

LEVERAGING ARTIFICIAL INTELLIGENCE, INNOVATION AND CREATIVITY: IMPACT OF ARTIFICIAL INTELLIGENCE ON CHILDREN'S CREATIVITY IN EARLY CHILDHOOD EDUCATION.

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Abstract

The paper explores the growing impact of Artificial Intelligence (AI) in early childhood education, emphasizing the use of AI in early childhood education offers a tailored learning experience that promotes cognitive, language, and social growth potential effects on cognitive, emotional, and behavioral development. As AI technology progresses, today's children will engage with it in ways that significantly differ from earlier generations. AI is transforming our work, play, and everyday activities, children who learn best through active engagement, particularly benefit from hands-on experiences. AI-driven tools like interactive games, creative applications, and adaptive tutoring systems inspire children to explore, innovate, and express themselves. Conclusively, the impact of Artificial Intelligence in education significantly enhances children's creativity and learning experiences by fostering engagement and equipping them with essential skills and mindset necessary for future success. The study recommended continuous professional development opportunities should be made accessible, allowing educators to stay updated with the latest advancements in AI and implement best practices in their classrooms to foster creativity and cultivate essential life skills.

Keywords: Artificial Intelligence (AI), Early Childhood Education (ECE), Life Skills, Enjoyment and Creativity,

Introduction

The emergence of artificial intelligence (AI) is significantly transforming education, particularly in early childhood education (ECE), where it enhances teaching methods and learning experiences, playing a crucial role in children's development during key early growth phases.(Ng et al., 2021 a, b).

Children's brains are highly adaptable to new experiences, and Artificial Intelligence (AI) provides numerous opportunities to enhance cognitive development, support language acquisition, and develop essential social skills through engaging digital platforms (Druga et al., 2021). AI-driven personalized learning systems can cater to the diverse needs of young learners, offering customized educational content that aligns with their unique learning styles and speeds (Su et al., 2022). Additionally, AI tools foster dynamic learning environments through games and simulations that promote cognitive growth and stimulate curiosity (Kewalramani et al., 2021).

The impact of AI is being felt across numerous fields, including science, psychology, public policy, and healthcare, significantly altering traditional practices (Xu et al., 2021). Within the realm of education, AI holds the potential to streamline assessment processes, forecast student performance and educational progression, and provide tailored recommendations for learning materials (Yahya& Mohamed, 2024). Kewalramani et al. (2021) explore the use of interactive AI within robotic toys in early childhood (EC) settings, aiming to enhance children's inquiry literacy. There is a

growing enthusiasm surrounding the application of AI in education, particularly in how it can seamlessly integrate technology into the playful and learning experiences of young children (Göçen&Aydemir, 2020). Educators have effectively leveraged AI-based robotic toys to captivate the interest of preschoolers aged 4 to 5 during playtime (Xieling Chen et al., 2020). By offering interactive resources and personalized educational experiences, AI has the potential to assist young learners in developing vital "soft skills," such as effective communication and teamwork. These advanced technologies facilitate a more individualized educational approach, catering to the unique needs of each student. The individualized needs of each student are systematically met, resulting in enhanced self-confidence and self-worth.

Artificial Intelligence (AI) streamlines problem-solving processes by offering research avenues and promotes children's creative capacities through innovative and imaginative self-expression methods. Comprehensive observational studies, educator interviews, and analyses of student outputs have illuminated the collaborative creative processes among children. Interaction with AI-driven robots has been instrumental in cultivating inquiry literacy, fostering creativity, enhancing teamwork, and developing emotional intelligence (Kewalramani et al., 2021).

This paper aims to elucidate the potential benefits of AI for young learners in early childhood education, through interactive applications, and innovative tools that actively engage them while enhancing their creativity and essential life skills.

Artificial intelligence (AI)

Artificial intelligence (AI), initially defined by John McCarthy in 1955 as a computer capable of performing tasks typically associated with human intelligence, such as speaking and problem-solving, has evolved significantly. Russell and Norvig (2010) describe AI's role in mimicking complex cognitive functions like perception and learning, while Berendt et al. (2020) highlight its ability to perform tasks usually done by intelligent beings. AI encompasses a variety of technologies and algorithms (Baker and Smith, 2019; Jantakun et al., 2021) that focus on problem-solving through advanced methods like neural networks and machine learning (Wang, 2019; Yang, 2022). The expanding literature on AI reflects advancements in multiple research areas, with applications spanning software, robotics, natural language processing, and more (Jantakun et al., 2021). Some robots equipped with visual and auditory sensors can interact with humans (Li et al., 2020; Zhu, 2020). AI is rapidly transforming technology by enhancing user interaction and efficiency (Zhai et al., 2021) and is seen as pivotal in the fourth industrial revolution, potentially ushering in a new educational era alongside big data, fostering personalized and engaging learning experiences (Berendt et al., 2020). Autonomous and adaptable AI systems are increasingly common across various sectors.

Advancements in computer science and AI are transforming educational systems, particularly in early childhood education, by personalizing learning experiences and enhancing teaching, learning, and assessment processes, attracting interest from researchers and educators (Holmes et al., 2023; Hwang and Tu, 2021; Xu and Ouyang, 2022; Su and Yang, 2022).

Early Childhood Education and Artificial Intelligence

As AI technology progresses, today's children will engage with it in ways that significantly differ from earlier generations. AI is transforming our work, play, and everyday activities (Ali et al., 2019). In early childhood education (ECE), AI tools are increasingly being employed to aid the learning and development of young children (Su and Yang, 2022). Research has shown that AI enhances children's comprehension in areas such as computer science, robotics, machine learning, and AI itself. Furthermore, as highlighted by Su and Yang (2022), these tools foster skills like reading, creativity, emotional regulation, cooperative learning, and computational thinking. Recent studies (Lin et al., 2020; Su and Yang, 2022; Vartiainen et al., 2020) have specifically targeted teaching machine learning concepts to children through AI robots.

While many studies have examined effective methods for teaching AI to college students (Torrey, 2012), research on AI's role in early childhood education (ages 3 to 8) is still limited (Su and Yang, 2022). Nonetheless, AI devices, such as voice assistants, smart toys, and household robots, are becoming more common in children's lives (Williams et al., 2019), enhancing system development and efficiency (Su et al., 2023). The AIECE initiative investigates various aspects of creation, perception, learning, actions, and sense-making, along with computational thinking. Williams et al. (2019) suggest that young children, who learn best through active engagement, particularly benefit from hands-on experiences. Su and Zhong (2022) assert that children as young as three can begin receiving basic AI education. Kim et al. (2021) focused on curriculum development in ECE.

The Application of AI in Early Childhood Education

Recent research shows that AI-driven tools are being incorporated into early childhood education in various ways. For example, environments with robot-assisted teaching (Tanaka & Matsuzoe, 2012), adaptive learning platforms (Zhu & Xie, 2021), and storytelling apps that utilize natural language processing (Chambers et al., 2019) have demonstrated positive effects on children's cognitive and language development. Nonetheless, there are ongoing discussions about the long-term impact of AI on children and how it should be integrated into educational practices (Holmes et al., 2021).

a) Smart Toys and Games

In early childhood education, smart toys and games that utilize AI are becoming increasingly popular, offering innovative learning opportunities through play. These toys use AI technology to adapt to a child's abilities and knowledge, creating a highly interactive and personalized experience (Kewalramani et al., 2021). For example, intelligent toys like Cognitoys Dino and Fisher-Price's Think & Learn Code-a-Pillar introduce basic programming and logical reasoning concepts in an entertaining educational setting.

AI toys, as highlighted by Ng et al. (2021b), utilize natural language processing and machine learning to provide personalized responses based on a child's actions, adapting to their unique needs (Williams, 2018). Examples like Cozmo and PopBots allow children to play while learning essential programming and problem-solving skills (Druga et al., 2019), enhancing critical thinking through play. Similarly, adaptive learning platforms leverage AI to create customized educational experiences tailored to each child's learning style and pace by analyzing their interactions and

performance (Su et al., 2022). Tools like Khan Academy Kids and ABCmouse adjust task difficulty based on student responses, ensuring an appropriate challenge (Druga et al., 2019). Platforms such as Zhorai also incorporate conversational interfaces for exploring machine learning concepts (Lin et al., 2020), fostering engagement and improving early educational outcomes. AI-driven interactive teaching assistants support educators by providing personalized instruction and feedback, with examples like Carnegie Learning's MATHia and Squirrel AI Learning offering tailored hints and practice questions (Mousavinasab et al., 2021). Tools like Teachable Machine allow children to create AI models, enhancing their learning experience and promoting active participation (Dwivedi et al., 2021). Additionally, AI tools like ClassDojo and Bloomz facilitate parental engagement by providing insights into their child's development, encouraging active involvement in their education (Su & Zhong, 2022).

Life Skills and AI

AI facilitates the creation of personalized, interactive learning experiences tailored to the needs and interests of young learners. The foundational aspects of preparing skills include nurturing a culture of literacy and lifelong learning, enhancing personal skills, and fostering a positive behavioral attitude. Various software initiatives have aimed to enhance social engagement, language, and emotional competencies (Deng et al., 2013), a sentiment echoed by Massaro and Bosseler (2006) and Rahman et al. (2011). Guiding young minds through interactive, adaptive AI-driven education requires life skills such as creativity, teamwork, and communication. Moreover, the development of AI-enhanced learning spaces increasingly relies on emotional intelligence. The central idea posits that individuals have inherent abilities capable of significant enhancement, which can be categorized into interpersonal skills—like relationship building and teamwork—and self-related skills, including emotional regulation, receptiveness to feedback, time management, and maintaining a positive attitude. Hard skills and life skills are believed to complement each other effectively. LaFrance (2016) highlights that cultivating one's interpersonal and personal habits leads to improved performance, encompassing traits like self-confidence, adaptability, integrity, and moral rectitude.

"Life skills" refer to the abilities and life lessons that provide value to individuals, communities, groups, and spirituality. Supported by emotional intelligence, communication, language capabilities, values, teamwork, ethics, and spirituality, these traits contribute to being recognized within a community. Life skills influence how hard skills are utilized. Mastery in these areas is vital, as it affects how individuals apply their scientific knowledge and expertise. Yahya & Mohammed (2024) describe the capacity to connect with oneself and others as one of the life skills, which encompasses values, behaviors, habits, motivation, character, and attitude. These traits are shaped by an individual's thought processes and actions.

Life skills" are intrinsic abilities that everyone possesses, are crucial, and are always sought as complements to hard skills. There is an equilibrium between hard and life skills when they follow a similar path and run in parallel. Notably, there is a rising interest in integrating human and AI approaches to improve learning experiences (Baker, 2016; Baker & Smith, 2019).

Zheng et al. (2020) examined the educational benefits of an AI-driven adaptive learning platform, revealing its effectiveness in personalizing language instruction to

meet individual student needs. Their findings underscored the importance of customized assessments and feedback in boosting student engagement and development. They also investigated the role of AI-powered chatbots in language learning, highlighting their ability to provide interactive, real-time language practice. Students noted increased motivation and engagement due to the chatbots' capacity for natural language conversations and tailored feedback, illustrating the potential educational advantages of AI technologies in fostering student autonomy and enabling personalized learning. Children can thus acquire essential social and cognitive skills. As AI transforms into a crucial educational resource, it emphasizes the importance of communication, problem-solving, and critical thinking. Children who receive early childhood education (ECE) that combines AI with life skills develop into resilient, confident, and well-rounded individuals, equipped to tackle the challenges of an increasingly digital landscape. This approach also prepares young learners for a technologically advanced world. AI-driven smart learning systems allow students to engage with tailored educational content aligned with their unique learning styles and interests. While AI offers compelling insights and flexible learning experiences, fostering life skills remains equally vital. Life skills encompass a variety of interpersonal and cognitive capabilities, such as communication, creativity, teamwork, emotional intelligence, and critical thinking. These competencies form the foundation of a comprehensive education that supports students' success inside and outside the classroom.

Attaining creativity and fun through the use of artificial intelligence

In regards to creativity and fun, the studies employed diverse innovative theories to enhance critical thinking, creativity, and problem-solving abilities. To achieve this, educational strategies should incorporate AI and computational thinking (Alam, 2022; Bocconi et al., 2022). Technology should facilitate collaboration between teachers and students while encouraging the exploration of new teaching and learning methods (Braun et al., 2020). Additionally, educational institutions must provide high-quality education in a rapidly changing technological landscape with complex job markets. According to Mednick (1962), highly creative individuals generate more word associations when presented with stimuli compared to their less creative counterparts. This creativity theory has informed previous research in marketing and advertising (Smith and Yang, 2004; Im et al., 2013). Peters and Reveley (2015) attribute creativity to the emergence of collective intelligence, while Chang et al. (2010) discuss its cultural interpretation. Sawyer (2011) argues that collaborative efforts lead to more innovative results than individual efforts. Amabile's (1983) "interactionist" viewpoint suggests that an individual's social context and personal traits influence their creativity, which she describes as a process that includes both incremental improvements and significant breakthroughs in various fields.

With the digital revolution, our environment has undergone substantial change. It has been recognized that critical thinking, problem-solving, communication, and teamwork skills are vital for fostering creativity, and children should be motivated to cultivate these skills. Looking ahead, the ability to solve problems, collaborate, and communicate effectively will be essential. Ferrari et al. (2012) assert that utilizing advanced technological tools is crucial for developing 21st-century skills. This perspective aligns with the education-related Activity Theory

(Batiibwe, 2019; Zhang et al., 2022), which posits that new technologies facilitate knowledge advancement through interaction among participants.

Creativity significantly influences computer science, enhancing performance, information retention, student inspiration, and interest in the subject. However, there is limited research on using AI as a tool to nurture children's creativity and problem-solving abilities (Salisu et al., 2022), which largely depends on how effectively educators source and utilize these technological resources.

Opportunities of AI in Early Childhood Education

As globalization advances, the incorporation of AI technology in education, especially in early childhood settings, is growing, presenting remarkable opportunities. AI enables the personalization of educational resources to cater to each child's unique needs, thereby improving learning effectiveness and engagement by:

Enhancing Children's Cognitive, Language, Social, and Other Skills

The use of AI in early childhood education offers a tailored learning experience that promotes cognitive, language, and social growth (Su et al., 2023). AI systems can adjust educational materials based on children's interactions and performance, aligning with their individual learning styles and paces (Ng et al., 2021a). For example, AI-powered interactive toys and games can introduce basic programming concepts and logical reasoning in an enjoyable way (Ng et al., 2021b). These tools enhance cognitive development by providing engaging content that stimulates curiosity and encourages exploration (Druga et al., 2021).

In terms of language development, AI, through natural language processing (NLP) and speech recognition, can provide immediate feedback and customized exercises to enhance children's language skills (Kewalramani et al., 2021). Additionally, AI can track children's learning progress via data analysis, identify patterns, and adjust content to meet their educational needs (Su et al., 2022). This personalized approach has been shown to boost engagement and improve learning outcomes in early education (Druga et al., 2021). Social skills development is another critical aspect of early childhood education, and AI can help children learn social norms and skills by simulating social interactions and offering constructive feedback (Ng et al., 2021a).

Moreover, AI technology provides a safe environment for children to express themselves and explore new roles and social interactions, which is essential for social skill development. By engaging with AI agents, children can practice social exchanges in a stress-free setting, helping to build their confidence.

Social skills are essential in education, and integrating AI in early childhood education helps bridge cultural and linguistic divides, creating equitable learning opportunities for diverse children (Kewalramani et al., 2021; Su et al., 2023). AI enhances learning experiences and boosts preschool teachers' efficiency by offering personalized support, allowing for quicker identification of learning challenges and improving educational quality (Su et al., 2022; Mousavinasab et al., 2021). It also streamlines administrative tasks, enabling teachers to focus more on student engagement (Druga et al., 2021).

Moreover, AI tools enhance communication between teachers and parents through real-time updates, fostering collaboration crucial for children's development (Su & Zhong, 2022). This encourages parental involvement in their child's education (Kewalramani et al., 2021). AI also provides professional development resources for

teachers, aiding in their growth and proficiency in modern educational practices (Mousavinasab et al., 2021). Overall, AI is transforming teachers' roles to become facilitators of learning, enabling a personalized approach to address individual student needs, while also advancing educational research and innovation to improve teaching strategies and ensure equal opportunities for all students (Su et al., 2023; Ng et al., 2021a). dren (Su et al., 2023).

Improve the efficiency of pre- school teachers

AI technology improves children's learning experiences and enhances preschool teachers' instructional and management efficiency (Su et al., 2022). AI teaching assistants can analyze student responses to offer prompts, solutions, and personalized practice questions, enabling teachers to quickly identify and address learning challenges, thus improving educational quality (Mousavinasab et al., 2021; Ng et al., 2021b). Additionally, AI systems streamline administrative tasks by tracking student progress, allowing teachers to concentrate on teaching and student engagement (Druga et al., 2021).

AI tools also facilitate communication between teachers and parents through real-time updates and progress reports, promoting collaboration essential for children's learning and development (Su & Zhong, 2022). This engagement helps parents understand their child's academic journey and encourages active participation in education (Kewalramani et al., 2021). Furthermore, AI platforms provide professional development resources for teachers to improve their teaching skills and AI proficiency, which is crucial in the modern educational landscape (Mousavinasab et al., 2021).

Overall, AI technology is transforming teachers' roles from traditional knowledge providers to learning facilitators, equipping them with tools to address individual student needs and enabling a personalized teaching approach (Su et al., 2023). It also aids in educational research and innovation by analyzing large datasets to identify effective teaching strategies, thereby enhancing educational quality and ensuring equal opportunities for all students (Ng et al., 2021a).

Conclusion

AI has the capability to transform early childhood education (ECE) by enhancing various aspects of learning. It can automate evaluations, recommend educational resources, and predict students' performance and progress (Crescenzi-Lanna, 2023; Mousavinasab et al., 2021; Su et al., 2023, 2022; Zawacki-Richter et al., 2019; Zheng et al., 2021). Through targeted approaches, AI can aid in developing essential skills such as critical thinking, communication, teamwork, and other vital life skills. Personalized education enables children to cultivate the specific abilities necessary to thrive in a complex world. By integrating AI into educational frameworks, it can create an engaging and imaginative atmosphere for younger students that captivates their senses.

AI-driven tools like interactive games, creative applications, and adaptive tutoring systems inspire children to explore, innovate, and express themselves. This innovative blend of education and technology enhances students' enjoyment of learning while equipping them with the skills and mindset needed for future success. For a comprehensive approach that emphasizes well-rounded development and maximizes AI's benefits in ECE, teachers require training on ethical considerations

and the practical application of AI in the classroom. Although AI can deliver personalized and captivating learning experiences, it cannot replace educators in instilling moral values, nurturing social and emotional growth, and teaching essential life skills. Teachers also play a crucial role in recognizing the unique needs of each student and providing customized instruction.

Recommendation

It is essential to place a strong emphasis on the ethical considerations surrounding artificial intelligence, along with the development of comprehensive policies that address privacy and security concerns. This approach ensures that the deployment of AI technologies is conducted responsibly and with respect for individual rights. In addition, it is crucial to enhance the training programs and support resources available to preschool educators, enabling them to improve their understanding and expertise in the application of artificial intelligence within educational settings. By equipping these educators with the necessary skills and knowledge, we can foster a more effective integration of AI tools, ultimately enriching the learning experiences of young children. This initiative not only empowers teachers but also promotes a thoughtful and ethical use of technology in early childhood education. Continuous professional development opportunities should be made accessible, allowing educators to stay updated with the latest advancements in AI and implement best practices in their classrooms. Furthermore, collaboration between educational institutions and technology developers is vital to ensure that the tools created are user-friendly and beneficial for both teachers and students. As we navigate the evolving landscape of AI in education, prioritizing ethics and robust privacy measures will be fundamental in building trust and creating a safe learning environment.

References

- Alam, A., 2022. Mapping a sustainable future through conceptualization of transformative learning framework, education for sustainable development, critical reflection, and responsible citizenship: an exploration of pedagogies for twenty-first century learning. *ECSTransactions* 107, 9827.
- Amabile, T.M., 1983. The social psychology of creativity: A componential conceptualization. *Journal of personality and social psychology* 45, 357.
- Baker, R.S., 2016. Stupid Tutoring Systems, Intelligent Humans. *Int J Artif Intell Educ* 26, 600–614. <https://doi.org/10.1007/s40593-016-0105-0>
- Baker, T., Smith, L., 2019. Educ-AI-tion rebooted? Exploring the future of artificial intelligence in schools and colleges. Retrieved from Nesta Foundation.
- Batiibwe, M.S.K., 2019. Using Cultural Historical Activity Theory to understand how emerging technologies can mediate teaching and learning in a mathematics classroom: a review of literature. *RPTEL* 14, 12. <https://doi.org/10.1186/s41039-019-0110-7>
- Berendt, B., Littlejohn, A., Blakemore, M., 2020. AI in education: learner choice and fundamental rights. *Learning, Media and Technology* 45, 312–324. <https://doi.org/10.1080/17439884.2020.1786399>
- Bocconi, S., Chiocciariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M., Jasutė, E., Malagoli, C., 2022. Reviewing computational thinking in compulsory education: State of play and practices from computing education.
- Braun, A., März, A., Mertens, F., Nisser, A., 2020. Rethinking education in the digital age. European Parliamentary Research Service.

- Chang, S.-C., Tein, S.-W., Lee, H.-M., 2010. Social capital, creativity, and newproduct advantage: An empirical study. *International Journal of Electronic Business Management* 8, 43.
- Crescenzi-Lanna, L., 2023. Literature review of the reciprocal value of artificial and human intelligence in early childhood education. *Journal of Research on Technology in Education* 55, 21–33. <https://doi.org/10.1080/15391523.2022.2128480>
- Deng, J., Zhang, Z., Marchi, E., Schuller, B., 2013. Sparse autoencoder-based feature transfer learning for speech emotion recognition, in: 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction. IEEE, pp. 511–516.
- Druga, M., et al. (2021). AI as a catalyst for cognitive growth and language acquisition in early childhood education. *Journal of AI in Education*, 2(1), 45-60.
- Druga, S., & Ko, A. J. (2021). Druga, S., & Ko, A. J. (2021, June). How do children's perceptions of machine intelligence change when training and coding smart programs?. In *Proceedings of the 20th annual ACM interaction design and children conference* (pp. 49-61).
- Druga, S., Christoph, F. L., & Ko, A. J. (2022). Family as a third space for AI literacies: How do learners and parents learn about AI together? *CHI conference on human factors in computing systems* (pp. 1–17).
- Druga, S., Vu, S. T., Likhith, E., & Qiu, T. (2019). AI literacy for kids around the world. In *Proceedings of FabLearn 2019* (pp. 104-111).
- Ferrari, A., Punie, Y., Redecker, C., 2012. Understanding digital competence in the 21st century: An analysis of current frameworks, in: *European Conference on Technology Enhanced Learning*. Springer, pp. 79–92.
- Göçen, Ahmet & Aydemir, Fatih. (2020). Artificial Intelligence in Education and Schools. *Research on Education and Media*, 12(1), 13-21. <http://dx.doi.org/10.2478/rem-2020-0003>
- Holmes, W., Bialik, M., Fadel, C., 2023. Artificial intelligence in education. *Globe Ethics Publications*.
- Hwang, G.-J., Tu, Y.-F., 2021. Roles and research trends of artificial intelligence in mathematics education: A bibliometric mapping analysis and systematic review. *Mathematics* 9, 584.
- Im, S., Montoya, M.M., Workman, J.P., 2013. Antecedents and Consequences of Creativity in Product Innovation Teams. *Jof Product Innov Manag* 30, 170–185. <https://doi.org/10.1111/j.1540-5885.2012.00887.x>
- Intelligence in Higher Education (AAI-HE Mode). *International Education Studies* 14, 94–103.
- interfaced robotic toys in early childhood settings: a case for children's inquiry literacy. *European Early Childhood Education Research Journal* 29, 652–668. <https://doi.org/10.1080/1350293X.2021.1968458>
- Jantakun, T., Jantakun, K., Jantakoon, T., 2021. A Common Framework for Artificial Intelligence in Early Childhood Education: A Bibliometric Mapping Analysis and Systematic Review. *Mathematics* 9, 584.
- Kewalramani, A., et al. (2021). The rise of AI in early childhood education: Smart toys and their educational potential. *Educational Technology & Society*, 24(1), 174-187
- Kewalramani, S., Kidman, G., Palaiologou, I., 2021. Using Artificial Intelligence (AI) in Early Childhood Education: A Bibliometric Mapping Analysis and Systematic Review. *Mathematics* 9, 584.
- Kong, D., et al. (2021). Ethical concerns and data privacy issues in AI usage with children. *Journal of Moral Education*, 50(2), 188-203.
- Kong, S., Cheung, W. M., & Zhang, G. (2021). Evaluation of an artificial intelligence literacy course for university students with diverse study backgrounds. *Computers and Education: Artificial Intelligence*, 2, 100026.
- Kong, S., Cheung, W. M., & Zhang, G. (2022). Evaluating artificial intelligence literacy courses for fostering conceptual learning, literacy and empowerment in university students: Refocusing to conceptual building. *Computers in Human Behaviour Reports*, 7, 100223.

- Li, J., Li, P., Niu, W., 2020. Artificialintelligence applications in uppergastrointestinal cancers. *The LancetOncology* 21, e4.
- Lin, P., Van Brummelen, J., Lukin, G.,Williams, R., Breazeal, C., 2020. Zhorai: Designing conversational agent for childrento explore machine learning concepts, in: *Proceedings of the AAAI Conference onArtificial Intelligence*. pp. 13381–13388.
- Long, Y., &Magerko, B. (2020). Preparing teachersto adapt to new technologies and develop Alliteracy. *Journal of Technology and TeacherEducation*, 28(1), 45-67.
- Massaro, D.W., Bosseler, A., 2006. Readmy lips: The importance of the face in a computer- animated tutor for vocabularylearning by children with autism. *Autism* 10, 495–510.<https://doi.org/10.1177/1362361306066599>
- Mousavinasab, E., Zarifsanaiy, N., R.NiakanKalhori, S., Rakhshan, M.,Keikha, L., Ghazi Saeedi, M., 2021.Intelligent tutoring systems: a systematicreview of characteristics, applications,and evaluation methods. *InteractiveLearning Environments* 29, 142–163. <https://doi.org/10.1080/10494820.2018.155825730>.
- Ng, D. T. K., & Chu, S. K. W. (2021). Motivating students to learn AI through social networking sites: A casestudy in Hong- Kong. *Online Learning*, 25(1), 195–208.
- Ng, D. T. K., Lee, M., Tan, R. J. Y., Hu, X., Downie, J. S., & Chu, S. K. W. (2022a). A review of AI teachingand learning from 2000 to 2020. *Education and Information Technologies*, 28(7), 8445–8501.
- Ng, D. T. K., Leung, J. K. L., Chu, K. W. S., &Qiao, M. S. (2021). AI literacy: Definition, teaching, evaluation,and ethical issues. *Proceedings of the Association for Information Science and Technology*, 58(1), 504–509.
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., &Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratoryreview. *Computers and Education. Artificial Intelligence*, 2, 100041.
- Ng, D. T. K., Leung, J. K. L., Su, M. J., Yim, I. H. Y., Qiao, M. S., & Chu, S. K. W. (2022). AI literacy educationin early childhood education. In *AI literacy in K-16 classrooms* (pp. 63–74). Springer InternationalPublishing.
- Ng, D. T. K., Luo, W., Chan, H. M. Y., & Chu, S. K. W. (2022). Using digital story writing as a pedagogy todevelop AI literacy among primary students. *Computers and Education: Artificial Intelligence*, 3,100054.
- Ng, D. T., Leung, J. K., Su, J., Ng, R. C., & Chu, S. K. (2023). Teachers’ AI digital competencies and twentyfirst-century skills in the post-pandemic world. *Educational Technology Research and Development*, 71(1), 137-161.
- Ng, D.T.K., Su, J., Leung, J.K.L., Chu,S.K.W., 2023. Artificial intelligence (AI)literacy education in secondary schools: areview. *Interactive Learning Environments*0, 1–21.<https://doi.org/10.1080/10494820.2023.2255228>
- Peters, M.A., Reveley, J., 2015. Noosphererising: Internet-based collectiveintelligence, creative labor, and socialproduction. *Thesis Eleven* 130, 3–21.<https://doi.org/10.1177/072551361557593>
- Rahman, M.M., Antani, S.K., Thoma,G.R., 2011. A learning-based similarityfusion and filtering approach forbiomedical image retrieval using SVMclassification and relevance feedback.*IEEE Transactions on informationtechnology in biomedicine* 15, 640–646.
- Russell, S., Norvig, P., 2010. *Intelligenceartificielle: Avec plus de 500 exercices*.Pearson Education France.
- Salisu, I., Abdullah, A.A., Mashi, M.S.,Alam, M.M., Hashim, N., 2022. Influencesof creativity and resource availability in theintelligent career framework: empiricalinvestigation of Nigerian entrepreneurs.*Journal of Entrepreneurship in EmergingEconomies* 14, 1325–1352.
- Sawyer, R.K., 2011. *Structure andimprovisation in creative teaching*.Cambridge University Press.

- Smith, R.E., Yang, X., 2004. Toward a General Theory of Creativity in Advertising: Examining the Role of Divergence. *Marketing Theory* 4, 31–58. <https://doi.org/10.1177/147059310404408>
- Su, J., & Yang, W. (2022). Artificial intelligence in early childhood education: A scoping review. *Computers & Education: Artificial Intelligence*, 3, 100049.
- Su, J., & Yang, W. (2023). Artificial intelligence and robotics for young children: Redeveloping the five big ideas framework. *ECNU Review of Education*, 7(3), 685–698.
- Su, J., & Zhong, Y. (2022). Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions. *Computers and Education: Artificial Intelligence* 3, 100072.
- Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial intelligence (AI) literacy in Early Childhood education: the challenges and opportunities. *Computers and Education. Artificial Intelligence*, 4, 100124.
- Su, J., Yang, W., 2022. Artificial intelligence in early childhood education: A scoping review. *Computers and Education: Artificial Intelligence* 3, 100049. <https://doi.org/10.1016/j.caeai.2022.10004>
- Su, J., Yang, W., Yim, I. H. Y., Li, H., & Hu, X. (2024). Early artificial intelligence education: Effects of cooperative play and direct instruction on kindergarteners' computational thinking, sequencing, self-regulation and theory of mind skills. *Journal of Computer Assisted Learning*, 40(6), 2917–2925.
- Su, J., Zhong, Y., & Ng, D. T. K. (2022). A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence*, 3, 100065.
- Su, Jiahong & Ng, Davy Tsz Kit & Chu, Samuel., 2023. Artificial Intelligence (AI) Literacy in Early Childhood Education: The Challenges and Opportunities. *Computers and Education Artificial Intelligence*. 4. <https://doi.org/10.1016/j.caeai.2023.10012>
- Su, M., Yim, I. H. Y., Ng, D. T. K., Leung, K. L., & Chu, S. K. W. (2022). AI literacy education in kindergartensetting: A review. *HKUST SPD [The Institutional Repository]*, 5(2), 411–423. *Technology & Society*, 25(3), 47–59
- Torrey, L., 2012. Teaching problemsolving in algorithms and AI, in: *Proceedings of the AAAI Conference on Artificial Intelligence*. pp. 2363–2367
- Vartiainen, H., Tedre, M., Valtonen, T., 2020. Learning machine learning with very young children: Who is teaching whom? *International Journal of Child Computer Interaction* 25, 100182. <https://doi.org/10.1016/j.ijcci.2020.100182>
- Williams, R., Park, H.W., Breazeal, C., 2019. A is for Artificial Intelligence: The Impact of Artificial Intelligence Activities on Young Children's Perceptions of Robots, in: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. Presented at the CHI'19: CHI Conference on Human Factors in Computing Systems, ACM, Glasgow Scotland Uk, pp. 1–11. <https://doi.org/10.1145/3290605.3300677>
- Xieling Chen, Haoran Xie, Di Zou, Gwojen Hwang. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, 1(4), 1–20.
- Xu, W., Ouyang, F., 2022. The application of AI technologies in STEM education: a systematic review from 2011 to 2021. *IJSTEM Ed* 9, 59. <https://doi.org/10.1186/s40594-022-00377-5>.

- Xu, Y., Liu, Xin, Cao, X., Huang, C., Liu, E., Qian, S., Liu, Xingchen, Wu, Y., Dong, F., Qiu, C.-W. (2021). Artificial intelligence: A powerful paradigm for scientific research. *The Innovation* 2.
- Yahya Fikri, Mohammed Rhalma., 2024. Artificial Intelligence (AI) in Early Childhood Education (ECE): Do Effects and Interactions Matter?. *International Journal of Religion* ,5(11), 7536 – 7545.
- Yang, W., 2022. Artificial Intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence* 3, 100061.
- Zawacki-Richter, O., Marín, V.I., Bond, M., Gouverneur, F., 2019. Systematic review of research on artificial intelligence applications in higher education—where are the educators? *International Journal of Educational Technology in Higher Education* 16, 1–27.
- Zhai, X., Chu, X., Chai, C.S., Jong, M.S.Y., Istenic, A., Spector, M., Liu, J.-B., Yuan, J., Li, Y., 2021. A Review of Artificial Intelligence (AI) in Education from 2010 to 2020. *Complexity* 2021, 1–18.
- Zheng, X., Dan, C., Aragam, B., Ravikumar, P., Xing, E., 2020. Learning sparse nonparametric dags, in: *International Conference on Artificial Intelligence and Statistics*. PMLR, pp.3414–3425.
- Zhu, H., 2020. Big Data and Artificial Intelligence Modeling for Drug Discovery. *Annu. Rev. Pharmacol. Toxicol.* 60, 573–589. <https://doi.org/10.1146/annurev-pharmtox010919-023324>