European Journal of Education and Pedagogy
Vol 5 | Issue 6 | November 2024
ISSN 2736-4534

REVIEW

Integrating ChatGPT into the Inquiry-Based Science Curriculum for Primary Education

Konstantinos T. Kotsis*

ABSTRACT

The integration of ChatGPT into an inquiry-based science curriculum for elementary school is investigated in this paper with an eye on increasing student involvement and learning results. Artificial intelligence-driven tools will help teachers enable individualized learning opportunities that foster young students' critical thinking and curiosity. The study emphasizes the need for a solid basis in scientific education since it develops critical thinking and problem-solving abilities necessary to negotiate the natural world's complexity. It also tackles the difficulties of using inquiry-based learning, including the pressure of standardized testing and the necessity of professional growth to provide instructors with successful approaches. The research concludes that including artificial intelligence in the classroom prepares students for a technologically driven future. It calls for careful evaluation of ethical consequences and thorough educator training to optimize its possible value. This research prepares the stage for following investigations on AI integration in different educational environments, possibly changing accepted teaching strategies.

Keywords: ChatGPT, curriculum, inquiry-based learning, primary education.

Submitted: September 27, 2024

Published: November 20, 2024

10.24018/ejedu.2024.5.6.891

Lab of Physics Education and Teaching, Department of Primary Education, University of Ioannina, Greece.

Corresponding Author:
e-mail: kkotsis@uoi.gr

1. Introduction

Integrating artificial intelligence (AI) tools into primary education presents an unprecedented opportunity to enhance pedagogical methodologies in the rapidly evolving educational technology landscape (Vidal, 2023). As educators increasingly seek to cultivate inquiry-based learning environments, the role of AI, particularly conversational agents like ChatGPT, is emerging as a pivotal component in shaping curriculum design (Blanco Fontao *et al.*, 2024). By harnessing the interactive capabilities of ChatGPT, educators can facilitate a more engaging science curriculum that encourages critical thinking and fosters a deeper understanding of scientific concepts among young learners. This paper will explore the theoretical underpinnings of inquiry-based learning, assess the effectiveness of AI-driven tools in supporting individualized learning experiences, and outline a framework for implementing an inquiry-oriented science curriculum that leverages ChatGPT to enrich student engagement and learning outcomes. This exploration aims to illuminate the potential benefits and challenges of integrating AI into primary science education.

Understanding the foundational principles of Inquiry-Based Learning (IBL) is central to developing an effective science curriculum. This pedagogical approach emphasizes student engagement through exploration, questioning, and critical thinking, allowing learners to construct knowledge through hands-on experiences (Roslan *et al.*, 2023). IBL distinguishes itself from traditional instructional methods by promoting active participation, where students formulate their inquiries and pursue investigations guided by educators. As noted in recent literature, adequate instruction involves diverse strategies harmonized with contextual factors, which aligns with IBL's inherent flexibility in accommodating varying learning styles (de Jong *et al.*, 2024). Furthermore, integrating Generative AI tools, such as ChatGPT, can enhance the IBL process by supporting content creation and facilitating feedback mechanisms, thereby enriching the educational experience (Moundridou *et al.*, 2024). This multifaceted approach fosters deeper understanding among primary students and instills a lifelong passion for inquiry and discovery in science education.

A strong foundation in science education during primary school is crucial for fostering young learners' critical thinking and problem-solving skills (Liu, 2024; Schäfer

et al., 2024). Early exposure to scientific concepts and inquiry-based methodologies not only cultivates curiosity but also equips students with the ability to navigate and comprehend the complexities of the natural world (Meier, 2020). This is particularly relevant considering advancements in teaching practices and educational technologies, such as ChatGPT, which can facilitate personalized learning experiences. Recent studies from Turkey (Akış, 2024) and Estonia (Laius & Presmann, 2024) noted that engaging students in hands-on activities demonstrates that inquiry-based approaches significantly enhance their understanding and application of scientific principles. Furthermore, incorporating modeling practices in life sciences education, as highlighted by research in Morocco, is essential for helping students visualize and engage with abstract concepts, thereby reinforcing the importance of science education at this formative stage (Ifqiren *et al*., 2023). Thus, a well-structured inquiry-based science curriculum can lay the groundwork for lifelong scientific literacy and informed citizenship.

Integrating technology in modern education fundamentally transforms pedagogical practices, particularly within inquiry-based science curricula (Ruzaman & Rosli, 2020). By employing platforms like ChatGPT, educators can facilitate interactive and personalized learning experiences that align with the diverse needs of learners (Mosaiyebzadeh *et al*., 2023). These technologies enable students to engage in a constructive dialogue, asking questions and exploring scientific concepts at their own pace, thereby nurturing critical thinking and problem-solving skills. The adaptability of technology accommodates various learning styles, allowing for differentiated instruction that can enhance student engagement and comprehension. As a result, educators can more effectively guide students through complex scientific inquiries, fostering an environment where curiosity and exploration are paramount. As these digital tools evolve, their role in education becomes increasingly essential, serving as resources for information and collaborators in the educational process (Ketelhut & Tutwiler, 2017).

2. Theoretical Framework of Inquiry-Based Learning

Inquiry-based learning (IBL) represents a shift from traditional pedagogical paradigms, emphasizing student engagement and exploration as pivotal components of the learning process (von Renesse & Ecke, 2014). Central to its theoretical framework is the notion that knowledge construction is inherently social and contextual, allowing learners to develop critical thinking and problem-solving skills through active participation. This pedagogical approach fosters a learner-centric environment where questions drive the learning experience, thus empowering students to pursue their interests, formulate hypotheses, and conduct investigations relevant to their lives. IBL aligns with constructivist theories, particularly those espoused by Piaget and Vygotsky, where learning is facilitated through social interaction and collaboration, potentially enhanced by digital tools like ChatGPT (Noguera, 2022). Integrating such technologies in primary science education supports inquiry and promotes diverse cognitive approaches, enriching students' learning experiences while conforming to the ideals of equity and accessibility in contemporary education (Bansal & Ramnarain, 2023).

A cornerstone of inquiry-based learning is student engagement, facilitating active rather than passive knowledge acquisition (Buchanan *et al*., 2016). This pedagogical approach nurtures curiosity, enabling learners to formulate questions and pursue answers through exploration and experimentation (Lazonder, 2022). Central to this process is the scaffolding of student inquiries, which involves strategically guiding learners while allowing them the autonomy to navigate their investigative paths. This balance between guidance and independence is essential in fostering critical thinking and problem-solving skills as students learn to evaluate evidence and draw conclusions based on their findings. Additionally, collaborative work among peers encourages the sharing of diverse perspectives, further enriching the learning experience. Ultimately, the fundamental principles of inquiry-based learning cultivate a dynamic classroom environment where students acquire information and develop the skills necessary for lifelong learning and adaptation in an ever-evolving world (Slotta & Linn, 2009).

A robust inquiry-based approach in science education fosters critical skills essential for navigating the complexities of the modern world. This teaching method enhances student engagement by encouraging curiosity and active participation, thus transforming learners into explorers who ask questions and seek answers through experiential learning. Research indicates that inquiry-based education improves problem-solving abilities and cultivates student creativity and teamwork (Perdana *et al*., 2023). By integrating these exploratory methods, teachers can create a dynamic classroom environment where students collaboratively investigate scientific concepts, leading to deeper understanding and knowledge retention. Incorporating technology, such as educational robotics, supports inquiry-based learning by providing hands-on experiences that align with contemporary pedagogical frameworks (Smyrnova-Trybulska *et al*., 2020). Ultimately, the benefits of inquiry-based science education extend beyond content mastery, promoting a culture of inquiry that prepares students for future academic and professional endeavors.

An essential obstacle in implementing IBL is the prevalent emphasis on standardized testing within education systems. Teachers often feel pressured to cover extensive curricula and ensure students perform well on assessments, which may prioritize rote memorization over critical thinking and exploration (Adiguna & Sutapa, 2019). This creates a misalignment between IBL methodologies, which require time and iterative processes for inquiry and discovery, and the narrow timeframes mandated by standardized testing requirements. Additionally, many educators may lack the training to effectively facilitate inquiry-based methods, resulting in uneven implementation across different classroom settings (Jenisová *et al*., 2013). Without proper professional development, teachers might revert to traditional models out of familiarity or lack confidence

in incorporating inquiry strategies, further perpetuating the cycle of limited engagement and shallow learning experiences. Addressing these challenges is crucial for successfully integrating IBL into primary education, as it ultimately promotes deeper understanding and long-term retention of scientific concepts.

3. Integrating ChatGPT into the Curriculum

Integrating ChatGPT into the curriculum presents a transformative opportunity for enhancing educational practices, particularly within an inquiry-based science framework. By leveraging the capabilities of AI, educators can foster a more engaging and interactive learning environment that encourages students to explore, question, and analyze scientific concepts. This aligns with current pedagogical trends advocating for the incorporation of active learning strategies, as highlighted by a longitudinal study examining teachers' perceptions of STE(A)M education (Lupión-Cobos *et al*., 2023). Additionally, the inquiry-based learning model has been shown to significantly improve students' academic performance in science, reinforcing that retention and understanding increase markedly when students actively participate in their learning process (Ramadansur *et al*., 2023). Thus, incorporating ChatGPT supports the inquiry-based approach and empowers educators to facilitate more personalized and adaptive learning experiences, ultimately enriching the educational landscape for primary learners.

As an advanced language model developed by OpenAI, ChatGPT harnesses the capabilities of deep learning to generate human-like text, making it a powerful tool for educational contexts (Kotsis, 2024a). Its architecture is based on the transformer model, facilitating nuanced understanding and generation of language across various topics. In primary education, particularly within inquiry-based science curricula, ChatGPT can serve multiple roles; it can act as a conversational partner, offering real-time feedback and encouragement while providing resources tailored to individual student needs (Kotsis, 2024b). The model's ability to simulate dialogue allows students to engage in exploratory questioning, fostering a deeper understanding of scientific concepts. Thus, integrating ChatGPT into the classroom enhances the learning experience by promoting critical thinking and prepares students for a more autonomous approach to inquiry and discovery in science education (Ketelhut & Tutwiler, 2017).

ChatGPT in science lessons requires a multi-faceted approach that enhances student engagement and comprehension (Kotsis & Tsiouri, 2024). One effective strategy involves using AI as a collaborative brainstorming partner where students can generate hypotheses and explore scientific concepts in a dynamic dialogue format. This interactive capability encourages deeper inquiry and critical thinking as learners are prompted to articulate questions and refine their understanding through iterative exchanges with the AI (Kotsis, 2024c). Additionally, educators might implement ChatGPT to facilitate personalized learning experiences, tailoring responses based on individual student needs and knowledge levels. For instance, students struggling with specific scientific terms can receive simplified explanations, while advanced learners can be challenged with complex scenarios that stimulate further exploration. Such targeted support bridges knowledge gaps and empowers learners to take ownership of their educational journeys, ultimately fostering a more inclusive and responsive learning environment.

Integrating ChatGPT into the primary education classroom presents a transformative potential for enhancing student engagement and improving learning outcomes through personalized interaction and formative assessment. The AI's ability to tailor responses and provide instant feedback fosters a more interactive learning environment where students can autonomously explore scientific inquiries. This aligns with inquiry-based learning principles, emphasizing student agency and collaborative exploration (Moundridou *et al*., 2024). Furthermore, the ability of ChatGPT to simplify complex concepts and communicate them in accessible terms can demystify challenging content areas, allowing for greater comprehension and retention among young learners. By bridging communication gaps in challenging subjects such as seismic engineering (Ray, 2024), ChatGPT may encourage a more profound engagement with the curriculum. As students harness this technology, they develop essential skills and cultivate a deeper interest in science, positively shaping their educational journey and outcomes.

4. Designing Curriculum Activities with ChatGPT

Integrating ChatGPT into curriculum activities presents a unique opportunity to enhance inquiry-based learning in primary education. By harnessing the capabilities of AI, educators can design interactive and responsive lesson plans that encourage students to engage with scientific concepts actively. This aligns with the findings of recent studies highlighting the benefits of inquiry-based education, emphasizing the need for students to engage in exploratory activities that foster critical thinking and problem-solving skills (Karklelytė, 2023). Moreover, the professional development opportunities for teachers to learn how to incorporate such technologies effectively can address the challenges identified in integrating STE(A)M subjects into curricula (Lupión-Cobos *et al*., 2023). By providing tailored resources and generating personalized inquiry prompts or activities, ChatGPT can alleviate some constraints teachers face, such as time and resource limitations, ultimately leading to a more enriched educational experience that meets the diverse needs of young learners.

4.1. Examples of Inquiry-Based Science Activities Using ChatGPT

Utilizing ChatGPT in inquiry-based science education can enhance student engagement and foster critical thinking skills. By prompting students to generate questions about a selected topic, such as ecosystems, ChatGPT can guide them through research activities that emphasize curiosity and exploration, aligning with contemporary educational approaches (Samara & Kotsis, 2024). For example, students might ask, "What factors affect the health of a local ecosystem?" Following this query, ChatGPT can facilitate a structured investigation by suggesting

methodologies for data collection, including observations and experiments, thereby transforming traditional learning into an interactive process. This aligns with the evolving educational frameworks that advocate for inquiry-based approaches, as highlighted in recent literature that emphasizes exploration and problem-solving in science learning (Karklelytė, 2023). Furthermore, incorporating technology supports visuality in science education and encourages exploration beyond the classroom, enhancing the educational experience and fostering sustainable practices (Makarskaitė-Petkevičienė, 2023).

4.2. Assessment Methods for Inquiry-Based Learning with ChatGPT

Effective IBL assessment methods involving ChatGPT must align with the chatbot's dynamic, interactive nature and the pedagogical framework it supports. Traditional assessment strategies can fall short of capturing the nuances of student engagement and understanding within IBL contexts (Sain *et al*., 2024). Therefore, a multifaceted approach is essential. For instance, formative assessments involving continuous feedback can inform students and educators about learning progress, enabling real-time adaptations. Tools like ChatGPT can facilitate peer assessments, where students can critique each other's inquiries and conclusions, fostering a collaborative learning environment. Project-based assessments allow learners to apply their inquiries in real-world scenarios, enhancing their conceptual understanding and relevance. Additionally, integrating digital portfolios can help track individual student growth over time, making the assessment process more holistic and reflective of their learning journey. Together, these methods create a robust framework for evaluating students in inquiry-based curricula that harness the capabilities of ChatGPT.

4.3. Teacher Training and Support for Effective Implementation

To successfully implement an inquiry-based science curriculum utilizing ChatGPT, robust teacher training and support mechanisms must be established. Educators require comprehensive professional development that not only familiarizes them with the technological aspects of ChatGPT but also integrates pedagogical strategies that enhance inquiry-based learning. This training should encompass hands-on workshops, collaborative planning sessions, and continuous support networks where teachers can share challenges and successes. Additionally, providing access to tailored resources and instructional materials can aid in building confidence and competence among educators, enabling them to facilitate more engaging and effective classroom experiences (Kotsis, 2024a, 2024b). Furthermore, ongoing mentorship from experienced educators or instructional coaches can support the sustained growth of teaching practices, ensuring that the curriculum is implemented effectively and adapted to meet students' diverse needs (Ketelhut & Tutwiler, 2017). By prioritizing such comprehensive support, schools can foster a culture of innovation and inquiry that benefits teachers and learners.

5. Discussion

Several restrictions exist in the paper on creating an inquiry-based science curriculum with ChatGPT for elementary education. One major drawback is the difficulty the focus on standardized testing inside educational systems presents. Teachers under this pressure may prioritize rote memory above critical thinking and inquiry-based learning (IBL) encouragement. The time-intensive character of IBL approaches runs counter to the limited durations dictated by standardized testing. This can impede the successful application of inquiry-based approaches in schools. Teachers may find it challenging to apply IBL without proper professional growth. This can lead to a return to conventional teaching strategies, restricting the pupils' involvement and depth of learning opportunities. At last, the report emphasizes issues like inadequate resources that can hinder the integration of inquiry-based approaches and technology into primary education environments. These constraints draw attention to the need for systematic reforms like matching educational policies with IBL ideas and giving teachers thorough tools and training to realize the possibilities of AI-driven tools like ChatGPT in primary education.

6. Conclusion

In this study into the integration of ChatGPT within an inquiry-based science curriculum for primary education, it is evident that such innovative tools can significantly catalyze both teaching and learning processes. The findings highlight how ChatGPT can facilitate deeper engagement through personalized learning experiences and scaffold inquiry-based activities that promote critical thinking and curiosity among young learners. This paper on integrating ChatGPT into an inquiry-based science curriculum for primary education outlines several practical implications:

By incorporating ChatGPT, the curriculum can significantly boost student engagement through personalized interactions and formative assessments. This approach allows students to explore scientific inquiries autonomously, fostering a more interactive and engaging learning environment. ChatGPT's ability to simplify complex concepts and communicate them quickly can help demystify challenging content areas. This leads to better comprehension and retention among young learners, aligning with the principles of inquiry-based learning (IBL).

Integrating AI tools like ChatGPT in education prepares students for future technological advancements. It also provides educators with versatile resources to address diverse learning needs, although it requires careful consideration of ethical implications and comprehensive educator training.

This study also highlights challenges such as the misalignment between IBL methodologies and standardized testing requirements and the need for professional development for educators. It recommends integrating technology to facilitate dynamic classroom discussions and personalized learning opportunities alongside professional development workshops for teachers.

These implications suggest that integrating ChatGPT can transform primary education by enhancing engagement, improving learning outcomes, and preparing students for future technological landscapes.

Integrating AI in educational settings prepares students for a technologically oriented future and equips educators with versatile resources to address diverse learning needs. Nevertheless, careful consideration must be given to ethical implications and the need for comprehensive educator training to maximize the potential of this digital tool. Ultimately, this inquiry sets the groundwork for future research on the nuances and effectiveness of AI integration in various educational contexts. This endeavor may profoundly reshape conventional pedagogical frameworks.

Future research must explore the efficacy of technology-enhanced learning environments, particularly in inquiry-based science education. As evidenced by the critical exploration of education practices in diverse contexts, including the examination of mathematical achievement interventions, frameworks like ChatGPT can serve as tools for engagement and as platforms for developing critical thinking in primary education. Future investigations should focus on longitudinal assessments that measure the impact of integrating AI-driven inquiry methodologies on student learning outcomes across various subjects. As indicated in the discourse on democracy and diversity in teaching practices, researchers must consider how these technologies facilitate inclusive learning experiences that respect diverse perspectives and foster a collaborative classroom culture. Such inquiries will provide essential insights for educators looking to refine curriculum design and pedagogical strategies in an increasingly digital landscape.

Incorporating inquiry-based approaches into science curricula necessitates educators and curriculum designers to embrace flexibility in pedagogical practices. By fostering an environment that encourages questioning, exploration, and critical thinking, educators empower students to take ownership of their learning experiences. One practical recommendation is integrating technology, such as ChatGPT, which can facilitate dynamic classroom discussions and personalized learning opportunities. Furthermore, professional development workshops should equip teachers with strategies to effectively utilize AI tools, synthesizing them into their instructional design. Collaborative projects that involve real-world problem-solving can bridge theoretical concepts with practical applications, enhancing student engagement. Ultimately, the success of an inquiry-based curriculum relies on continuous reflection and adaptation. Thus, educators and curriculum designers must remain vigilant in assessing student needs and curriculum effectiveness, ensuring a responsive educational landscape that nurtures curiosity and innovation in primary science education.

Conflict of Interest

The author declares that there is no conflict of interest.

References

Adiguna, B., & Sutapa, P. (2019). Challenges of inquiry based learning in physical and health education. *ICONECT 2019: Proceeding of the 2nd International Conference Education Culture and Technology, ICONECT 2019*, Kudus, Indonesia: European Alliance for Innovation, pp. 456. https://doi.org/10.4108/eai.20-8-2019.2288092.

Akış, A. P. (2024). Using arduino in science, technology, engineering, and mathematics (STEM) education: Bibliometric analysis. *Science Education International*, *35*(2), 73–84. https://doi.org/10.33828/sei.v35.i2.1.

Bansal, G., & Ramnarain, U. (2023). *Inquiry-Based Science in the Primary Classroom*. Taylor & Francis.

Blanco Fontao, C., López Santos, M., & Lozano, A. (2024). ChatGPT's role in the education system: Insights from the future secondary teachers. *International Journal of Information and Education Technology*, *14*(8), 1035–1043. https://doi.org/10.18178/ijiet.2024.14.8.2131.

Buchanan, S., Harlan, M., Bruce, C., & Edwards, S. (2016). Inquiry based learning models, information literacy, and student engagement: A literature review. *School Libraries Worldwide*, *22*(2), 23–39. https://doi.org/10.29173/slw6914.

de Jong, T., Lazonder, A. W., Chinn, C. A., Fischer, F., Gobert, J., Hmelo-Silver, C. E., Koedinger, K. R., Krajcik, J. S., Kyza, E. A., Linn, M. C., Pedaste, M., Scheiter, K., & Zacharia, Z. C. (2024). Beyond inquiry or direct instruction: Pressing issues for designing impactful science learning opportunities. *Educational Research Review*, *44*, 100623. https://doi.org/10.1016/j.edurev.2024.100623.

Ifqiren, S., Bouzit, S., Kouchou, I., & Selmaoui, S. (2023). Modelling in the scientific approach to teaching life and earth sciences: Views and practices of Moroccan teachers. *Journal of Education and E-Learning Research*, *10*(4), 605–615. https://doi.org/10.20448/jeelr.v10i4.5003.

Jenisová, Z., Braniša, J., & Melušová, J. (2013). Implementation of Inquiry-based learning supported by digital technologies in courses of professional development for chemistry teachers. *2013 International Conference on Advanced ICT and Education (ICAICTE-13)*, Atlantis Press, pp. 220–224. https://doi.org/10.2991/icaicte.2013.47.

Karklelytė, I. (2023). Primary school teachers' experiences of inquiry-based education in science lessons. *Natural Science Education in a Comprehensive School*, *29*, 4–19. https://doi.org/10.48127/gu/23.29.04.

Ketelhut, D. J., & Tutwiler, M. S. (2017). *Science Learning and Inquiry with Technology*. Routledge.

Kotsis, K. T. (2024a). ChatGPT develops physics experiment worksheets for primary education teachers. *European Journal of Education Studies*, *11*(5), 1–20. https://doi.org/10.46827/ejes.v11i5.5274.

Kotsis, K. T. (2024b). ChatGPT in teaching physics hands-on experiments in primary school. *European Journal of Education Studies*, *11*(10), 126–148. https://doi.org/10.46827/ejes.v11i10.5549.

Kotsis, K. T. (2024c). Integration of artificial intelligence in science teaching in primary education: Applications for teachers. *European Journal of Contemporary Education and E-Learning*, *2*(3), 27–43. https://doi.org/10.59324/ejceel.2024.2(3).04.

Kotsis, K. T., & Tsiouri, E. (2024). Utilizing ChatGPT for primary school earthquake education. *European Journal of Contemporary Education and E-Learning*, *2*(4), 145–157. https://doi.org/10.59324/ejceel.2024.2(4).12.

Laius, A., & Presmann, M. (2024). The pre-service teachers' perceptions of integrated teaching, inquiry learning, using ICT and real-life examples in science classes. *Science Education International*, *35*(2), 92–101. https://doi.org/10.33828/sei.v35.i2.3.

Lazonder, A. W. (2022). Inquiry-based learning. *International Encyclopedia of Education (Fourth Edition)*, pp. 630–636. https://doi.org/10.1016/B978-0-12-818630-5.14072-2.

Liu, F. (2024). A study on the dilemma and countermeasures of science teaching in primary schools. *International Journal of Education and Humanities*, *12*(3), 67–71. https://doi.org/10.54097/q68khs43.

Lupión-Cobos, T., Lagarón, D. C., Ariza, M. R., & Domènech-Casal, J. (2023). STEM education in the spanish context: Key features and issues. *Reforming Science Teacher Education Programs in the STEM Era: International and Comparative Perspectives*, Cham: Springer International Publishing, pp. 181–198.

Makarskaitė-Petkevičienė, R. (2023). Trends in early science education. *Natural Science Education*, *20*(1), 4–9. https://doi.org/10.48127/gunse/23.20.04.

Meier, D. R. (2020). Science, nature, and inquiry-based learning in early childhood. *Nature education with young children* (pp. 11–30). Routledge.

Mosaiyebzadeh, F., Pouriyeh, S., Parizi, R., Dehbozorgi, N., Dorodchi, M., & Batista, D. M. (2023). Exploring the role of ChatGPT

in education: Applications and challenges. *Proceedings of the 24th Annual Conference on Information Technology Education*, Association for Computing Machinery, pp. 84–89. https://doi.org/10.1145/3585059.3611445.

Moundridou, M., Matzakos, N., & Doukakis, S. (2024). Generative AI tools as educators' assistants: Designing and implementing inquiry-based lesson plans. *Computers and Education: Artificial Intelligence*, *7*, 100277. https://doi.org/10.1016/j.caeai.2024.100277.

Noguera, I. (2022). Moving forward in social constructivist theories through agile learning in the digital age. In *Agile learning and management in a digital age* (pp. 107–125). Routledge. https://doi.org/10.4324/9781003188728-9.

Perdana, D., Saptasari, M., & Susanto, H. (2023). The effects of inquiry project-based learning on the increasing student's science literacy skills and creative thinking skills. *AIP Conference Proceedings*, AIP Publishing, vol. 2569, no. 1. https://doi.org/10.1063/5.0131311.

Ramadansur, R., Sutomo, E., Rizky, R., & Sembiring, A. K. (2023). Exploring the efficacy of inquiry-based learning for human respiratory system: Students' achievement at high school setting. *Paedagogia: Jurnal Pendidikan*, *12*(2), 309–330. https://doi.org/10.24239/pdg.Vol12.Iss2.439.

Ray, P. P. (2024). ChatGPT in transforming communication in seismic engineering: Case studies, implications, key challenges and future directions. *Earthquake Science*, *37*(4), 352–367. https://doi.org/10.1016/j.eqs.2024.04.003.

Roslan, A. N., Phang, F. A., Pusppanathan, J., & Nawi, N. D. (2023). Challenges in implementing inquiry-based learning (IBL) in physics classroom. *AIP Conference Proceedings*, AIP Publishing, vol. 2569, no. 1. https://doi.org/10.1063/5.0117509.

Ruzaman, N. K., & Rosli, D. I. (2020). Inquiry-based education: Innovation in participatory inquiry paradigm. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(10), 4–15. https://doi.org/10.3991/ijet.v15i10.11460.

Sain, Z. H., Ayu, S. M., & Thelma, C. C. (2024). Exploring the ChatGPT era: Finding equilibrium between innovation and tradition in education. *Middle East Research Journal of Humanities and Social Sciences*, *4*(4), 116–121. https://doi.org/10.36348/merjhss.2024.v04i04.001.

Samara, V., & Kotsis, K. T. (2024). Use of the artificial intelligence in teaching the concept of magnetism in preschool education. *Journal of Digital Educational Technology*, *4*(2), ep2419. https://doi.org/10.30935/jdet/14864.

Schäfer, J., Reuter, T., Karbach, J., & Leuchter, M. (2024). Domain-specific knowledge and domain-general abilities in children's science problem-solving. *British Journal of Educational Psychology*, *94*(2), 346–366. https://doi.org/10.1111/bjep.12649.

Slotta, J. D., & Linn, M. C. (2009). *WISE Science: Web-Based Inquiry in the Classroom*. Teachers College Press.

Smyrnova-Trybulska, E., Staniek, D., & Zegzuła, D. (2020). Robotics in education. A survey report: A case study. *International Journal of Research in E-Learning*, *6*(1), 1–18. https://doi.org/10.31261/IJREL.2020.6.1.08.

Vidal, J. (2023). Emerging technologies: The birth of artificial intelligence (AI) in education. *SSRN*. https://doi.org/10.2139/ssrn.4512063.

von Renesse, C., & Ecke, V. (2014). Inquiry-based learning and the art of mathematical discourse. *PRIMUS*, *25*(3), 221–237. https://doi.org/10.1080/10511970.2014.921799.