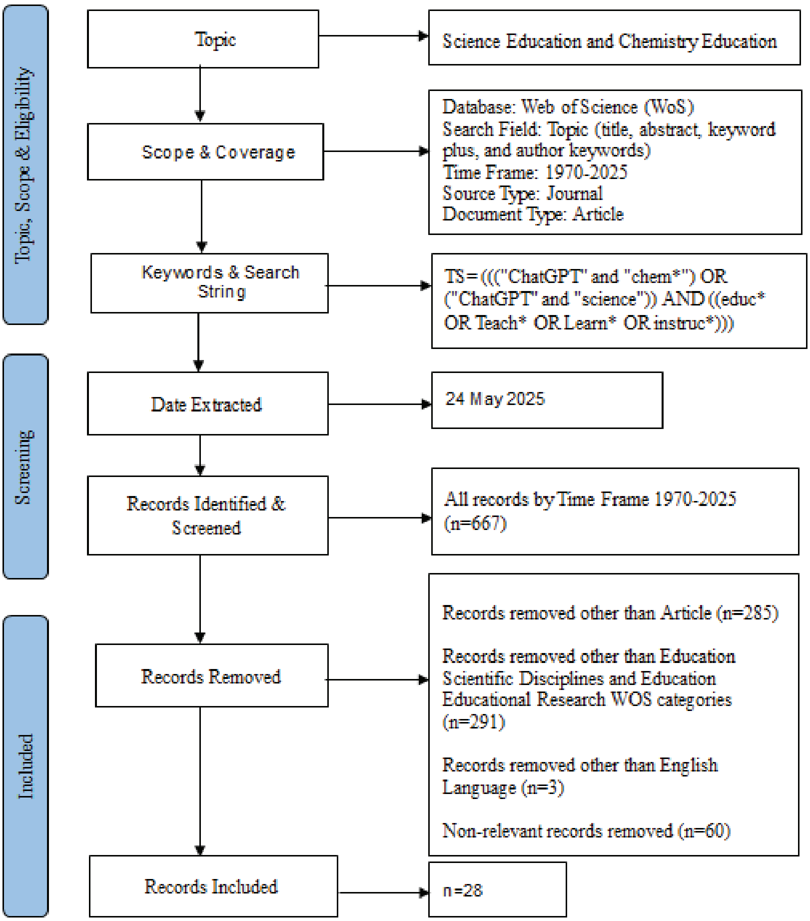

Figure 1. The PRISMA flow diagram of the study

RESULTS AND DISCUSSION

This section addresses six research questions concerning the use of ChatGPT in science and chemistry education. The first research question explores the distribution of the reviewed articles across different WoS indexes according to their year of publication. Table 1 presents details about the publication trends and indexing status of the 28 reviewed articles.

As shown in Table 1, most of the studies were published between 2023 and 2025. Specifically, half of the reviewed articles (50%) were published in 2024, followed by 8 articles (28.6%) in 2025 and 6 articles (21.4%) in 2023. This concentration of recent publications highlights growing interest in the use of ChatGPT within science and chemistry education, indicating that it is a rapidly evolving and contemporary research area. This finding aligns with the analysis by Feldman-Maggor et al. (2025) and Festiyed et al. (2024). Furthermore, the indexing of the reviewed articles across different WoS categories provides valuable insights into their visibility and disciplinary orientation. The ESCI accounts for the largest share, with 13 articles (46.4%), suggesting a significant body of new research emerging from a wide range of journals. The SSCI accounts for 9 articles (32.2%), highlighting the strong presence of educational and social science perspectives. The remaining 6 articles (21.4%) are indexed in both SCI-Expanded and SSCI, suggesting an interdisciplinary nature of some studies. These findings suggest a concentration of relevant research in ESCI-indexed journals, with a notable peak in output during 2024. However, a comparative analysis across publication years could not be performed due to the lack of similar studies, based on the available literature.

Table 1 Publication Year and WoS Index of The Reviewed Articles

WoS Index	*Publication year*			*N*	*%*
	2023	2024	2025		
ESCI	3	7	3	13	46.4
SSCI	-	6	3	9	32.2
SCI-Expanded ve SSCI	3	1	2	6	21.4
N (%)	6 (21.4)	14 (50)	8 (28.6)	28	100

The second research question investigates the distribution of the reviewed articles across the journals in which they were published.

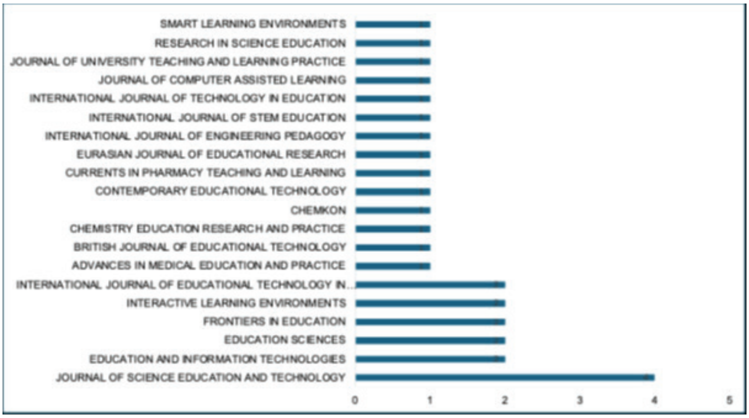

Figure 2. Distribution of reviewed articles according to the journals.

The Figure 2 indicates that the reviewed articles were published in a diverse range of journals. The most prominent journal, having published the highest number of reviewed articles, is the "Journal of Science Education and Technology," with four articles. Following this, a small group of journals published two articles. Additionally, a significant number of other journals each published one article. Overall, the distribution of reviewed articles across a wide spectrum of journals, as presented in Figure 2, highlights the interdisciplinary nature of the research on ChatGPT use in science and chemistry education.

The third research question examines the distribution of the reviewed articles According to their countries

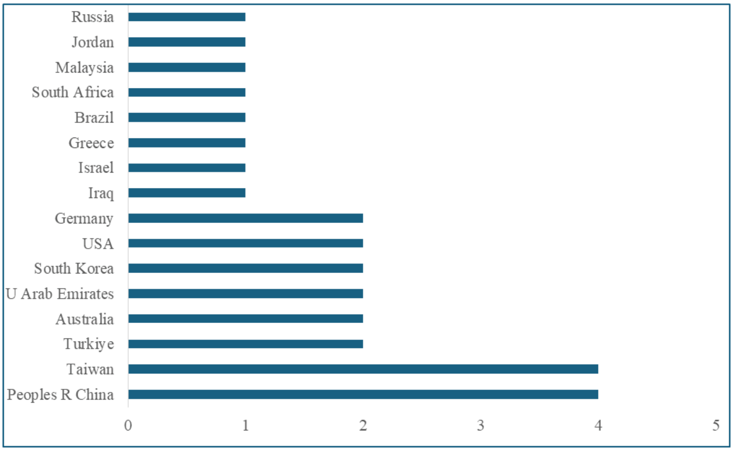

Figure 3. Distribution of reviewed articles according to their countries

According to Figure 3, China and Taiwan are the leading countries in terms of number of publications, each contributing four articles to the reviewed literature. This suggests that both China and Taiwan play an active role in ChatGPT-related research, especially in the fields of science and chemistry education. However, this finding contrasts with the those of Fonseca (2024) who reported that the United States has the highest percentage of publications, and Park and Martin (2024), who found that studies exploring ChatGPT in chemistry and physics education are predominantly concentrated in Europe and the U.S. This inconsistency with the findings of our study may be due to the differences in the publication selection criteria employed by the researchers. Following the two top contributing countries, Turkiye, Australia, United Arab Emirates, South Korea, the United States, and Germany each contributed two articles, indicating a moderate level of contribution in our study. Additionally, eight other countries including Iraq, Israel, Greece, Brazil, South Africa, Malaysia, Jordan, and Russia, each contributed only one article to the reviewed literature. These findings, together with the findings from Figure 2, highlight the international relevance of the topic and its recognition by researchers from diverse geographical regions. Nevertheless, considering the low number of published studies, it is reasonable to expect that this situation may change in the future

The fourth research question explores the distribution of the reviewed articles according to their research designs. Figure 4 indicates that the qualitative research designs are the most prevalent, with 16 articles falling into this category. In contrast, both quantitative and mixed-methods research designs are equally represented, each with six articles. While quantitative studies primarily focus on numerical data and statistical analysis, mixed-method studies integrate both qualitative and quantitative elements. That the combined number of quantitative and mixed-method studies (12) is still lower than qualitative studies alone highlight the dominant role of qualitative methodologies in this set of reviewed articles.

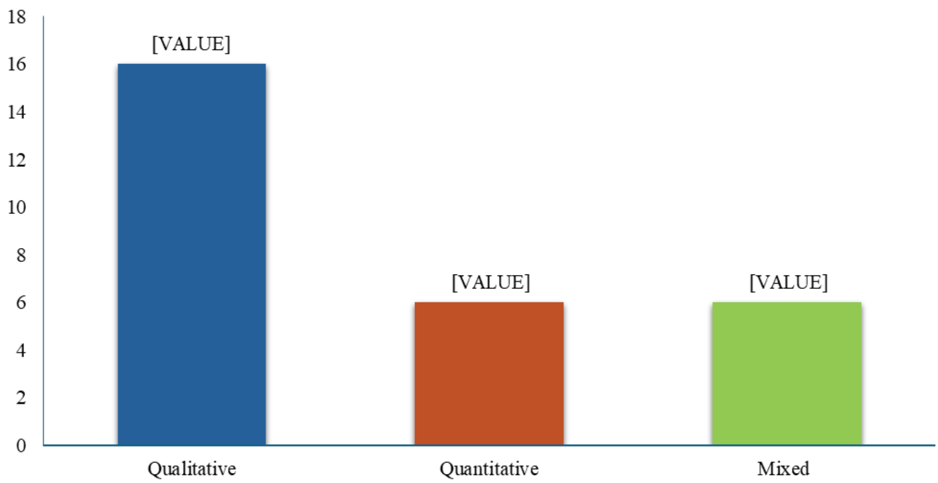

Figure 4. Distribution of reviewed articles according to their research designs

This distribution suggests that the research in this field tends to prioritize deep contextual understanding, detailed analysis of participant experiences or perspectives, and underlying motivations (Lim, 2025), rather than focusing primarily on statistical generalizations, numerical measurements (Lim, 2024).

The fifth research question aimed to determine which types of instruments were used for the data collection process. Since it was seen that a variety of instruments were utilized to collect data, the data collection techniques were categorized according to instrument type for a clearer presentation of the results. For example, achievement, knowledge, and other similar tests were grouped into a single category. The instruments employed in the reviewed papers are presented in Table 2.

The instruments listed in Table 2 are classified into five distinct categories, namely Interviews, Questionnaires and Scales, Tests, AI Interactions and Generated Content, and Articles. It is evident that "Questionnaires & Scales" and "AI Interactions & Generated Content" are the most frequently employed instrument types, each appearing 12 times. Following these, "Interviews" were used nine times, and "Tests" were used six times. "Articles" were the least frequent and used only two times. These differing frequencies of instruments used suggest varying methodological preferences in the reviewed literature. For instance, semi-structured interviews were used more frequently than focus groups, indicating a preference for capturing individual perspectives over group interactions. Similarly, the repeated use of Higher-Order Thinking Skills (HOTS) scales highlights a focus on complex cognitive abilities. The integration of interviews, questionnaires, and traditional tests reflects a strong commitment to methodological triangulation. By combining qualitative and quantitative tools, researchers tried to enhance the validity and comprehensiveness of their findings. While interviews provide nuanced, context-rich data, questionnaires and tests offer standardization and scalability, allowing for broader generalizations.

Table 2 Data Collection Instruments

Instrument Types	Data Collection Techinques	N
Interviews	Semi-structured interviews and focus group discussions	1
	Focus group interviews	2
	Semi-structured interviews	6
Questionnaires & Scales	Computational thinking questionnaire	1
	Intrinsic motivation questionnaire	1
	Cognitive load instrument	1
	Pre- and post-treatment surveys	1
	A 24-Item scenario questionnaire	1
	Online questionnaire	1
	A pre- and post-test questionnaire	1
	S-STEM questionnaire	1
	Scale developed by researchers	1
	Higher-order thinking skills (HOTS) scale	2
	Self-regulated learning (SRL) scale	1
Tests	Achievement test	1
	Conceptual science knowledge test	1
	Students' reading performance test	1
	Chemistry knowledge test	1
	Science knowledge test	1
	Knowledge construction test	1
AI Interactions & Generated Content	Specific questions related to science education posed to ChatGPT	1
	Representations found in science education images produced by Generative AI	1
	Biochemistry questions posed to ChatGPT	1
	Dialogues constructed from interactions between a chemistry teacher and ChatGPT	1
	ChatGPT-generated course plan for classroom assessment in science education	1
	Responses generated by ChatGPT to two sample tasks focusing on the topic of surfactants	1
	ChatGPT-4o generated lesson plans for classroom assessment in science education	1
	ChatGPT-generated experimental design	1
	Homework Physics problems queried to ChatGPT-4	1

	Dynamics problems posed to ChatGPT-4	1
	Clinical Chemistry multiple-choice questions posed to ChatGPT	1
	Competitive Indian examinations applied to ChatGPT	1
Articles	Publications on the assessment practises in science education	1
	Publications from different databases	1

The most striking and contemporary findings of this table is the prominence of the "AI Interactions & Generated Content" category. This category of instruments demonstrates a growing interest in understanding the role, capabilities, and implications of artificial intelligence, especially large language models like ChatGPT, within science and chemistry education. Researchers have not only employed ChatGPT to assist with instructional design but have also critically evaluated their outputs through various forms of interactions, such as posing subject-specific questions, solving homework problems, generating lesson plans and even designing experiments. Overall, this variety of instruments clearly indicates the growing importance of ChatGPT in science and chemistry education as a multifaceted educational agent, serving simultaneously as a teaching assistant, a knowledge base, and a benchmark for evaluating human responses (Alabidi et al., 2023; Ameen et al., 2024; Choi, 2025; Liang et al., 2023; Okulu & Muslu, 2024). The "Articles" category further suggests a foundational literature review or a meta-analysis. The absence of a systematic review of the instruments used in studies like this one makes it difficult to draw meaningful comparisons with earlier work. However, the frequent use of questionnaires in these studies can be attributed to the fact that these instruments can be self-administered, enable the collection of qualitative, quantitative, and mixed data, and are also practical and effective for collecting data from large participant groups within a short period of time (Garber et al., 2023, 2023).

The last research question aimed to compare the objectives and key findings of the reviewed articles to determine whether the objectives were mostly met or fulfilled. The abstract, introduction, and method sections were examined to determine the objectives of the reviewed articles. Key findings were synthesized from the abstract, results, discussion, and conclusion sections. The objectives of the articles and their key findings were then compiled in Table 3 to facilitate comparison.

Table 3. Comparison of The Objectives and Key Findings of The Reviewed Articles

Article	Objectives	Key Findings
Adeyele & Ramnarain (2024)	Examining science teachers' views on integrating ChatGPT into Inquiry-Based Learning 5E Model	Teachers' awareness and adoption of ChatGPT into IBL 5E Model vary.
Alabidi et al. (2023)	To evaluate the capability of ChatGPT in assessing scientific content.	Effective use of ChatGPT in science assessments requires strong teamwork between institutions.
Ameen et al. (2024)	Effects of ChatGPT on computational thinking of chemistry and computer science students.	ChatGPT significantly increased academic and computational thinking in the experimental group, though computer science students outperformed chemistry students on both tests.
Bhardwaj & Bedi (2025)	Evaluation of the performance of ChatGPT-3.0 as a potential tool for self-learning	ChatGPT significantly enhanced education technology and effectively served as an instructor for those preparing for competitive examinations covering technical, aptitude, and general studies subjects
Chen & Chang (2024)	Examine the impact of AI-supported game-based learning on science achievement, intrinsic motivation, cognitive load, and learning behaviors	AI-assisted game-based learning increased students' intrinsic motivation, decreased cognitive load, and facilitated effective learning behaviors in science learning
Cheung et al. (2024)	Examine students' comprehension of two ChatGPT-generated socio-scientific texts on climate change and how it evolves after a reading-science intervention	While students initially struggled with epistemic evaluation of ChatGPT's climate change texts, a targeted intervention significantly improved their performance in all reading domains, though mastering the more complex areas remained difficult.
Choi (2025)	Explore the use of generative artificial intelligence (GenAI) in Earth Science simulation lessons and evaluate its impact on learning outcomes and earth science pre-service teachers' pedagogical competencies.	The study showed that GenAI (ChatGPT) improved Earth science lessons' engagement and AI literacy, but highlighted challenges with visual aids and the need for critical information verification.
Cooper (2023)	Investigate ChatGPT's responses to science education-related questions, its potential use in science teaching, and its role as a research tool, with reflections on its effectiveness.	ChatGPT can generate useful educational resources, but its outputs may lack evidence, contain , and pose ethical issues, and therefore require careful evaluation by science educators and researchers.
Cooper & Tang (2024)	Critically analyze DALL-E 3 and ChatGPT-generated images of science classrooms and educators, explore their cultural representations and implications for inclusivity and stereotype reinforcement in science education	GenAI images of science education both reinforce traditional stereotypes (e.g., lab coats, beakers) and show diversity in ancestry, gender, and teaching settings, indicating a blend of traditional biases and a shift towards inclusivity

Dindorf et al. (2024)	Examine the decision-making competence regarding sugar substitute selection among chemistry and sports and health students, with an emphasis on differences in evaluation skills, decision criteria, and the incorporation of ChatGPT in their decision processes	Significant gains in evaluation competence for both student groups, along with distinct differences in competence factors, decision criteria, and ChatGPT usage between chemistry and sports and health students
Elmas et al. (2024)	Evaluate the accuracy and validity of responses generated by ChatGPT to biochemistry questions, with particular attention to its confidence in the answers provided	ChatGPT has limitations in providing scientifically accurate responses, containing some misconceptions, and thus serves as a partially reliable but not fully validated resource for scientific inquiries
Feldman-Maggor et al. (2025)	Examine the role of teachers' TPACK, CK, and PCK in shaping prompt engineering practices and responsible application of generative AI in chemistry teaching	Effective use of GenAI in chemistry education requires teachers' TPACK, PCK, and AI literacy, emphasizing the importance of prompt engineering, bias awareness, and the need to extend TPACK to include AI competencies.
Hamid et al. (2023)	Explore how students perceive the use of ChatGPT (GPT-3.5) for data searching and problem-solving in the context of process-driven problem-based learning	ChatGPT can improve collaboration, engagement, and motivation in PDPBL but concerns about its accuracy and reliability persist, with most students recognizing its value as a potential alternative to traditional methods.
Huang et al. (2025)	An analysis of online academic dishonesty practices among students in Chinese universities	Male and science students are more prone to online plagiarism and cheating, female students perceive E-AD (online academic dishonesty) as more harmful, and students' online academic ethical judgments are a key predictor of all forms of E-AD
Ishmuradova et al. (2025)	Construct a valid and reliable instrument to measure pre-service science teachers' perceptions of generative AI integration in science education and evaluate their views on its practical application.	A scale developed with four dimensions—optimism, readiness, inclusivity, and concerns about AI in science education—and identified distinct profiles of pre-service teachers, ranging from enthusiastic to skeptical, with the scale showing strong reliability
Jang & Choi (2025)	Investigate Korean physics educators' views on the use of ChatGPT in physics education and the potential societal and educational changes driven by generative artificial intelligence	Physics educators view ChatGPT as useful for problem-solving and personalized learning, but express concerns about its reliability, potential to widen educational inequalities, and reduce teacher influence, stressing the need for improved digital skills and reforms

Lee et al. (2024)	Analyze how the Guidance-based ChatGPT-assisted Learning Aid (GCLA) influences learners' self-regulated learning, critical thinking abilities, and knowledge development in higher education's blended contexts	By providing guidance instead of direct answers, GCLA markedly enhanced students' self-regulated learning, higher-order thinking, and knowledge construction when compared to conventional ChatGPT usage in a blended learning setting
Liang et al. (2023)	Investigate how ChatGPT can enhance physics learning and assess its performance in solving dynamics problems through prompt-based interactions	ChatGPT can solve physics problems, explain solutions, and generate new exercises with a level of understanding that reflects human-like comprehension of variables and underlying physical principles
Monteiro et al. (2024)	Examine K-12 science teachers' perceptions of ChatGPT's impact on school assessments and education quality, as well as to identify the potential difficulties of AI integration in schools.	Explore how K–12 science teachers perceive the effects of ChatGPT on student assessment and educational quality and uncover potential barriers to effective AI implementation in schools.
Nam & Bai (2023)	Analyze how authors writing for prominent STEM and higher education outlets view the role of ChatGPT in shaping STEM research and redefining human intellectual engagement in higher education.	Writers have diverse concerns about ChatGPT's impact on academic research, education, and human resources, with shared emphasis on ethical issues and uncertainty about the future of human intelligence in STEM and higher education
Ng et al. (2024)	Evaluate the effectiveness of GPT-driven chatbots in supporting students' science learning and self-regulated learning (SRL) skills, compared to rule-based chatbots (Nemobot), and identify best practices for their integration in science education	GPT-driven SRLbot significantly enhanced students' self-regulated learning, science motivation, and knowledge compared to the Nemobot, with student interaction levels being a key predictor of SRL gains independent of gender
Okulu & Muslu (2024)	Explore how ChatGPT can be utilized to develop course plans for pre-service science teachers, with a focus on enhancing learning through its integration into educational practices	ChatGPT effectively supports course plan development by offering adaptable content and saving time, while highlighting the value of iterative collaboration between human expertise and AI despite limitations such as external communication constraints and occasional inconsistencies

Pawlak (2024)	Explore the challenges that ChatGPT presents for teaching and learning in chemistry education, illustrated through example tasks involving surfactants using surfactant-related tasks	ChatGPT can produce detailed answers to complex chemistry problems, but its frequent inaccuracies, invented sources, and undetectable plagiarism present significant risks to student learning, academic integrity, and cognitive engagement
Peikos & Stavrou (2025)	Explore how prompt engineering and PCK-informed prompts influence the pedagogical content knowledge reflected in ChatGPT-generated lesson plans for primary science education.	Using PCK-based prompts with PCK elements and support materials can improve the instructional quality of AI-generated science lesson plans, though they still require human validation and suitability for young learners
Sallam et al. (2024)	Assess the performance of ChatGPT (GPT-3.5 and GPT-4), Bing, and Bard in comparison to postgraduate students in Clinical Chemistry.	ChatGPT-4 significantly outperformed human postgraduate students and other AI models on a Clinical Chemistry multiple-choice exam, suggesting its advanced potential and raising questions about current assessment practices in higher education
Scoggin & Smith (2023)	Explore how general chemistry students design experiments based on typical textbook questions and, conversely, how they translate laboratory experiments into standard general chemistry questions, in order to inform instructional practices and support broader participation in experimental design. Also, examine ChatGPT's capabilities in generating experimental designs corresponding to typical general chemistry questions, specifically using one of the questions given to the students	General chemistry students were more successful with experimental design elements clearly stated or approached individually, but less so with implicit or combined tasks, whereas ChatGPT produced a nearly complete and accurate design, highlighting its potential impact on instruction and assessment

Wang et al. (2024)	Investigate how GPT-4 handles real-world physics problems of differing data specificity, identifying its common failure modes and testing if prompt engineering improves its accuracy	GPT-4 performs well on clearly defined physics problems but struggles with real-world problems lacking specific data, often due to modeling errors, poor assumptions, and calculation mistakes
Wu et al. (2025)	Introduce and evaluate PA-GPT, an AI-supported peer assessment tool using ChatGPT to enhance knowledge, skills, attitudes (KSA), and higher-order thinking skills (HOTS) in STEM education, with a focus on addressing challenges in Asian higher education contexts	PA-GPT, when used as a peer assessment tool, was more effective than standard ChatGPT in improving students' knowledge building, higher-order thinking skills (like critical thinking, problem-solving, and creativity), and positive attitudes toward STEM subjects and 21st-century learning

Table 3 shows that nearly all the reviewed articles successfully addressed their stated objectives, often providing nuanced insights into the capabilities, impacts, and challenges of integrating ChatGPT into science and chemistry education. These papers have examined the potential, benefits and challenges of ChatGPT in this field from various perspectives. In general, AI tools have been found to improve learning processes. For example, ChatGPT has been found to increase academic achievement and computational thinking (Ameen et al., 2024), be effective as a self-learning tool (Ng et al., 2024), improve motivation and engagement (Chen & Chang, 2024; Pawlak, 2024), and even outperform human students (Sallam et al., 2024). It has also been shown to be useful in areas such as lesson plan development and learning material creation (Peikos & Stavrou, 2025). Thus, ChatGPT demonstrate considerable promise in enhancing various aspects of science and chemistry education. However, the results highlighted not only the positive aspects, but also important limitations and challenges associated with the integration of these technologies. The articles identified potential risks in ChatGPT responses (Cooper, 2023; Elmas, Adiguzel-Ulutas, & Yilmaz, 2024), such inaccuracies (Hamid et al., 2023), biases (Cooper & Tang, 2024), fabricated sources and risks of undetected plagiarism (Pawlak, 2024), ethical concerns (Cooper, 2023), and difficulties related to visual aids (Choi, 2025). Additionally, it was emphasized that effective use requires teachers to possess specific competencies such as TPACK and PCK (Feldman-Maggor et al., 2025; Peikos & Stavrou, 2025), AI literacy, and critical fact-checking skills (Choi, 2025). Divided perceptions among teachers and authors about the benefits of ChatGPT and concerns about plagiarism were also observed (Monteiro et al., 2024).

CONCLUSION

This study conducted a systematic review to examine the role of ChatGPT in science and chemistry education. The PRISMA approach was followed during the literature review process and a total of 28 relevant articles were retrieved from the WoS database, covering publications from 1970 to 24 May 2025. The literature review focused on the research questions related to WoS indexes, journals, countries, research designs, instruments, objectives, and key findings of the reviewed papers.

The analysis of the reviewed articles according to their WoS index and publication years showed that they were all published between 2023 and 2025 and predominantly indexed in ESCI. Moreover, the year 2024 emerged as the most productive year, accounting for exactly half of the total publications. Figure 2 and Figure 3 indicated that the reviewed articles exhibited significant diversity in terms of both the journals in which they were published and their countries of origin. The fact that most journals included only one or two articles, rather than being concentrated in just a few journals (Figure 2), suggests that this research area appeals to a broad academic audience and is likely to be multidisciplinary. Similarly, the finding that the articles originated from a wide range of countries across different continents such as Asia, Europe, North America, South America, Africa and Australia indicates that interest in this research area is globally widespread (Figure 3).

The analysis of the data in Figure 4 revealed that qualitative research designs were by far the most used approach among the reviewed articles. While quantitative and mixed-method designs were employed with equal frequency, they were significantly less prevalent than qualitative approaches. This indicates that a substantial proportion of the research in this field emphasizes qualitative methodologies, reflecting a focus on in-depth understanding and contextual analysis. Furthermore, the analysis of the 'instrument' category demonstrated that the reviewed studies used a diverse range of data collection tools, combining traditional ones such as interviews, questionnaires, scales, and tests with more innovative approaches (Table 2). A particularly notable aspect is the integration of ChatGPT in science and chemistry education, as both a data source and a subject of study. Researchers examined its responses to complex questions, its ability to generate instructional materials, and its role in performing academic tasks. This diverse collection of instruments suggests a robust methodological framework, capable of capturing both qualitative and quantitative data, and effectively exploring the evolving role of ChatGPT in this field.

Finally, two main themes emerged from the comparison of the objectives and results of the reviewed literature (Table 3). The first one is that ChatGPT is a powerful tool with the potential to transform science and chemistry education. It has been found that ChatGPT enhances academic achievement and motivation, reduces cognitive load, supports the development higher -order thinking skills, and fosters positive attitudes toward STEM fields. Additionally, ChatGPT has been identified as an effective educational technology for exam preparation by acting as both a self-learning tool and a virtual. It has also been found that it helps teachers save time in lesson content preparation, supports the developments of personalized learning strategies, and is effective in generating scientific content for assessment purposes. The second theme concerns the limitations and risks of using ChatGPT. It has been determined that scientific accuracy of the ChatGPT' outputs may be limited, its incorrect use may lead to ethical issues, it may fabricate sources, and it poses a risk of reducing teacher effectiveness. Therefore, teacher should develop Technological Pedagogical Content Knowledge (TPACK) and artificial intelligence (AI), and ethical skills, while students must also acquire critical thinking and AI skill. Additionally, educational administrators should ensure that teachers and students receive adequate training in the ethical use of ChatGPT. Overall, the results of this study indicates that there is a limited amount of research in this field. Thus, it is recommended that researchers carry out more quantitative or mixed-method studies along with qualitative studies on the advantages and disadvantages of using ChatGPT in the context of science and chemistry education.

It is also important to note that this study has certain limitations. First, the scope of the literature review was restricted solely to the Web of Science (WoS) database, thereby excluding other databases such as Scopus, ERIC, and Google Scholar. As a result, relevant studies that may have been indexed in those platforms were not included in the analysis. Second, only publications written in English were considered, which excludes potentially valuable research conducted in other languages. Lastly, the study included only peer-reviewed journal articles. Other types of publications such as conference proceedings and books were not considered. Therefore, these limitations may have introduced selection bias and limited the comprehensiveness of the findings regarding the role of ChatGPT in science and chemistry education.

REFERENCES

Adeyele, V. O., & Ramnarain, U. (2024). Exploring the integration of ChatGPT in inquiry-based learning: Teacher perspectives. *International Journal of Technology in Education*, *7*(2), 200–217.

Alabidi, S., AlArabi, K., Alsalhi, N. R., & al Mansoori, M. (2023). The dawn of ChatGPT: transformation in science assessment. *Eurasian Journal of Educational Research*, 106, 321–337. https://doi.org/10.14689/ejer.2023.106.019

Ameen, L. T., Yousif, M. R., Alnoori, N. A. J., & Majeed, B. H. (2024). The impact of artificial intelligence on computational thinking in education at university. *International Journal of Engineering Pedagogy*, *14*(5), 192-203. https://doi.org/10.3991/ijep.v14i5.49995

Bhardwaj, R. G., & Bedi, H. S. (2025). ChatGPT as an education and learning tool for engineering, technology and general studies: Performance analysis of ChatGPT 3.0 on CSE, GATE and JEE examinations of India. *Interactive Learning Environments*, *33*(1), 321–334. https://doi.org/10.1080/10494820.2024.2344054

Bhullar, P. S., Joshi, M., & Chugh, R. (2024). ChatGPT in higher education—A synthesis of the literature and a future research agenda. *Education and Information Technologies*, *29*(16), 21501–21522. https://doi.org/10.1007/s10639-024-12723-x

Birkle, C., Pendlebury, D. A., Schnell, J., & Adams, J. (2020). Web of Science as a data source for research on scientific and scholarly activity. *Quantitative Science Studies*, *1*(1), 363–376. https://doi.org/10.1162/qss_a_00018

Chen, C.-H., & Chang, C.-L. (2024). Effectiveness of AI-assisted game-based learning on science learning outcomes, intrinsic motivation, cognitive load, and learning behavior. *Education and Information Technologies*, 29(14), 18621–18642. https://doi.org/10.1007/s10639-024-12553-x

Cheung, K. K. C., Pun, J. K. H., & Li, W. (2024). Students' holistic reading of socio-scientific texts on climate change in a ChatGPT scenario. *Research in Science Education*, *54*(5), 957–976. https://doi.org/10.1007/s11165-024-10177-2

Choi, Y.-S. (2025). Earth science simulations with generative artificial intelligence (GenAI). *Journal of University Teaching and Learning Practice*, 22(1). https://doi.org/10.53761/nf1yqr46

Clark, T. M. (2023). Investigating the use of an artificial intelligence chatbot with general chemistry exam questions. *Journal of Chemical Education*, *100*(5), 1905–1916. https://doi.org/10.1021/acs.jchemed.3c00027

Cooper, G. (2023). Examining science education in ChatGPT: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology*, *32*(3), 444–452. https://doi.org/10.1007/s10956-023-10039-y

Cooper, G., & Tang, K.-S. (2024). Pixels and pedagogy: Examining science education imagery by generative artificial intelligence. *Journal of Science Education and Technology*, *33*(4), 556–568. https://doi.org/10.1007/s10956-024-10104-0

Dewi, C. A., Rahayu, S., Muntholib, M., & Parlan, P. (2024). The importance of problem-solving skills in chemistry learning as a demand in the 21st century. *AIP Conference Proceedings*, *3098*(1), 020009. https://doi.org/10.1063/5.0223797

Dindorf, C., Weisenburger, F., Bartaguiz, E., Dully, J., Klappenberger, L., Lang, V., Zimmermann, L., Fröhlich, M., & Seibert, J.-N. (2024). Exploring decision-making competence in sugar-substitute choices: A cross-disciplinary investigation among chemistry and sports and health students. *Education Sciences*, *14*(5), 531.

Elmas, R., Adiguzel-Ulutas, M., & Yilmaz, M. (2024). Examining ChatGPT's validity as a source for scientific inquiry and its misconceptions regarding cell energy metabolism. *Education and Information Technologies*, *29*(18). 25427–25456. https://doi.org/10.1007/s10639-024-12749-1

Feldman-Maggor, Y., Blonder, R., & Alexandron, G. (2025). Perspectives of generative ai in chemistry education within the TPACK framework. *Journal of Science Education and Technology*, *34*(1), 1–12. https://doi.org/10.1007/s10956-024-10147-3

Festiyed, -, Tanjung, Y. I., & Fadillah, M. A. (2024). ChatGPT in science education: A visualization analysis of trends and future directions. *International Journal on Informatics Visualization*, *8*(3–2), 1614. https://doi.org/10.62527/joiv.8.3-2.2987

Fonseca, C. (2024, June 18). The use of ChatGPT in chemistry: The bibliometric analysis. *10th International Conference on Higher Education Advances (HEAd'24)*. https://doi.org/10.4995/HEAd24.2024.17276

Garber, B. D., Mulchay, C., & and Knuth, S. (2023). Questionnaires in child custody evaluations: The forgotten ubiquitous medium. *Journal of Family Trauma, Child Custody & Child Development*, *20*(1), 20–36. https://doi.org/10.1080/26904586.2022.2086657

García-Carmona, A. (2025). Scientific thinking and critical thinking in science education. *Science & Education*, *34*(1), 227–245. https://doi.org/10.1007/s11191-023-00460-5

Hamid, H., Zulkifli, K., Naimat, F., Yaacob, N. L. C., & Ng, K. W. (2023). Exploratory study on student perception on the use of chat AI in process-driven problem-based learning. *Currents In Pharmacy Teaching and Learning*, *15*(12), 1017–1025. https://doi.org/10.1016/j.cptl.2023.10.001

Huang, C. L., Shao, X., Wu, C., & Yang, S. C. (2025). Navigating the digital learning landscape: Insights into ethical dilemmas and academic misconduct among university students. *International Journal of Educational Technology in Higher Education*, *22*(1), 29. https://doi.org/10.1186/s41239-025-00516-2

Ishmuradova, I. I., Zhdanov, S. P., Kondrashev, S. V., Erokhova, N. S., Grishnova, E. E., & Volosova, N. Y. (2025a). Pre-service science teachers' perception on using generative artificial intelligence in science education. *Contemporary Educational Technology*, *17*(3), ep579.

Jang, H., & Choi, H. (2025). A Double-edged sword: Physics educators' perspectives on utilizing ChatGPT and its future in classrooms. *Journal of Science Education and Technology*, *34*(2). 267–283. https://doi.org/10.1007/s10956-024-10173-1

Karakose, T. (2023). The utility of ChatGPT in educational research—Potential opportunities and pitfalls. *Educational Process: International Journal*, *12*(2), 7-13. https:// 10.22521/edupij.2023.122.1

Lee, H.-Y., Chen, P.-H., Wang, W.-S., Huang, Y.-M., & Wu, T.-T. (2024). Empowering ChatGPT with guidance mechanism in blended learning: Effect of self-regulated learning, higher-order thinking skills, and knowledge construction. *International Journal of Educational Technology in Higher Education*, *21*(1), 16. https://doi.org/10.1186/s41239-024-00447-4

Liang, Y., Zou, D., Xie, H., & Wang, F. L. (2023). Exploring the potential of using ChatGPT in physics education. *Smart Learning Environments*, *10*(1), 52. https://doi.org/10.1186/s40561-023-00273-7

Lim, W. M. (2024). What is quantitative research? An overview and guidelines. *Australasian Marketing Journal*, *0*(0), 1-7. https://doi.org/10.1177/14413582241264622

Lim, W. M. (2025). What is qualitative research? An overview and guidelines. *Australasian Marketing Journal*, *33*(2), 199–229. https://doi.org/10.1177/14413582241264619

Mburu, T. K., Rong, K., McColley, C. J., & Werth, A. (2025). Methodological foundations for artificial intelligence-driven survey question generation. *Journal of Engineering Education*, *114*(3), e70012. https://doi.org/10.1002/jee.70012

Misbah, M., Hamidah, I., Sriyati, S., & Samsudin, A. (2022). A bibliometric analysis: Research trend of critical thinking in science education. *Journal of Engineering Science and Technology*, 17, 118–126.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., ... & Prisma-P Group. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1). 1-9.

Monteiro, F. F., Souza, P. V. S., da Silva, M. C., Maia, J. R., da Silva, W. F., & Girardi, D. (2024). ChatGPT in Brazilian K-12 science education. *Frontiers in Education*, *9*, 1321547. https://www.frontiersin.org/articles/10.3389/feduc.2024.1321547/full

Nam, B. H., & Bai, Q. (2023). ChatGPT and its ethical implications for STEM research and higher education: A media discourse analysis. *International Journal of STEM Education*, *10*(1), 66. https://doi.org/10.1186/s40594-023-00452-5

Ng, D. T. K., Tan, C. W., & Leung, J. K. L. (2024). Empowering student self-regulated learning and science education through ChatGPT: A pioneering pilot study. *British Journal of Educational Technology*, 55(4),1328–1353. https://doi.org/10.1111/bjet.13454

Nightingale, A. (2009). A guide to systematic literature reviews. *Surgery (Oxford)*, *27*(9), 381–384. https://doi.org/10.1016/j.mpsur.2009.07.005

Okulu, H. Z., & Muslu, N. (2024). Designing a course for pre-service science teachers using ChatGPT: What ChatGPT brings to the table. *Interactive Learning Environments*, *32*(10), 7450–7467. https://doi.org/10.1080/10494820.2024.2322462

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Park, H. K., & Martin, S. N. (2024). Exploring the role of ChatGPT in science education for Asia-Pacific and beyond: A systematic review. *Asia-Pacific Science Education*, *10*(2), 233–264. https://doi.org/10.1163/23641177-bja10079

Paul, J., Lim, W. M., O'Cass, A., Hao, A. W., & Bresciani, S. (2021). Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR). *International Journal of Consumer Studies*, *45*(4), O1–O16. https://doi.org/10.1111/ijcs.12695

Pawlak, F. (2024). ChatGPT-a revolution for teaching and learning in chemistry education. *Chemkon*, *31*(2). 48–53. https://doi.org/10.1002/ckon.202300010

Peikos, G., & Stavrou, D. (2025). ChatGPT for science lesson planning: An exploratory study based on pedagogical content knowledge. *Education Sciences*, *15*(3), 338. https://doi.org/10.3390/educsci15030338

Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications*, *9*(1), 12. https://doi.org/10.3390/publications9010012

Salih, S., Husain, O., Hamdan, M., Abdelsalam, S., Elshafie, H., & Motwakel, A. (2025). Transforming education with AI: A systematic review of ChatGPT's role in learning, academic practices, and institutional adoption. *Results in Engineering*, *25*, 103837. https://doi.org/10.1016/j.rineng.2024.103837

Sallam, M., Al-Salahat, K., Eid, H., Egger, J., & Puladi, B. (2024). Human versus Artificial Intelligence: ChatGPT-4 outperforming Bing, Bard, ChatGPT-3.5 and humans in clinical chemistry multiple-choice questions. *Advances in Medical Education and Practice*, 15, 857–871. https://doi.org/10.2147/AMEP.S479801

Scoggin, J., & Smith, K. C. (2023). Enabling general chemistry students to take part in experimental design activities. *Chemistry Education Research and Practice*, *24*(4), 1229–1242. https://doi.org/10.1039/d3rp00088e

Stephenson, N. S., & Sadler-McKnight, N. P. (2016). Developing critical thinking skills using the Science Writing Heuristic in the chemistry laboratory. *Chemistry Education Research and Practice*, *17*(1), 72–79. https://doi.org/10.1039/C5RP00102A

Wang, K. D., Burkholder, E., Wieman, C., Salehi, S., & Haber, N. (2024). Examining the potential and pitfalls of ChatGPT in science and engineering problem-solving. *Frontiers in Education*, *8*, 1330486. https://www.frontiersin.org/articles/10.3389/feduc.2023.1330486/full

Wang, P., Jing, Y., & Shen, S. (2025). A systematic literature review on the application of generative artificial intelligence (GAI) in teaching within higher education: Instructional contexts, process, and strategies. *The Internet and Higher Education*, *65*, 100996. https://doi.org/10.1016/j.iheduc.2025.100996

Wu, T. T., Lee, H. Y., Chen, P. H., Lin, C. J., & Huang, Y. M. (2025). Integrating peer assessment cycle into CHATGPT for STEM education: A randomised controlled trial on knowledge, skills, and attitudes enhancement. *Journal of Computer Assisted Learning*, *41*(1), e13085. https://doi.org/10.1111/jcal.13085

Chapter 4

THE SOCIAL MATRIX OF READING HABITS: STUDENT PERSPECTIVES ON PARENTAL AND TEACHER ROLES

Ceyda TÜRKKAŞ[1,] *Sevinç TERZİOĞLU*[2]

1 Millî Eğitim Bakanlığı, Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü, 0000-0003-1252-4461
2 Millî Eğitim Bakanlığı, Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü, 0009-0004-6537-8829

"A person is a child of their habits."
İbn Haldun

Introduction

The development level of a society is closely linked to individuals' knowledge, skills, and cultural capital. In this regard, reading stands out as one of the most essential means for fostering personal growth and supporting lifelong learning. The prevalence of reading habits—which is increasingly recognized as a priority goal of language education—has come to be regarded as an indicator of societal progress and overall welfare (Aydoğdu, 2020). Furthermore, the fact that reading skills play a decisive role in the development of other core language competencies such as writing (Ilahi & Amna, 2025) and speaking (Uçgun, 2007) positions this habit at the very center of language education.

At this point, questions regarding how reading habits are formed and which dynamics support their development gain importance. Habits are shaped through repeated conscious practice and the influence of an individual's social environment (Atalay & Gönül, 2023). Reading habits, as a cornerstone of an individual's lifelong learning journey, are not merely personal actions but also social constructs. Parents and teachers, who are among the key actors in this process, guide students through their practices and approaches; their behaviors and attitudes directly influence students' engagement with reading. Therefore, the acquisition of reading habits and their effects on the individual have both personal and societal dimensions. This necessitates a multidimensional approach to understanding the factors that contribute to the development of such habits. In this context, in order to assess the broader societal reflections of reading habits shaped by individual attitudes and social interactions, it is essential to examine the current state of reading habits in Türkiye, along with relevant educational policies and their implementation.

Reading Habits in Türkiye: An Analysis Based on National Statistics and Ministry of National Education Policies

Although Türkiye's performance in reading has shown improvement compared to previous years, it still does not meet the desired level. According to the PISA 2022 results report (MoNE, 2024), Türkiye ranked 36th among 81 participating countries in terms of reading skills, and its average score has declined compared to the previous PISA 2018 results. Findings from the Reading Habits in Türkiye survey (MoC, 2017) reveal that 47.4% of individuals do not read books outside of textbooks or materials related to their field of study. The main reasons cited for this include lack of time (25%), a general dislike of reading (23%), boredom while reading (15%), and the belief that reading is unnecessary (11%).

One of the current educational policies implemented by the Ministry of National Education is the The Century Of Türkiye Maarif Model which embodies a holistic approach to education that is student-centered and emphasizes social interaction as well as school-family collaboration (MoNE, 2025a). This model offers a multi-actor structure that supports students' cognitive and social development, in which parents and teachers play a central role as foundational pillars of the learning process. The primary goal of the Maarif Model is to raise competent and virtuous individuals, and literacy skills are at the heart of achieving this profile. A closer examination of the primary and lower secondary Turkish language curricula reveals that the concepts of "love of books" and "reading habits" are emphasized through dedicated themes and texts, occupying a significant place within the scope of instructional content (MoNE, 2025b; MoNE, 2025c). In line with the objectives of this model, the development of reading habits is not considered merely as the acquisition of an individual skill, but rather as a dynamic process shaped within a network of social relationships. The influence of parents and teachers on students aligns with the core principles of the Maarif Model, forming a critical foundation for the acquisition and sustainability of reading habits. Furthermore, in recent years, the Ministry of National Education has implemented several initiatives that support the development of reading habits, such as No School Without a Library, The Richness of Our Language, and The Project for Identifying, Enhancing, and Monitoring Students' Vocabulary (MoNE, 2025d). These initiatives underscore the vital role of reading in shaping educational policies and reflect a systematic effort to cultivate literacy at a national level.

In addition to policies and practices, theoretical approaches that emphasize the skills individuals develop through interaction with their social environment offer a comprehensive perspective on the formation of reading habits. In this context, Sociocultural Development Theory emerges as a prominent framework for explaining the phenomenon.

An Analysis of Reading Habits through the Lens of Sociocultural Development Theory

Sociocultural approaches to development and learning emphasize the interplay between individual and social dimensions, highlighting their simultaneous and dynamic interaction (John-Steiner & Mahn, 1996). One of the most prominent figures in the field of education, Lev Vygotsky (1962), as the leading advocate of Sociocultural Development Theory, underscores the significance of the social environment in learning processes and prioritizes the social dimension over the individual. Within this theoretical framework, Vygotsky introduced the concept of the Zone of Proximal Development (ZPD), which refers to the crucial role of a competent, supportive social context in guiding and shaping learning. The concept emphasizes that learning is most effective when supported by knowledgeable others within a learner's potential development range. This idea has been metaphorically conceptualized as "scaffolding," referring to the structured support provided by more capable individuals—such as parents and teachers—that enables learners to progress beyond their current level of independent functioning (Yıldırım, 2016; Yüksel, 2024). By proposing that a child's cognitive development is directed by social interactions and mediated by the surrounding social environment, Vygotsky highlights the pivotal role of both parents and teachers in facilitating learning.

A substantial body of academic research focused on language skills has been grounded in the framework of Sociocultural Development Theory (Carrera & Mazzarella, 2001; Kapanadze, 2019; Öter & Yücel, 2024). As one of the core language skills, reading habits can likewise be considered a competence that develops through social interaction with figures in the child's environment, such as parents and teachers. A child's relationship with books is often shaped by the guidance, modeling, or direct participation of an adult, and these external factors play a crucial role in shaping the child's Zone of Proximal Development. Therefore, reading should be regarded not merely as a skill acquired through individual effort, but as one that emerges and matures through dynamic interactions with the social environment. In this study, students' perceptions of the roles of parents and teachers in the development of reading habits are examined within the framework of Vygotsky's Sociocultural Development Theory. In this context, the decisive role of adult guidance in the development of reading skills is analyzed in depth.

Theoretical explanations demonstrating that reading habits are shaped within a sociocultural context indicate the need for a new metaphorical approach to conceptualize the multidimensional nature of this process. Accordingly, this study will explore the social patterns of reading habits through the lens of the "matrix" metaphor.

Conceptualizing Reading Habits through the Matrix Metaphor: A Sociocultural Perspective

The term "matrix" is employed across a wide range of disciplines—including mathematics, economics, and physics—with varying definitions. In the present study, however, the concept is adopted as a metaphor, drawing from its meanings in both visual arts and the social sciences. According to the Turkish Language Association (TDK, 2025), the primary definition of matrix refers to a "printing mold" used in visual arts. In the context of the social sciences, the term denotes "a structure or system formed by interpersonal social relationships." In this study, the concept of the social matrix refers to the network of social relationships and the structural foundation through which these relationships are organized—factors that collectively influence the acquisition and development of reading habits in students.

The social matrix represents a structuring and guiding process in which social actors—such as parents and teachers—interactively shape students' reading behaviors. Much like how a printmaker leaves distinct impressions on a matrix that result in unique outcomes with each print, parents and teachers function as "impression matrices" in the development of children's reading habits. The attitudes, approaches, and role-modeling behaviors of these social actors leave enduring imprints on a child's cognitive and emotional development. Within this framework, every child is a unique "print," shaped by the specific configuration of their developmental experiences. The matrix that shapes this individuality is composed of the network of interactive relationships established within the family and school environment. Just as a physical matrix molds a tangible form, the social matrix reflects the social environment that shapes a student's reading attitudes and habits. Notably, this matrix is not static; it is multilayered, dynamic, and in a constant state of transformation.

The social matrix metaphor employed in this study offers a powerful tool for describing the interactive and multidimensional nature of the educational environment. Parents and teachers play both directive and formative roles in the development of students' reading habits by influencing their social and cognitive growth across multiple dimensions. The way in which the social matrix functions—and the extent to which it is effective—is directly linked to how students perceive the attitudes and behaviors of their parents and teachers. At this point, students' perspectives on those who form the foundation of their Zone of Proximal Development and guide their developmental processes—namely, parents and teachers—are of particular importance for understanding the structure and impact of the social matrix.

Research indicates that students' reading motivation is shaped not only by internal factors—such as their interests and desires—but also by external influences, including teachers, parents, and peers (Adıyaman & Türkyılmaz, 2023; Yıldız & Akyol, 2011; Yıldız, 2013). Although the process of acquiring reading habits centers on the child, it is evident that children require support and guidance throughout this journey. When examining research findings concerning the components of the social matrix—specifically, the degree to which various individuals influence the development of reading habits—it is found that teachers account for 26.6% and parents for 28.2% of the influence (MoC, 2017), while grandparents are reported to have an effect rate of 30% (Kesebir-Toktar, 2012). Other studies report higher percentages for teachers' influence, including 70% (Tosunoğlu, 2002), 62% (Gökçe, 2012), 57% (Arıcı, 2005), and 52% (Kesebir-Toktar, 2012). According to the 2019 Reading Culture Survey (OKUYAY, 2019), parents are identified as the primary factor that increases reading frequency, with family support correlating positively with students' reading rates. The importance of the family factor becomes even more pronounced when considering the need to cultivate reading skills from an early age (Akaydın & Çeçen, 2015). In this context, understanding a child's interests, needs, and personal characteristics is the first and most essential step toward fostering a love of reading (Dökmen, 1994; Karakullukcu & Çelik, 2020), and parents are the first practitioners and key determinants of this step. Following parents, teachers—who serve as role models in schools, the child's first structured social setting—play a crucial role (Arslan & Polat, 2025; Can et al., 2016; Mete, 2012; Taşkesenlioğlu, 2013). Students tend to identify with their teachers and take them as role models (Altuntaş et al., 2020; Karakullukcu & Çelik, 2020). Therefore, the presence of a teacher who models reading behaviors is of significant importance.

However, it is important to note that the social actors constituting the social matrix—such as parents, teachers, peers, and the immediate environment—can have both supportive and inhibitive effects on the development of reading habits (Telli, 2021). Parental and teacher expectations and practices may sometimes lead to the development of negative attitudes toward reading in children (Duran & Erkek, 2018). For instance, attempting to instill reading habits through inappropriate disciplinary methods may result in unintended outcomes, whereas enriching the reading process through various techniques—such as silent reading, read-aloud sessions, or visual reading strategies—can enhance students' interest in reading (Wahyuningsih et al., 2024).

Purpose of the Study

This study seeks to explore the following research questions based on the dynamic structure referred to as the social matrix of reading habits:

- What mistakes do students think parents make when trying to build reading habits in their children?

-

- What do students think parents should do to help their children become readers?
- What inappropriate behaviors do students see in teachers when they try to get students to read?
- What ways do students think teachers should use to help students develop reading habits?

These questions aim to reveal the influence of parents' and teachers' roles—as key components of the social matrix—on the development of reading habits from the perspective of students.

Significance of the Study

Reading is a habit that is acquired over time through effort and perseverance, ultimately aiming to make reading a natural part of one's daily life (Karakullukcu & Çelik, 2020). In order for reading skills to evolve into a habit—a repeated behavior—interventions must begin at an early age. It is expected that a positive attitude toward reading will emerge during the preschool years, develop into a habit during primary education, and transform into a reading culture by the high school period (İşleyen & Günal, 2023). However, research shows that students' positive attitudes and enthusiasm toward reading tend to decline as they progress through school levels (Balcı, 2009). Therefore, the secondary school period is considered a critical window for interventions related to reading and offers a valuable opportunity for research due to its potential to reflect accumulated experiences. A review of the existing literature reveals that most studies on reading habits focus on primary school students and investigate the influence of various external variables. Although there are studies examining high school students' reading culture based on different variables (İşleyen & Günal, 2023), there is a notable gap in research specifically investigating the perceived sources of problems from students' own perspectives. Moreover, recent research recommendations emphasize the need to explore student viewpoints in future studies (Güneş et al., 2024).

In this study, the roles of parents and teachers—external factors influencing reading motivation—are discussed based on students' perspectives, with the aim of shedding light on the social construction of reading habits. It is anticipated that the findings of this research will serve as a guiding resource for policymakers, educators, and parents, and contribute to the development of strategies aimed at strengthening a culture of reading both in educational settings and within families.

Method

This study is a qualitative case study aiming to gain an in-depth understanding of the roles of parents and teachers within the social matrix of reading habits, based on students' experiences and perceptions. The case study design is defined as the investigation of a real-life phenomenon within a clearly identifiable and bounded context (Creswell, 2021), and it seeks to provide a detailed and descriptive understanding of the case (Merriam, 2018). The research focuses on students' perspectives regarding the changes needed in the process of developing reading habits. The research questions are designed to explore the difficulties and areas for improvement in the functioning of the social matrix, aiming to reveal how students evaluate these two key social actors.

The participants of this study consisted of 228 secondary school students enrolled at different grade levels. Since reading-related attitudes and behaviors may vary depending on school type (İşleyen & Günal, 2023), the sample was limited to students from science high schools—where higher academic performance is associated with a greater likelihood of extensive reading experience. As the data collection tool, a qualitative questionnaire composed of four open-ended questions was used. The instrument was developed by the researcher and refined based on expert feedback. Data were collected from students within the school setting and analyzed using content analysis with the assistance of the MAXQDA software. The responses were organized and presented under appropriate themes and categories.

The demographic information of the participants comprising the study group is presented in Figure 1 and Figure 2.

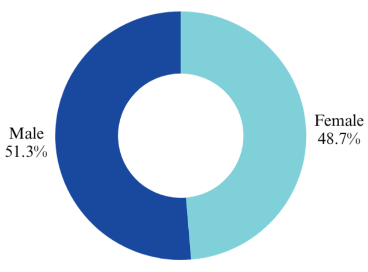

Figure 1. *Gender distribution*

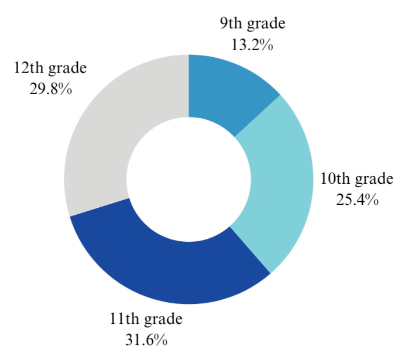

Figure 2. *Grade level distribution*

An examination of the personal characteristics of the study group reveals a balanced distribution in terms of gender. Regarding grade levels, the distribution is predominantly composed of 10th, 11th, and 12th-grade students, which reflects the grade-level composition of the science high school where the study was conducted.

Findings

An analysis of the research data revealed four main tables that align with the study's research questions. These tables reflect students' perspectives on the following aspects of the reading habit acquisition process: mistakes made by parents and what parents should do in this process; mistakes made by teachers and what teachers should do in this proces. The themes and codes presented in the tables are organized according to the frequency of recurring statements in the participants' responses. Findings related to students' views on the mistakes made by parents during the acquisition of reading habits are presented in Table 1**.**

Table 1. Parental Mistakes in the Acquisition of Reading Habits According to Student Views

Themes	Codes	Frequency of Recurrence
Related to Pressure	Forcing / exerting pressure	120
	Punishing	7
	Scolding / shouting / reprimanding	5
	Making reading a prerequisite for engaging in enjoyable activities	4
	Turning reading into a duty or obligation	3
	Having overly high expectations for reading	3
	Insisting on prioritizing academic subjects over reading	1
	Insisting on printed books and not allowing e-books	1
Related to Book Selection and Acquisition	Not allowing children to choose their own books	30
	Making inappropriate book selections	19
	Failing to provide guidance in book selection	3
	Not buying books	3
	Buying too many books	1
Related to the Role of Modeling	Not setting an example by reading	52
	Not reading together with the child	3
	Failing to provide a reading-oriented environment	2
Related to Indifference and Neglect	Using technological devices while the child is reading	16
	Not valuing the issue	8
	Not spending time with the child	3
	Being late in encouraging the development of the habit	3
	Not knowing the child	2
	Speaking negatively about books	1
Related to Flexible Approaches	Not enforcing reading / allowing flexibility	4
	Allowing phone use	3
	Not applying punishment	2
	Introducing phone use at an early age	2
	Allowing the child to read books on the phone	1
Related to Encouragement	Using rewards	6
	Failing to encourage with positive words	2
	Failing to explain the importance of reading	2

When Table 1 is examined, it is observed that, according to student responses, parental mistakes are grouped under six main themes in order of frequency: related to pressure, related to book selection/acquisition, related to the role of modeling, related to indifference and neglect, related to flexible approaches, and related to encouragement. Students most frequently reported that parents make mistakes by forcing them to read, failing to model reading behaviors, not allowing them to choose their own books, making inappropriate book selections, and using technological devices while their child is reading.

Selected student statements related to these codes are as follows:

"Forcing children to read does more harm than good. Reading should be something one enjoys, but parents only issue commands. This leads to feelings of guilt in children.." (K57)

"They shouldn't expect something from their children that they don't do themselves. They don't read, yet constantly tell their kids to read. Children imitate what they see from adults." (K67)

"Forcing a child to read books they dislike is a big mistake. Instead of encouraging a love for reading, it causes aversion.." (K73)

"They guide their children toward the wrong types of books. In my opinion, it's better for children to read books that match their interests and abilities." (K15)

"They tell their children to read, but they themselves are busy with phones, computers, and other devices." (K124)

Students' suggestions for what parents should do to support the development of reading habits are presented in Table 2.

Table 2. Student Suggestions for Parents Regarding the Development of Reading Habits

Themes	Codes	Frequency of Recurrence
Related to the Role of Modeling	Reading together	61
	Being a role model by reading	40
	Scheduling reading hours at home	32
Related to Book Selection and Acquisition	Identifying books that align with the child's interests and preferred genres	60
	Providing access to books through regular acquisition	31
	Allowing children autonomy in their book selection	10
	Ensuring that children read age-appropriate literature	6
	Establishing a home library to promote literacy engagement	6
	Encouraging the reading of entertaining and engaging books	4
	Introducing children to high-quality and enriching literature	4
	Initiating reading habits through the use of children's magazines	1
	Facilitating a gradual transition from entertaining texts to culturally enriching literature	1
Related to Encouragement	Rewarding reading behaviors	22
	Introducing books at an early age	18
	Explaining the importance and benefits of reading	17
	Encouraging and motivating children to read	9
	Stimulating curiosity through reading-related activities	9
	Taking children to book fairs to increase exposure	2
	Making regular visits to libraries	1
	Integrating children into reading environments and fostering a literate community	1
	Prioritizing the child over digital distractions or technology	1
Concerning Reading Practices	Reading books aloud to the child	14
	Engaging in diverse reading activities, such as oral reading or dramatization	8
	Making reading enjoyable through gamified and multimedia-based methods	7
	Linking books with films by watching movie adaptations or reading books based on films	4
	Discussing books read and encouraging children to articulate their understanding	4
	Narrating stories to foster imagination and listening skills	2
	Participating in shared reading of common texts	1
	Monitoring reading progress by reading the same books as the child	1

Related to Pressure	Avoiding coercion and undue pressure in reading activities	11
	Employing punitive measures such as scolding, pressuring, or punishment in relation to reading	10
	Promoting regular and daily reading routines	10
	Reducing children's exposure to digital devices and limiting smartphone use	9
	Providing flexibility in determining reading time to support autonomy and intrinsic motivation	1
Related to Planning	Developing structured reading plans tailored to the child's needs	4
	Integrating reading into the child's daily routine as a consistent practice	2

Upon examining Table 2, it becomes evident that students' suggestions directed at parents for fostering reading habits can be categorized—based on frequency of recurrence—under the following thematic headings: role modeling, book selection/acquisition, encouragement, reading practices, pressure-related behaviors, and reading planning. The students primarily emphasized suggestions such as *reading together, identifying books aligned with the child's interests, serving as a reading role model, and purchasing books*. Selected representative statements reflecting these suggestions are presented below.

"I would suggest reading together. If possible, we would read the same book in the evening hours and have a conversation about it afterward. Eventually, the habit would be picked up from me." (K9)

""I would buy books suited to the child's age and interests—fun and appealing ones—so that when bored, they would turn to books instead of technology." (K74)

"Together with my spouse, I would read books every day in the living room, in a place where the child could see us. Sooner or later, the child would want to join us in reading." (K10)

"Instead of making them save their allowance to buy books, I would offer a selection and purchase whichever book they liked." (K84)

Table 3 presents the findings related to students' perspectives on parental mistakes in fostering reading habits.

Table 3. Errors Attributed to Teachers in the Acquisition of Reading Habits: Student Views

Themes	Codes	Frequency of Recurrence
Related to Pressure	Applying pressure or coercion to force reading	98
	Punishing, humiliating, or yelling at students who do not read	19
	Imposing strict time limits on reading tasks	6
	Creating competition among students based on reading performance	2
	Forcing students to read aloud in class against their will	1
	Reporting students to their parents as a disciplinary response to reading-related issues	1
Related to Book Selection and Acquisition	Failing to allow students autonomy in book selection	30
	Choosing inappropriate or unengaging books for students	7
	Applying a one-size-fits-all approach by assigning the same book to all students	7
	Commenting on the book while students are still in the process of reading it	2
Regarding Educational Process	Linking reading activities to grades or formal assessments	18
	Treating reading merely as a homework assignment	16
	Failing to allocate dedicated time for reading sessions	4
	Omitting elements of fun and enjoyment from reading practices	4
	Inability to meaningfully integrate reading into the instructional process	3
	Lack of monitoring and follow-up regarding students' reading development	1
Concerning Individual Behavioral Tendencies	Failing to recognize the importance of the topic	14
	Being unable to encourage students beyond traditional advice	7
	Lacking a friendly or approachable attitude toward students	1
	Displaying prejudiced or biased attitudes	1
Related to Reading Tendencies	Failing to recommend books appropriate for the child	6
	Not presenting reading as an engaging or meaningful activity	4
	Emphasizing the drawbacks of reading rather than its benefits	4
	Prioritizing academic subjects over reading activities	2
	Not engaging in discussions about the books read	1

Related to Flexible Approaches	Not resorting to punishment	4
Related to the Role of Modeling	Engaging with a phone while children are reading during designated reading time	2
	Failing to model reading behavior	2
Related to Students' Expectations	Not providing rewards for reading	1
	Not purchasing books for the child	1
Related to Encouragement	Providing rewards for reading	1

An analysis of Table 3 reveals that, according to student perspectives, teacher-related mistakes in fostering reading habits are grouped—based on frequency of recurrence—under the following thematic categories: coercion and pressure, book selection, integration into the educational process, individual attitude, approach to reading, flexibility, role modeling, meeting student expectations, and encouragement. Students most frequently reported that teachers make mistakes by forcing students to read, not allowing autonomy in book selection, punishing those who do not read, and assigning reading solely as homework.

A selection of representative student statements related to these codes is provided below.

"They think they can make students love reading by forcing them to read books. I believe they are being too strict." (K44)

"Making us read books they have chosen themselves and then turning it into an exam." (K18)

"For those who don't read, they assign even more reading or writing homework. How is anyone supposed to enjoy reading this way?" (K201)

"Assigning book reading as homework only wastes students' time and causes them to lose interest in reading." (K31)

Table 4 presents the suggestions offered by students to parents regarding the development of reading habits.

Table 4. Student Recommendations for Teachers on Fostering Reading Habits

Themes	Codes	Frequency of Recurrence
Related to Educational Planning	Organizing structured reading sessions.	82
	Monitoring reading participation through tools such as tracking charts or logs.	10
	Designing reading programs, including classroom-based adaptations and planning.	3
	Fostering reading habits at early educational stages.	2
	Organizing designated reading days to promote a culture of reading.	1
Related to Educational Practices / Avtivities	Creating a competitive environment (e.g., through reading contests)	28
	Encouraging reading through engaging activities (e.g., games, role-playing)	16
	Facilitating discussions or talks about books	15
	Asking students to recount or summarize what they have read	8
	Organizing reading activities in diverse settings	6
	Conducting book discussion sessions	5
	Implementing post-reading writing activities	2
	Designing reading comprehension exercises	2
	Arranging visits to book fairs, libraries, and similar venues	2
	Supporting the development of writing skills	1
Related to Encouragement	Providing incentives and rewards for reading	30
	Explaining the significance and benefits of reading	13
	Establishing or enhancing classroom/school libraries	11
	Fostering a love for reading through encouraging and positive language	9
	Giving books as gifts to promote reading	4
	Stimulating curiosity and interest in reading	3
	Demonstrating the practical and cognitive benefits of reading	2
Related to Book Selection and Acqusition	Guiding students toward books aligned with their interests and preferences	27
	Providing book recommendations tailored to student needs	13
	Adopting an individualized approach to reading support	3
	Introducing students to a variety of literary genres	2
	Allowing students autonomy in book selection	2
	Assigning short and accessible texts to promote reading fluency	1
Related to Pressure	Assigning reading as homework	13
	Avoiding coercion or pressure in reading practices	6
	Linking reading activities to grading or assessment	4
	Avoiding the association of reading with grades	1

Related to the Role of Modeling	Modeling reading behavior by reading alongside students	5
	Engaging in shared reading experiences through common texts	3
	Sharing personal reading experiences and favorite books with students	2

When Table 4 is examined, it becomes evident that students' suggestions to teachers for fostering reading habits are categorized—based on their frequency of repetition—under the following themes: educational planning, instructional practices/activities, encouragement strategies, book selection, avoidance of pressure, and the teacher's role as a model. Among these, students most frequently emphasized suggestions such as organizing reading hours, providing rewards, creating a competitive environment, and guiding students toward books that align with their interests and preferences.

Selected quotations illustrating these suggestions are presented below:

"I would dedicate one of my lessons to reading time. During that hour, I would read along with them, offer recommendations, and try to spark their curiosity." (K176)

"I would organize book reading competitions with rewards." (K103)

"They shouldn't force the whole class to read the same book. Since each student has different interests and tastes, they should recommend books they think the student will actually enjoy." (K10)

Discussion and Conclusion

The research findings offer significant insights into the perceived roles of parents and teachers within the social matrix of reading habits, as reported by students. Based on the data obtained, students stated that the most common mistakes made by parents in this process include "imposing pressure or forcing children to read, failing to act as reading role models, and not allowing children to choose their own books." In contrast, they emphasized that parents should "engage in shared reading activities, help find books that match the child's interests, and model reading behavior themselves."

Regarding teachers, students reported similar criticisms. They pointed out that teachers' most frequent mistakes were "applying pressure, not giving students the autonomy to select books, and punishing those who do not read." According to the students, teachers should instead "organize regular reading sessions in school, provide positive reinforcement, and create a sense of healthy competition."

For both groups, the concept of "pressure" emerged as the most commonly criticized approach. These findings are consistent with the conceptual framework that defines the social matrix as a potential "framework of pressure." They underscore the need for parents and teachers to adopt attentive and supportive roles in shaping students' reading attitudes. It can be inferred that authoritarian or coercive approaches may negatively affect the development and sustainability of reading habits by undermining students' motivation.

At this point, it is noteworthy that students presented divergent views regarding the use of reward and punishment methods in fostering reading habits. While a majority emphasized the importance of rewards and the avoidance of punishment or pressure, a smaller group expressed support for more directive strategies, indicating a spectrum of perceptions.

One frequently cited criticism from students toward both parents and teachers was "not allowing the child/student to choose their own reading material." This finding aligns with research demonstrating that students exhibit higher motivation when engaged in reading based on their personal preferences (Yıldız & Akyol, 2011).

Moreover, studies have shown that extrinsic motivational factors such as rewards, recognition, and competition can positively influence students' reading motivation (Wigfield & Guthrie, 1997). Schools serve as the most suitable settings for implementing these strategies. These findings support students' suggestions in the current study that teachers should incorporate reward systems and foster a competitive reading environment.

From a sociocultural perspective, Vygotsky's Sociocultural Development Theory posits that children internalize the beliefs and attitudes they observe in their environment. In line with this theory, students' criticisms of parents not modeling reading behavior and their expectations for shared reading experiences reveal a strong need for positive and supportive attitudes within the home environment.

Another key finding derived from the frequency analysis is that the number of problems (f=312) and suggestions (f=424) related to parents exceeded those related to teachers (problems: f=270; suggestions: f=337). This discrepancy highlights the primary influence of the family factor, which is also confirmed by the 2019 Reading Culture Survey (OKUYAY, 2019), emphasizing the dominant role of parents.

In conclusion, the social matrix of reading habits should be understood as a multi-actor, socially interactive, and complex structure. Strengthening this matrix is a critical step toward achieving holistic and sustainable educational development. The development of reading habits can be effectively supported through a reinforced social matrix in which parents and teachers adopt student-centered, supportive, and role-model-based approaches.

Recommendations

Based on the findings of this research, the following recommendations can be made for practitioners: Reading should be removed from the realm of coercion and pressure during the process of acquiring reading habits. Instead, parents and teachers should collaborate to design encouraging practices and activities that guide children toward books aligned with their interests. In line with the suggestions provided by students, there is a clear need for initiatives that enhance the role of parents as reading role models and for the enrichment of educational planning by teachers through activities that promote reading engagement.

For researchers, it is recommended that similar studies be conducted across different educational levels, school types, and geographic regions, and that future research include the perspectives of all stakeholders involved in the zone of proximal development. Additionally, longitudinal action research on this topic may support the exploration of various instructional methods and techniques, thereby contributing to evidence-based planning and policy development at broader institutional levels.

Kaynakça

Adıyaman, B. ve Türkyılmaz, M. (2023). Ortaokul öğrencilerinin okuma motivasyonlarının çeşitli değişkenler açısından değerlendirilmesi. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 9*(3), 971-987. https://doi.org/10.31592/aeusbed.1230595

Akaydın, Ş. ve Çeçen, M. A. (2015). Okuma becerisiyle ilgili makaleler üzerine bir içerik analizi. *Eğitim ve Bilim*, *40*(178).

Altuntaş, B., Can, R. ve Karadeniz, A. (2020). Öğretmen ve öğrencilerinin okuduğu/tavsiye ettiği kitaplar ve bu kitapları beğenme nedenleri üzerine bir araştırma. *International Journal of Languages' Education and Teaching*, *8*(4), 101-109.

Arslan, A. ve Polat, M. S. (2025). İlkokul öğrencilerinin okuma alışkanlıkları ile eleştirel düşünme eğilimleri arasındaki ilişki. *Millî Eğitim Dergisi*, *54*(245), 321-354.

Arıcı, A. F. (2005). *İlköğretim ikinci kademe öğrencilerinin okuma durumları (beceri-ilgi-alışkanlık-eğilim)* [Yayımlanmamış doktora tezi]. Atatürk Üniversitesi.

Atalay, N. B. ve Gönül, B. (2023). Bilinçli Alıştırma Kavramının Vygotsky'nin Bilişsel Gelişim Kuramı Çerçevesinde Değerlendirilmesi. *Uluslararası Akademik Birikim Dergisi*, *6*(4).

Aydoğdu, H. (2020). Okuma alışkanlığı ve okul kütüphanelerinin bireysel gelişime etkisi üzerine bir değerlendirme. *Millî Eğitim Dergisi*, *49*(225), 201-226.

Balcı, A. (2009). İlköğretim 8. sınıf öğrencilerinin kitap okuma alışkanlığına yönelik tutumları/Elementary 8th grade students' attıtudes towards reading habits. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *6*(11), 264-299.

Can, A., Deniz, E. ve Çeçen, M. A. (2016). Ortaokul öğrencilerinin okuma tutumları. *Turkish Studies (Elektronik)*, *11*(3), 645-660.

Carrera, B., & Mazzarella, C. (2001). Vygotsky: enfoque sociocultural. *Educere, 5*(13), 41-44.

Creswell, J. W. (2021). *Nitel araştırma yöntemleri: Beş yaklaşıma göre nitel araştırma ve araştırma deseni (*M. Bütün ve S. B. Demir, Çev.). (6. Baskı). Siyasal Kitabevi.

Dökmen, Ü. (1994). *Okuma becerisi, ilgisi ve alışkanlığı üzerine psiko-sosyal bir araştırma.* Millî Eğitim Bakanlığı Yayınları.

Duran, E. ve Erkek, G. (2018). Ortaokul 8. sınıf öğrencilerinin okuma ön yargılarının belirlenmesi. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 4*(1), 1-17.

Gökçe, E. (2012). İlköğretim öğrencilerinin kitap okuma alışkanlıkları. S. Sever (Ed.), 3. *Ulusal Çocuk ve Gençlik Edebiyatı Sempozyumu* içinde (ss. 823-833). Ankara Üniversitesi.

Güneş, L. C., Durualp, E. ve Durualp, E. (2024). Ankara'da yaşayan ortaokul öğrencilerinin kitap okuma alışkanlıklarının bazı değişkenler açısından incelenmesi. *Türk Kütüphaneciliği*, *38*(4), 181-204.

Ilahi, R. K., & Amna, F. A. (2025). The effect of estacoll and reading habit on the eleventh grade students' writing recount text: A lesson learned from private schools. *Journal of Languages and Language Teaching*, *13*(1), 505-514.

İşleyen, E.ve Günal, Y. (2023). Ortaöğretim öğrencilerinin okuma kültürlerinin incelenmesi: bir karma yöntem araştırması. *Ana Dili Eğitimi Dergisi*, *11*(3), 657-677. https://doi.org/10.16916/aded.1276113

John-Steiner, V., & Mahn, H. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. Educational Psychologist, 31(3–4), 191–206. https://doi.org/10.1080/00461520.1996.9653266

Kapanadze, D. Ü. (2019). Vygostky'nin sosyo-kültürel ve bilişsel gelişim teorisi bağlamında Türkçe öğretiminin değerlendirilmesi. *Süleyman Demirel Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi*, *1*(47), 181-195.

Karakullukcu, N. ve Çelik, Y. (2020). İlkokul öğrencilerine kitap okuma alışkanlığı kazandırmada sınıf öğretmenlerinin rolü. *Adnan Menderes Üniversitesi Eğitim Fakültesi Eğitim Bilimleri Dergisi, 11*(2), 1-14.

Kesebir-Toktar, E. (2012), *Edirne ili merkez ilçesinde bulunan ilköğretim 1. kademe öğrencilerinin okuma alışkanlıkları ve kütüphane kullanımları.* [Yayımlanmamış yüksek lisans tezi]. Trakya Üniversitesi.

KTB. (2017). *Türkiye'de Kitap Okuma Alışkanlıkları Araştırması.* https://meb.ai/iYBF9g

MEB. (2024). *PISA 2022 Sonuç Raporu.* https://meb.ai/Y1RruP

MEB. (2025a). *Türkiye Yüzyılı Maarif Modeli. https://tymm.meb.gov.tr/*

MEB. (2025b). *İlkokul Türkçe Dersi Öğretim Programı.* https://meb.ai/yovImn

MEB. (2025c). *Ortaokul Türkçe Dersi Öğretim Programı.* https://meb.ai/UxFDQ3V

MEB. (2025d). *Talim ve Terbiye Kurulu Başkanlığı.* https://ttkb.meb.gov.tr/

Merriam, S. B. (2018). *Nitel araştırma: Desen ve uygulama için bir rehber* (S. Turan, Çev.). Nobel Yayın.

Mete, G. (2012). Ilkögretim 8. sınıf öğrencilerinin okuma alışkanlığı üzerine bir araştırma: Malatya ili örnegi. *Dil ve Edebiyat Eğitimi Dergisi*, *1*(1), 43.

OKUYAY. (2019). *Okuma Kültürünü Yaygınlaştırma Platformu 2019 Yılı Okuma Kültürü Araştırması.* https://meb.ai/CYTAPE

Öter, V. ve Yücel, D. (2024). Vygotsky'nin sosyal çevre kuramının yabancı dil Türkçe öğrenimine etkisi: Erbil örneği. *Socıal Scıences Studıes Journal (SSSJournal)*, *9*(116), 8696-8704.

Taşkesenlioğlu, L. (2013). Ortaöğretim öğrencilerinin okuma alışkanlıkları üzerine bir inceleme. *Karadeniz Sosyal Bilimler Dergisi*, *5*(9).

TDK. (2025). *Matris.* https://sozluk.gov.tr/

Telli, A. (2021) *Ortaokul öğrencilerinin okuma güdülenmeleri ile ebeveynlerinin eğitim düzeyi ve okuma kültürü görünümleri arasındaki ilişki üzerine bir inceleme* (Yayınlanmamış yüksek lisans tezi). Pamukkale Üniversitesi Eğitim Bilimleri Enstitüsü, Pamukkale.

Tosunoğlu, M. (2002). Türkçe öğretiminde okuma alışkanlığı ve çocukların okuma eğilimleri. *Türk Dili*, *2*(609), 547–563.

Uçgun, D. (2007). Konuşma eğitimini etkileyen faktörler. *Sosyal Bilimler Enstitüsü Dergisi*, *22*(1), 59-67.

Vygotsky, L. (1962). *Thought and language* (E. Hanfmann & G. Vakar, Trans.). MIT Press.

Wahyuningsih, N. E., Maghfiroh, A., Sugianto, A., & Laksana, S. D. (2024). Parental influence on children's reading habits. *Tarbawi: Journal on Islamic Education, 9*(1), 86–94.

Wigfield, A., & Guthrie, J. T. (1997). Relations of children‟s motivation for reading to

the amount and breadth of their reading. *Journal of Educational Psychology, 89*, 420–432.

Yıldırım, Y. (2016). Eğitim sosyolojisi perspektifi ile Piaget ve Vygotsky'nin bilişsel gelişim kuramları üzerine sosyolojik bir analiz denemesi. *Bartın University Journal of Faculty of Education, 5*(2), 617-628.

Yıldız, M. (2013). İlköğretim 3, 4 ve 5. sınıf öğrencilerinin okuma motivasyonlarının incelenmesi. *Eğitim ve Bilim*, *38*(168).

Yıldız, M. ve Akyol, H. (2011). İlköğretim 5. sınıf öğrencilerinin okuduğunu anlama, okuma motivasyonu ve okuma alışkanlıkları arasındaki ilişki. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi*, *31*(3), 793-815.

Yüksel, C.Y. (2024). *Çocukların gelişiminde iş birliğinin gücü: yakınsal gelişim alanı ve yapı iskelesi.* https://www.hiwellapp.com/blog/yakinsal-gelisim-alani#h-yakinsal-gelisim-alani-nedir