Learning for All with AI? 100 Influential Academic Articles of Educational Robots

Book · April 2023

Ronghuai Huang
Beijing Normal University

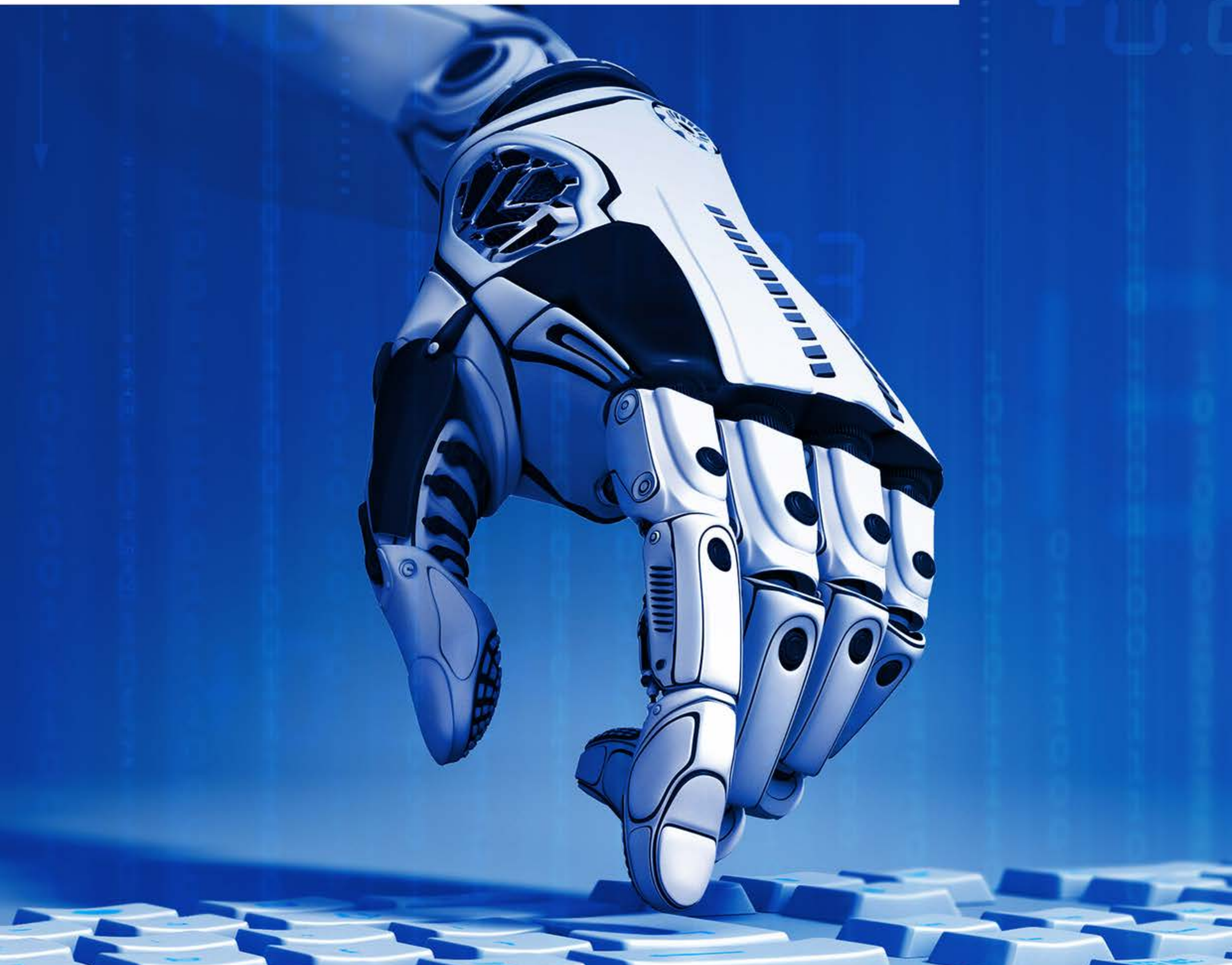
Michael Adarkwah
Friedrich Schiller University Jena

UNESCO CHAIR ON
AI IN EDUCATION

unesco
Chair

Learning for All with AI?

100 Influential Academic Articles of Educational Robots



United Nations
Educational, Scientific and
Cultural Organization

International Research
and Training Centre
for Rural Education

北京师范大学智慧学习研究院
Smart Learning Institute of Beijing Normal University

Learning for All with AI? 100 Influential Academic Articles of Educational Robots

Please cite the work as follows:

Huang, R., Liu, D., Chen, Y., Adarkwah, M. A., Zhang, X.L., Xiao, G.D., Li, X., Zhang, J.J., Da, T. (2023).

Learning for All with AI? 100 Influential Academic Articles of Educational Robots. Beijing: Smart Learning Institute of Beijing Normal University.

Learning for All with AI?

100 Influential Academic Articles of Educational Robots

Preface

Embracing a New Era: Facilitating Teaching and Learning through Robotics

Artificial Intelligence and Robotics in Education

Artificial intelligence (AI) is rapidly developing, which has already brought us to what can be considered the "intelligent era" where AI has penetrated almost every aspect of society. This can be seen by the series of sophisticated products and services that have emerged to form an "AI ecosystem" which has brought with it the benefits of the technology to individuals, to businesses and to service of public interest. In 2019, UNESCO published the Beijing Consensus on Artificial Intelligence and Education (UNESCO, 2019), the first ever document to offer guidance and recommendations on how best to harness AI technologies for achieving the Education 2030 Agenda. In 2021, United Nations Educational, Scientific, and Cultural Organization (UNESCO) issued "AI and education: guidance for policy-makers" (Miao et al., 2021) which shared the belief that the use of AI-enabled or 'smart' robots in education is a way in which AI can be leveraged to enhance education. In "Gathering Strength, Gathering Storms: The One Hundred Year Study on Artificial Intelligence (AI100) 2021 Study Panel Report" (Michael et al., 2021) issued by Stanford University, robotics is also regarded as one of the most important advances in AI, and its development was driven in part by the need to support social distancing during the COVID-19 pandemic. In 2022, UNESCO published "K-12 AI curricula: A mapping of government-endorsed AI curricula" (UNESCO, 2019) to guide the future planning of enabling policies, the design of national curricula or institutional study programs, and implementation strategies for AI competency development.

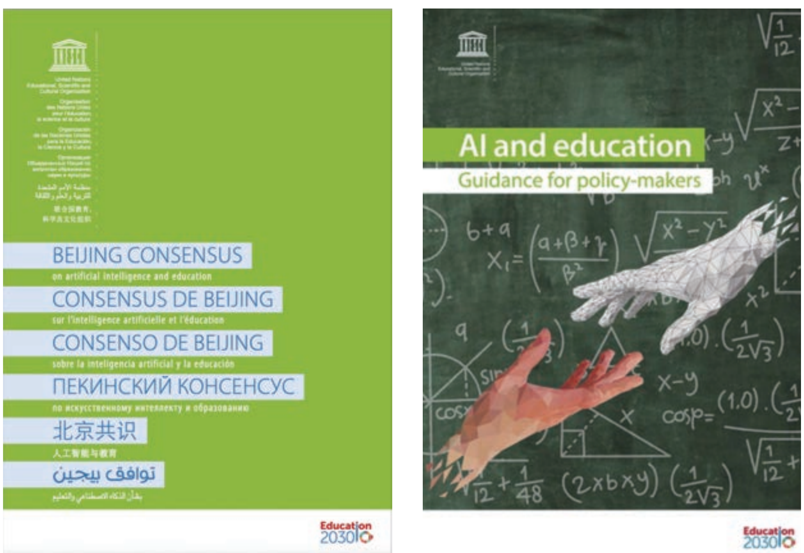


Figure 1 Beijing Consensus on Artificial Intelligence and Education (left) and AI and education: Guidance for policy-makers (right)

Guiding Policies for Promoting Educational Robots

Various countries all over the world have issued statements regarding AI in the field of education. The US National Science Foundation issued the "US Innovation and Competition Act of 2021" (United States, 2021), which clarified that AI was identified as a key field and would become a focus of the United States in responding to challenges. The Ministry of Defense of the UK released "The Defense Artificial Intelligence Strategy" (UK Ministry of Defence, 2022) which elaborated on the importance of AI, the strategic vision of the British government for AI, the advantages of the development of artificial intelligence in the UK, the four strategic objectives and the methods to achieve these strategic objectives. The German government likewise published its strategy for AI in 2018 (Germany, 2018). This strategy put forward three core objectives, twelve action areas and relevant promotion measures for the development of AI technology in Germany, in order to accelerate the development and application of AI technology and ensure Germany's future competitiveness.

Against a background of fierce competition, the State Council of China published "Development Planning for a New Generation of Artificial Intelligence" (State Council of China, 2017) in 2017, putting forward the guiding ideology, strategic objectives, key tasks and guarantee measures for the development of China's new generation of AI. The Ministry of Education of China has additionally issued the "Educational Informatization 2.0 Action Plan" (Ministry of Education of the People's Republic of China, 2018) in 2018 and "Guiding Opinions on Promoting the Construction of New Educational Infrastructure and Building a High-Quality Education Support System" (Ministry of Education and other six departments of China, 2021) in 2021. All these statements set the strategy of educational transformation and modernization, by strengthening the research and application of key technologies such as intelligent teaching assistants, educational robots, intelligent companions and those related to language and text informatization.

Learning with Educational Robots

Educational robots form an important part of the smart learning environment. In recent years, there has been a rise in the popularity of the application of robots in education to offer teachers and students interactive and engaging ways to enhance the learning process. Around the world, governments are launching initiatives aimed at the optimal use of robots that incorporates AI to advance education in this intelligent era. In China, 15 departments including the Ministry of Industry and Information Technology have issued "The 14th Five-Year Plan" for robot industry development in 2021. In the report, it is proposed that service robots and special robots should be applied in the fields of warehousing and logistics, education and entertainment, cleaning services, security inspection, medical rehabilitation, etc.

Scientific breakthroughs and practical explorations have been made over the past decades in each of the above-stated fields, and this trend is forecasted to continue throughout the near future. Numerous published studies emphasize the improvement of learning performance and accomplishment of teaching goals through robotics. Incorporating robotics in education is essential for educational environments seeking to provide novel and innovative learning methods needed to equip students with twenty-first-century skills such as fostering and enhancing thinking skills (Evripidou et al., 2020), problem-solving skills (Atmatzidou et al., 2017), creativity (Nemiro et al., 2017), motivation (Master et al., 2017; Daniela & Strods, 2018), and computational thinking (Chen et al., 2017). The application of robots in students with special needs is also acquiring a great importance (Di Lieto et al., 2020). Therefore, with such a wide range of uses, robotic products and platforms have continued to emerge in order to meet different educational scenario requirements. In homes, educational robots can be used as intelligent toys for children's entertainment robots can play games with preschool children, monitor their safety and health condition, language learning partners (particularly for ages 3-5 at the critical period for language acquisition), and learning companions for individual development. In classroom, robots can help students to do their assignments, be utilized as teaching aids for Science, Technology, Engineering, Mathematics (STEM) courses, and play the role of a teaching assistant to provide three kinds of services to the teachers including pre-class preparation, in-class assistance and after-class assistance. In training centers, robots can assist special education, like providing social assistance treatment for kids with autism. In schools, robots also can play the role of a smart classroom manager to provide context-aware control of hardware and software facilities. In vocational training, robots can also help industrial manufacturing training, surgical medical training, and rehabilitation. Robots can also provide companionship and cognitive training for the senior people. In all, educational robots serve a wide range of educational needs. They can not only innovate existing teaching and learning activities, but also create new educational services. As the scope of educational services covers a wide range of user groups and a variety of educational settings, there is a wide market for educational robots covering different age groups and application scenarios.

Figure 2 Article No. in Web of Science Core (SSCI+SCI Index)

Figure 3 "The Next Big Things: Global Development Status and Trends in Educational Robots" (left) and "Educational Robots White Paper 2019: The Global Development" (right)

Purpose of This Handbook

Smart Learning Institute(SLI) of Beijing Normal University is a comprehensive research station dedicate to scientific research, technology development and social experiments, and is committed to enabling global engagement and development of smart education strategies. In 2016, SLI published “The Next Big Things: Global Development Status and Trends in Educational Robots”, the first publication with the theme of educational robots in China. It has effectively promoted the research and development of educational robots, and therefore accelerate educational informatization. In 2019, SLI issued “Educational Robots White Paper 2019: The Global Development”, which is an attempt to analyze current status and development trends of global educational robots.

The principal objective of this handbook is to present state-of-the-art of educational robotics and how they can be harnessed to facilitate learning. To do this, a systematic approach has been utilized to present findings and discussions of hundred influential journal articles in the field of educational robotics in the past six years (2018-2023). The potential educational opportunities and challenges as a result of the incorporation of robotics in education are presented for educators and researchers to explore best practices in using robotics for learning and create effective solutions to tackle emerging problems.

By analyzing educational robotics, the handbook attempts to place emphasis on how robotics can be leveraged to provide sound pedagogical principles essential for the development of transferable skills needed in our contemporary society.

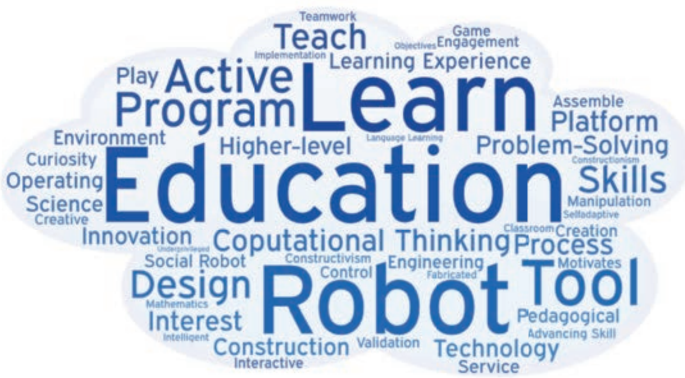


Figure 4 Word cloud generated from research articles

The handbook provides the reader with the key research organizations and journals that have extensively contributed to the field of educational robotics in the past six years. Additionally, the popular and relevant terms and theories in educational robotics are provided to help the reader gain background knowledge of the subject matter. The hundred influential academic articles obtained from the systematic search of literature are further categorized into seven thematic areas in educational robotics to highlight the key areas researchers are focusing on. The handbook aims to guide a reader in comprehending how different types of robots are utilized to promote learning among different types of students in different contexts and in different disciplines of study.

Acknowledgment

First and foremost, we wish to convey our utmost appreciation to the authors of the selected 100 articles, including but not limited to Tony Belpaeme of Ghent University, Rianne Van Den Berghe of Utrecht University, Marina Umaschi Bers of Tufts University, Huili Chen of Massachusetts Institute of Technology, Olimpia Pino of University of Parma, José-Manuel Sáez-López of Spanish National University of Distance Education, Mojtaba Shahab of Sharif University of Technology, whose efforts have significantly enriched the field of educational robotics research. Ow-

ing to constraints of space, this handbook has only included 40 articles for excerpt. However, we emphasize that all articles have high academic value.

We would like to acknowledge the contribution of several experts for their helpful comments and advices to enhance the quality of this handbook, especially Prof. Lei Fan of Capital Normal University, Prof. Xiangen Hu of University of Memphis, Prof. Zoran Miljkovic of University of Belgrad, Prof. Danimir Mandic of University of Belgrade, Prof. Mario Dumancic of University of Zagreb, and Yanyan Li of Beijing Normal University. We would like to thank all the experts who participated in our interview to provide a solid base for the formation of this handbook, namely Prof. Linmi Tao of Tsinghua University, Prof. Haiguang Fang of Capital Normal University, Prof. Chungming Own of Tianjin University, Prof. Jianxin Pang of UBTECH Robotics Corp Ltd, Mr. Kanqing Wang of LEGO Education and Mr. Ning Cui of UBTECH Robotics Corp Ltd. We would also like to thank Dr. Tingwen Chang and Mrs. Junxiu Wang of Beijing Normal University, who has been actively involved in the discussion and planning of this handbook project.

Many people have helped us in finalizing this handbook. We would like to acknowledge the diligent efforts of those researchers who coordinated the preparation and production of this handbook, namely Yuhe Wang, Zhaoyu Lin, Zhichao Yang and Stephanie Hollings.

Reading Guidelines of This Handbook

Defining Educational Robots

This handbook covers two types of educational robots: educational robotics and educational service robots.

Educational robotics is a series of activities, curriculums, physical platforms, educational resources, or educational philosophy aim to assist teaching and learning activities. Through design, assembling, programming and operation, educational robotics arouses the interest and curiosity of the students and nurtures learners' competencies. Modular robots and robot kits are common accessories in educational robotics, such as Lego Mindstorms, mBot are commonly used educational robotics for robotic teaching through hands-on activities.

Educational service robots are service robots with intelligence capable of teaching and learning. They are commonly used in auxiliary and management teaching in such domains as STEM education, language learning, and special needs learning programs. Different from the products commonly used in educational robotics, educational service robots have a fixed structure. In addition, users do not disassemble these robots by themselves. Educational Service Robots can be in the form of humans, animals, or vehicles in different shapes and sizes.

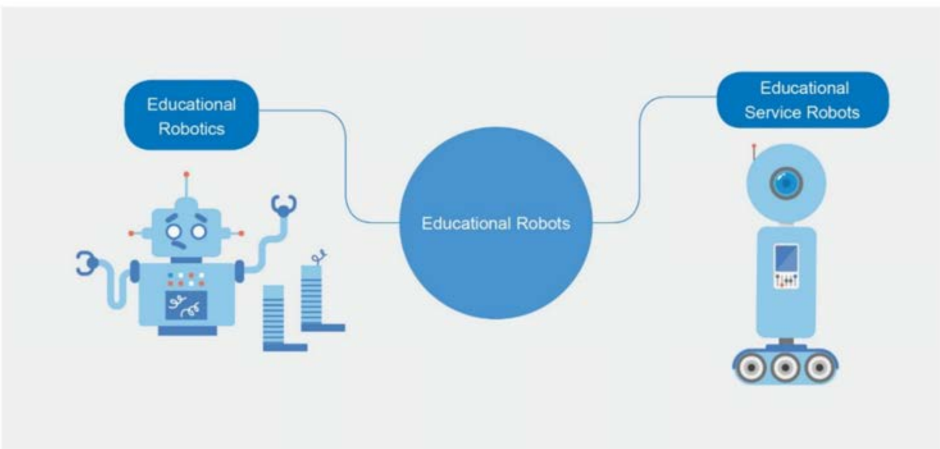


Figure 5 Educational robotics and educational service robots

The Selection of Papers and User Guidance

The 100 influential academic articles selected in this handbook had to be highly cited, with a cutting-edge proposal, representative of their fields and most trendy. In order to find these articles, the following process was followed:

Highly cited articles from Web of Science Core Collection

First, we retrieved data from the Web of Science Core Collection, which contains extensive resources on the online platform. It is a well-known trusted citation index for academic research, including no less than 21,000 peer-reviewed, high-quality academic journals accessible across the world. The included publications cover more than 250 disciplines in natural sciences, social sciences and humanities, as well as conference proceedings and books in various kinds of disciplines. Due to the large number of data included in it, we selected the Web of Science Core Collection as the main source of data used in this report.

We processed the data collected from published documents, which were selected based on the criteria: (1) the publications had to be rigorously designed; (2) the publications had to have arrived at conclusions through reliable and valid empirical research; (3) the publications had to be published after a rigorous peer-reviewed process; (4) the publications had to be related to the use of robots in the educational field. The data were obtained via publications in the online database Web of Science Core Collection (including databases of SCIE, SSCI, A&HCI and CPCI-S) using the terms (education* AND robot*) OR (teacher* AND robot*) OR (child* AND robot*) OR (student* AND robot*) OR (classroom* AND robot*) in titles from the timeframe of 2018 to 2022. Overall, we identified 484 peer-reviewed articles. Then, these articles were sorted by citation score and the top 100 articles with high citations were selected to represent highly cited articles.

Representative papers of top researchers and organizations

We conducted a statistical analysis of the total citation counts for each author of the selected literature and then sorted the authors in descending order based on their citation counts. We selected the top 20 authors with the highest citation counts, as well as the three papers that these authors were cited most frequently in the literature under analysis.

We also conducted a statistical analysis of the total citation counts for each research institution of the selected literature and then sorted the institutions in descending order based on their citation counts. We selected the top 20 institutions with the highest citation counts, as well as the three papers that these institutions were cited most frequently in the literature under analysis.

Snowballing literature from reference

To solicit literature on two key topics which are cognitive training for senior people and ChatGPT, we utilized the snowballing method.

Finally, we manually deleted articles that were irrelevant to the field of education and got the final list of articles to be reviewed and summarized in this handbook.

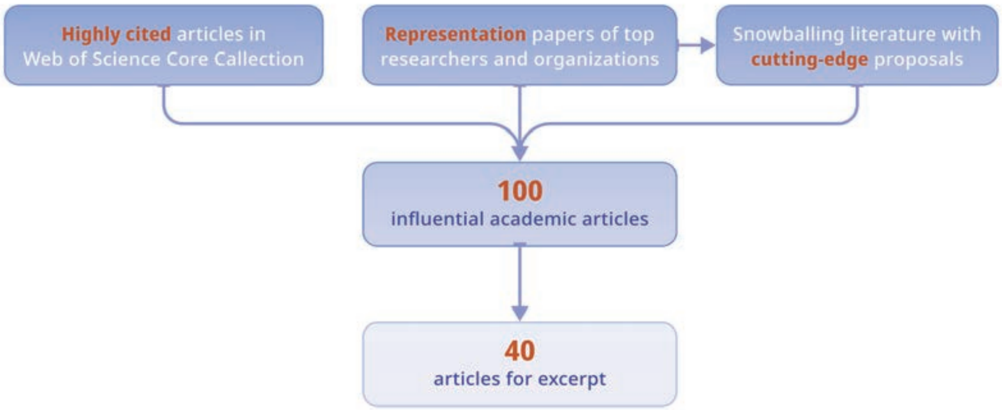


Figure 6 Search and selection process

How to Use This Handbook

You can read from any page of this handbook; however, the articles are integrated into seven topics for systematic comprehension. Please notice the index in each paper, and do find the relevant information (organization, publication, robot and terminology) in the chapter "Background Material Necessary for the Effective Use of This Handbook".

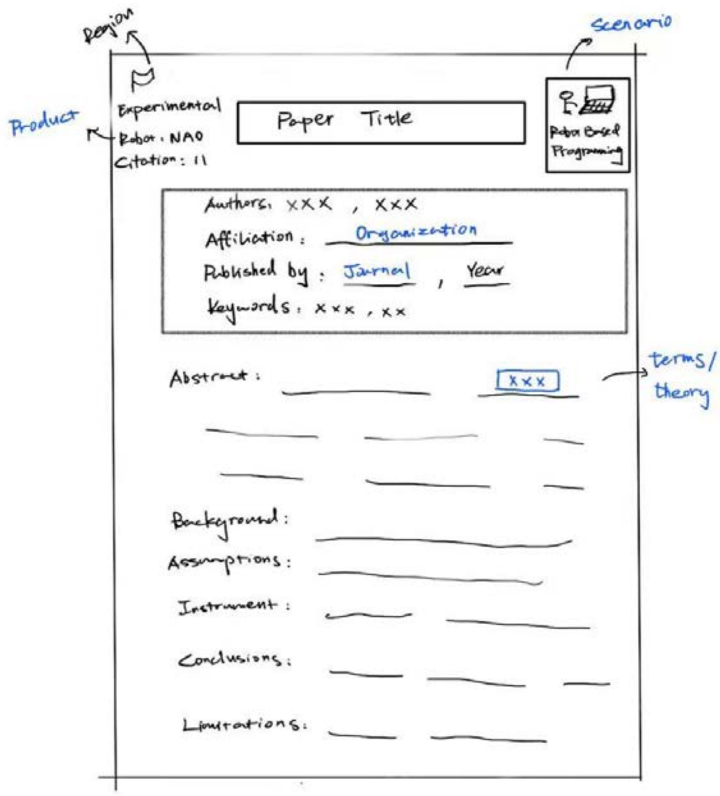


Figure 7 Graphical guide for reading

Thematic Topics of Educational Robot

The 100 Influential academic articles reveal main thematic areas where educational robotics have been applied to enhance the learning outcomes of students.

A new theme that has emerged is topic one, "Personalized tutoring through conversational agents", which focused on a new advanced form of artificially intelligent chatbots, ChatGPT, which has become a hot discussion topic at the present and will possibly continue to be one in the future. Potential issues to be discussed in the use of the conversational agent (ChatGPT) are technical concepts, inclusion and ethical issues, usability and user experience, academic integrity and machine-human collaboration.

Topic two, "Robotics in STEM Education", dealt with robotics for the implementation of STEM education which is an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons. Robotics was seen to provide rich and attractive learning experiences in STEM education and facilitated student engagement in the learning process.

In topic three, “Robotics-Oriented Programming”, educational robotics application in the field of computer science, in particular programming, was presented. Here robotics was found to stimulate the creativity and problem-solving abilities of learners but there are key challenges confronting current robot-based programming such as the impossibility of promoting the popularity of engineering colleges in robot-based programming because of the lack of necessary equipment to promote the concept in engineering college, the shortage of qualified teachers and the issue of how teaching materials can be used to meet the demand for different grades students.

A new form of AI, social robots, was the main focus of topic four, “Language Learning with Social Robots”. Thus, studies on how social robots can be used to promote language learning were discussed.

The main discussion point for topic five, “Teaching with robotics in classrooms ”, was how robotics can augment traditional pedagogical practices. The articles presented made a case for how educational robotics can be a valuable tool to help in the visualization of abstract knowledge.

How robots can help students with neurological disabilities, specifically, autism was the main theme for topic six, “Robot-assisted special education”. These studies found that children with autism perceive robots as less intimidating and more interesting, hence, these robots enable them to easily interact and engage in activities.

Finally, the last topic, “Robot-Based Cognitive Training for the Senior People with Special Needs”, expounded on the potential of educational robots in promoting cognitive training for the senior people. Robotics was revealed as an accelerator of lifelong learning and good quality of life for the senior people.

Topic 1. Personalized Tutoring through Conversational Agents

The fourth industrial revolution keeps pushing the advancement of technology in the form of artificial intelligence (AI), robotics and natural language processing (NLP) which increasingly makes the use of conversational agents (such as chatbots) in education a possibility. Advanced conversational agents are powered by AI and exploit NLP to have text-based dialogues with users. A conversational agent can also make use of speech recognition technology to have a spoken conversation with a user. Developers of conversational agents design them to mimic human-like conversations in a way that is indistinguishable from having actual interaction with a human. As a result, some conversational agents are imbued with human qualities like personality, emotion and humor. AI-powered conversational agents are able to offer learning support and enable a learner to engage in self-assessment which can be difficult to provide in

Figure 8 An era of ChatGPT

traditional learning environments. In addition to providing personalized learning to users, conversational agents adopt human pedagogical roles such as learning companions, coaches or tutors in educational settings. Pedagogic conversational agents also promote collaborative learning in technology-enhanced learning environments such as E-learning, online learning, massive open online courses (MOOC) and in other virtual worlds. The use of conversational agents as pedagogical agents is underscored as having the potential to enhance learning outcomes and memory and increase the motivation of learners to engage in the learning process. At the same time, it brings up discussions on academic integrity while applying such technology.

One of the key recent developments of conversational agents is Chat Generative Pre-trained (ChatGPT)Transformer, a new AI model which leverages NLP to perform a wide array of tasks. ChatGPT is a large language model that uses deep learning algorithms trained on vast amounts of data by OpenAI, to generate human-like responses to user prompts. By the end of November 2022, ChatGPT was officially released to the public and immediately brought the ChatGPT phenomenon to almost everywhere - medical, economic, finance, journalism, etc. Within one week, ChatGPT garnered more than one million subscribers, and the number has continued to raise to a hundred million in less than two months, which broke the record for taking the shortest time to reach 100 million monthly users. On March 15th 2023, OpenAI released GPT-4 as the latest milestone. GPT-4 is a large multimodal model that is able to accept a prompt of text and images, and understand and express logical ideas behind the images. It can also teach a range of subject personalized by learner’s skill level.

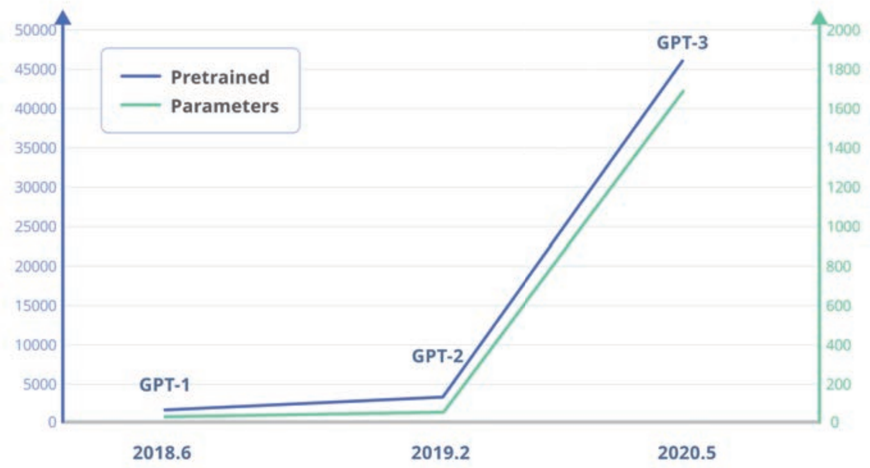


Figure 9 Evolution of GPT model

In the context of education, educators and students already unlocked several application scenarios. Educators can use it to create content like course outlines, presentations, coding, quizzes, grading, scientific papers, etc. Students can use it for helping solve questions, writing essays and getting formative feedback on their work. Several academic studies have already been made on exploring possible scenarios integrating ChatGPT in science education, engineering education, mathematical education, medical education, media education and special education.

Table 1 Possible scenarios and examples of ChatGPT application in different fields

Possible Scenarios	Examples
Science Education	• Generate valid and reliable science items • Provide feedback, scaffolding, and dialogue • Elicit their reasoning and understanding
Medical Education	• Generate natural language responses to various medical scenarios
Engineering Education	• Use for software testing education
Media Education	• Generate novel stories, headlines, captions, summaries, and analyses • Enhance journalistic skills such as interviewing, fact-checking and storytelling
Mathematics Education	• Generate natural and coherent mathematical explanations for its answer such as arithmetic, algebra, calculus and logic
Special Education	• Offers speech-to-text or text-to-speech solutions to help people with visual impairment

Despite the popularity ChatGPT enjoys, people share mixed feelings regarding the way forward. ChatGPT may have profound implications for education such as transforming learning goals, learning methods, learning outcomes and learning assessment. However, ChatGPT could challenge educators to rethink their roles, methods and expectations. Just like other generative AI, ChatGPT has certainly brought opportunities and benefits to education but also implies threats and pitfalls.

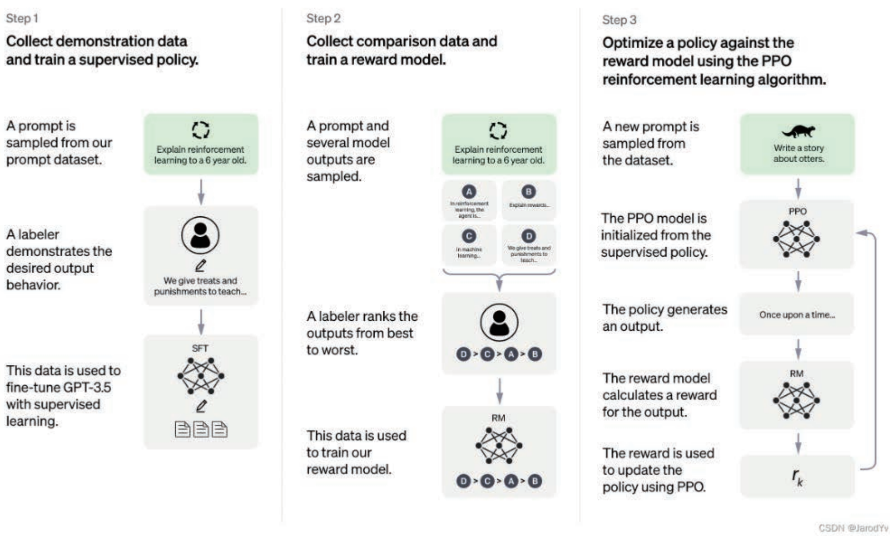


Figure 10 Framework of ChatGPT

The benefits and opportunities of using ChatGPT in education include:

- ChatGPT may be used as a virtual intelligent tutor for personalized tutoring offering personalized recommendations, interactive learning, creative problem-solving and collaborative learning experience.

- ChatGPT may also help to create an adaptive learning environment to stimulate mastery learning, where a student can progress at their own pace and learn more efficiently and effectively providing personalized learning experiences that are tailored to their needs and abilities.
- ChatGPT can also be used as inspiration - one can adapt, mix or reinterpret AI-generated ideas to their own work.
- ChatGPT achieves state-of-the-art results on several translation benchmarks, which is able to make learning content more accessible.
- ChatGPT can leverage automation of the working processes to spare teachers from grading, assessment and other time-consuming work, and hence allow them more time to focus on teaching.

Meanwhile, threats and pitfalls include:

- Cheating and plagiarism due to the use of ChatGPT, as ChatGPT can generate university-level papers, and professors already find it hard to tell whether it was written by a bot or by a student.
- Like other generative AI models, ChatGPT heavily relies on data. Depending on the quality of the data, it may occasionally generate incorrect information and may occasionally produce harmful instructions or biased content.
- ChatGPT often provides a “semblance of truth” and “hallucinated misinformation”, just like Sam Altman, CEO of OpenAI mentioned, “ChatGPT is incredibly limited, but good enough at some things to create a misleading impression of greatness.” Considering the realistic natural dialogues ChatGPT offers, the misleading is often hard to be perceived.
- The privacy and data security of users should also be of great concern.
- ChatGPT will aggravate the issue of equitability as more privileged students were/are able to benefit much more from educational technology compared to more disadvantaged students.

Anyway, the era of ChatGPT has already arrived and just like other technology, ChatGPT will penetrate the field of education. To achieve the proper use of technology, education focused on the critical thinking of the next generation will become of more importance, as to filter out inaccuracies of AI. Clear guidelines should be made to clarify the acceptable and non-acceptable use of such tools. ChatGPT will also leave a trace and a marketplace for the emergence of better detection tools.

The selected highly cited papers below are organized as follows:

Paper “What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education” tackles the merits, shortcomings, and other relevant issues to address in the application of chatbots in education. To do this, a recently developed and arguably the most advanced chatbot as of now, ChatGPT, is used as a case study. ChatGPT is touted to revolutionize education because of its capability to provide real-time responses to user text inputs and engaged in novel creation. The paper put forward that while there is education transformation potential as a result of ChatGPT, it also presents educational dangers that need to address.

Paper “ChatGPT for Good? On Opportunities and Challenges of Large Language Models for Education”draws on existing research and their own experience to discuss how large language models (LLMs) can support education and learning through natural language processing and understanding including automated learning analytics, automated writing and intelligent learning assistance. At the same time, the paper also highlights the potential issues associated with using LLMs such as lack of transparency and privacy concerns, as well as how to ensure fairness and neutrality.

Paper “Preparing Educators and Students for ChatGPT and AI Technology in Higher Education” aims to provide an overview of ChatGPT, including the background of ChatGPT, its capabilities, benefits, and potential challenges and limitations. Additionally, this study addresses the implications for educators and higher education institutions and offers recommendations for addressing the concerns surrounding the use of ChatGPT and AI in higher education.

Paper “Engineering Education in the Era of ChatGPT: Promise and Pitfalls of Generative AI for Education” proposes that with the rapid development of generative artificial intelligence especially ChatGPT, personalized and effective learning experiences as well as creating realistic virtual simulations for hands-on learning can be provided to students. Meanwhile, ethical conerns are also raised. Hence, engineering educators should study how to adapt the engineering education ecosystem to ensure the future engineers can take full advantages of technology while ensuring that it is used for good.

Paper “How Does ChatGPT Perform on the United States Medical Licensing Examination? The Implications of Large Language Models for Medical Education and Knowledge Assessment” argues that ChatGPT marks a significant improvement in natural language processing models on the tasks of medical question answering. By performing at a greater than 60% threshold on the NBME-Free-Step-1 data set, the paper shows that the model achieves the equivalent of a passing score for a third-year medical student. Additionally, the researchers highlight ChatGPT’s capacity to provide logic and informational context across the majority of answers. These facts taken together make a compelling case for the potential applications of ChatGPT as an interactive medical education tool to support learning.

Topic 2. Robotics in STEM Education

STEM is the abbreviation for the four disciplines of Science, Technology, Engineering and Mathematics. STEM education is a comprehensive education based on the idea that these four areas of learning should be taught together in an integrated manner, as opposed to teaching them separately. With this holistic learning style, students apply science, technology, engineering and mathematics in contexts that make connections between the classroom and the world around them. Among the practical approaches to STEM education, robotics, with its multi-disciplinary nature is used in more and more instructional experiments. Through activities of building robotics and problem-solving, teachers can combine technology and engineering topics to make science and mathematics concepts more concrete by utilizing real-world applications. Robotics can be especially effective in teaching STEM, as it can help students with visualizing and understanding the abstract concepts so often found in STEM. Furthermore, due to its easy access, ease of operation and attractiveness using robotics in STEM education is becoming more popular and plays a key role in STEM education.

In many studies, robots are considered constructive and hands-on learning environments that are suitable for a better understanding of STEM subjects. Usually, two kinds of educational robots are employed in STEM learning. One type is the robot which is built with various construction kits. The other is a robot product generated by a robot manufacturer, and hence it comes completely assembled. Both types of robots are widely used in STEM education and are attractive to students as they are easily accessible and manipulated by students. In the context of task-centered or project-based STEM learning with robotics, students can experience cooperative learning and work in small groups to build robots, write programs and discuss solutions to problems. Thus, robots provide an engaging and hands-on learning experience that can make learning more enjoyable for students.

Figure 11 Robotic tool kits for STEM education

The academic research on robotics for the implementation of STEM education mainly focuses on the following areas:

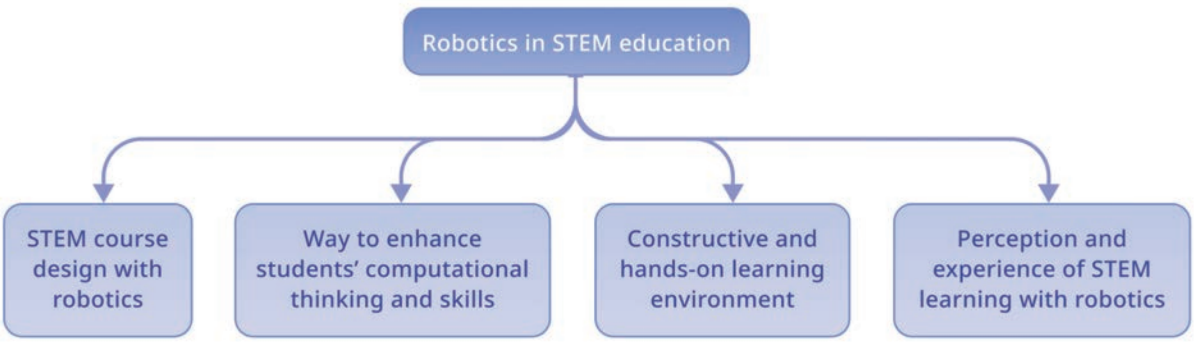


Figure 12 Robotics in STEM education

- Use robotics to develop a STEM course, and explore context structure, learning patterns, learning groups, learning effects, etc.
- Exploring the means of developing students' computational thinking, metacognitive skills, problem-solving skills and so on through STEM education with robotics.
- Providing a constructive and hands-on learning environment to implement STEM education.
- Focusing on the students' and teachers' perception and experience of STEM learning with educational robotics, in terms of factors like acceptance, belief, attitude, confidence, interest, anxiety, etc.

The selected highly cited papers below are organized as follows:

The paper "Empowering technology and engineering for STEM education through programming robots: a systematic literature review" reviewed 23 studies to provide programming experiences for robotics for children, between the ages of zero and eight, and for pre- or in-service teachers of early childhood education. This review revealed that computer programming through robotics can be a promising educational tool and an application for the integration of technology and engineering in early childhood STEM education.

The paper "Robotics and STEM learning: students' achievements in assignments according to the P3 Task Taxonomy-practice, problem-solving, and projects" presented the case of the development and evaluation of a STEM-oriented 30 hours robotics course for junior high school students . The project was aimed at exploring students' working patterns, achievements in learning the course and the impact of this experience on students' motivation to learn STEM subjects.

The paper "Robotics to develop computational thinking in early Childhood Education" described the experiences of 131 children participating in a quasi-experiment using experimental and control groups to verify the effect of educational robot activities on children's acquisition of computational thinking and programming skills.

The paper "Using mastery learning theory to develop task-centered hands-on STEM learning of Arduino-based educational robotics: psychomotor performance and perception by a convergent parallel mixed method" aimed to explore psychomotor performance and perception of task-centered hands-on STEM learning of educational robotics.

The paper "Collaborative Robotics, More Than Just Working in Groups" explored how collaboration interventions and prior student experiences affect a student's learning motivation, problem-solving skills and science process skills in STEM education.

The paper "Preparing Teachers to Engage Rural Students in Computational Thinking Through Robotics, Game Design, and Culturally Responsive Teaching (CRT)" focused on teacher challenges and adaptions related to rural students' involvement in robotics and game design. In order to do so, micro-topographic mapping methods were used to examine how CRT affects teachers' STEM practices in three different learning environments. The researchers concluded that teachers' beliefs about CRT and attitudes toward computational thinking (CT) and STEM practices are malleable but vary based on the environment.

Figure 13 STEM education activity

The paper "An ultra-low-cost line follower robot as an educational tool for teaching programming and circuit's foundations" presented an ultra-low-cost line following robot that was developed through the integration of free educational software, low-cost electronics and mechanical devices which has been used as a teaching and learning tool to increase the student's confidence/performance and interest in STEM education.

Topic 3. Robotics-Oriented Programming

Programming is the implementation of logic to facilitate specified computing operations and functionality which consists of traditional education (C++ and Java) and robotics. Different from robotics, traditional education has an abstract programming structure and often students are not able to reach sufficient maturity levels without guidance. Robot-based programming is the process of defining specific commands of an application for an educational robot which is an interesting teaching tool that will help teachers when going through many topics while keeping students engaged. And moreover, it is suitable for all levels and age groups. Learning computer programming often goes along with growing other skills such as logical thinking, problem-solving through tests, modifications and optimization, problem modeling, etc. Robotics is highly stimulating for younger students, and allows them to grow important soft skills such as problem-solving, creativity and team spirit. In higher education, robotics allows students to work with real hardware in order to be prepared for the challenges of real physical work. Studies have shown that the main problems of current robot-based programming comprise three main points. First of all, it is impossible to promote the popularity of engineering colleges in robot-based programming because of the lack of necessary equipment. Secondly, the shortage of qualified teachers is a key factor that restricts the development of robot-based programming education. Therefore, it is necessary to improve the professional ability of front-line teachers to promote robot-based programming. Finally, related teaching materials should be used to meet the demand for students of all grade levels.

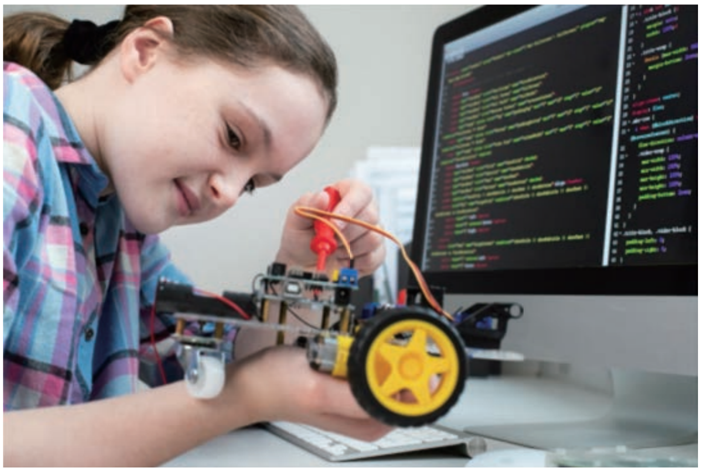


Figure 14 Programming used in a technology-driven environment

Using robot-based practices to develop activities helps students evaluate smart components from pedagogical and technological perspectives based on data gathered from real-world tasks. Students can gain interdisciplinary knowledge through the robot-based mechatronics process, and they can apply the knowledge and techniques learned to multiple areas. More importantly, during the hands-on process of building a robot, students can acquire techniques for using hands-on tools and enhance their hands-on ability. In addition, to control the robot to complete real-world tasks, students must first acquire the skills of programming design which promotes their computational thinking ability.

Robot-based programming can be widely adopted for all education levels, from early childhood to adolescents. For different academic levels, the academic research on robot-based programming mainly focuses on different areas as follows:

- For early childhood, robot-based programming mainly focuses on how to induct computational thinking.
- For elementary school students, robot-based programming mainly focuses on how to develop computational thinking.

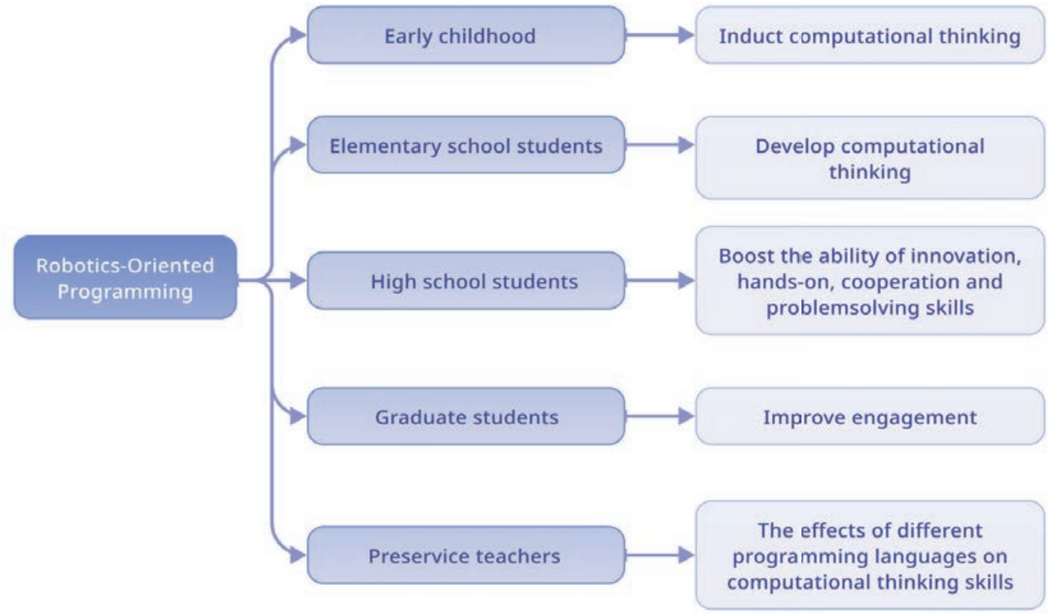


Figure 15 Robot-based practices in programming

- For high school students, robot-based programming mainly focuses on how to boost the ability of innovation, hands-on, cooperation and problem-solving skills.
- For graduate students, robot-based programming mainly focuses on how to improve engagement.
- For preservice teachers, robot-based programming mainly focuses on the effects of different programming languages on computational thinking skills.

The selected highly cited papers below are organized as follows:

The paper "Coding as a playground: Promoting positive learning experiences in childhood classrooms" introduces coding and computational thinking in early childhood education. By analyzing the research findings, it is confirmed that robots are an effective way to promote communication, collaboration and creativity in classroom settings.

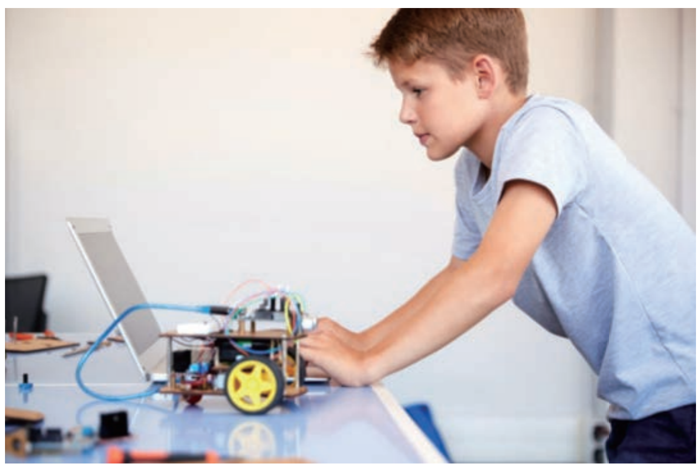


Figure 16 Programming based on robot

The paper "Active Learning Environments with Robotic Tangibles: Children's Physical and Virtual Spatial Programming Experiences" studies the difference between real physical robots and virtual ones. Evaluations of both in the context of free play and open-ended learning activities show that both systems afford opportunities for young children to engage in spatial programming, creating improvisational and sequential programs that mediate interactions between the environment, robots and humans in responsive and creative ways.

The papers “A Tool for Introducing Computer Science with Automatic Formative Assessment”, “How Does the Degree of Guidance Support Students’ Metacognitive and Problem Solving Skills in Educational Robotics?” and “High School Students’ Views on the PBL Activities Supported via Flipped Classroom and LEGO Practices” all focused on how to boost students’ engagement, how to investigate the development of students’ problem-solving skills and how to increase motivation and interest in the lesson, respectively. “A Tool for Introducing Computer Science with Automatic Formative Assessment” measured indicators of student engagement and found that girls’ engagement with Chatbot was higher than boys for most indicators and in the online competition, the task completion rate for the students that decided to use Chatbot was five times higher than for the students that chose to use the renowned animation and game programming tool, Alice. “How Does the Degree of Guidance Support Students’ Metacognitive and Problem Solving Skills in Educational Robotics?” investigated the development of students’ metacognitive and problem-solving skills in the context of educational robotics activities and the article’s results show that strong guidance in solving problems can have a positive impact on students’ metacognitive and problem-solving skills. Meanwhile, students eventually reach the same level of metacognitive and problem-solving skills development independently of their age and gender. “High School Students’ Views on the PBL Activities Supported via Flipped Classroom and LEGO Practices” investigated high school students’ views on instructions based on LEGO applications. The researchers in this project stated that by partaking in the study, the student’s motivation and interest in the lesson increased. Additionally, in the group work the students were found to have cooperated, exchanged ideas, shared tasks, took responsibility and socialized with their friends.

The paper “Student in the shell: The robotic body and student engagement” explored how the embodiment of graduate students in robotic surrogates was related to their engagement in a class with other robotically and non-robotically embodied classmates. The study’s results showed that nonverbal communication with one’s robotic body is a dominant form of interaction and engagement in synchronous learning contexts and multiple contextual factors affect robotic students’ engagement.

The paper “The effects of different programming trainings on the computational thinking skills” points out there is uncertainty about how to develop computational thinking in teachers and how to transfer it to the classroom environment. This paper hence focused on the effects of different programming languages on computational thinking skills. Pre-tests and post-tests show that robot has a significant difference compared with programming languages.

Topic 4. Language Learning with Social Robots

Language learning is a crucial aspect of human development as it allows individuals to communicate, interact and express themselves. With advancements in technology, the way we learn languages has changed, and social robots have emerged as a new platform for language learning. Social robots are defined as machines that can socially interact and communicate intelligently with humans. Language learning with social robots refers to the use of robots as a teaching aid for language education. This approach incorporates technology, artificial intelligence and pedagogy to create an interactive and engaging learning experience. Social robots are designed to interact with humans, respond to their actions and provide feedback in a natural and human-like manner. This creates a more personalized and enjoyable learning experience, compared to traditional language learning methods.

The use of social robots for language learning has received mixed reviews, with some research suggesting that they can be effective tools for enhancing language acquisition and motivation, while others have found limited benefits. Positive reviews emphasize the interactive and engaging nature of social robots, which can make language learning more fun and interesting for students. Social robots can also provide personalized feedback by adapting to the individual needs and pace of each student. This can help to increase motivation and engagement in language learning. However, some negative reviews highlight the limitations of social robots, including their high cost and limited accessibility for all students. Additionally, there is a concern that the use of social robots may oversimplify language learning and not fully prepare students for real-life communication.

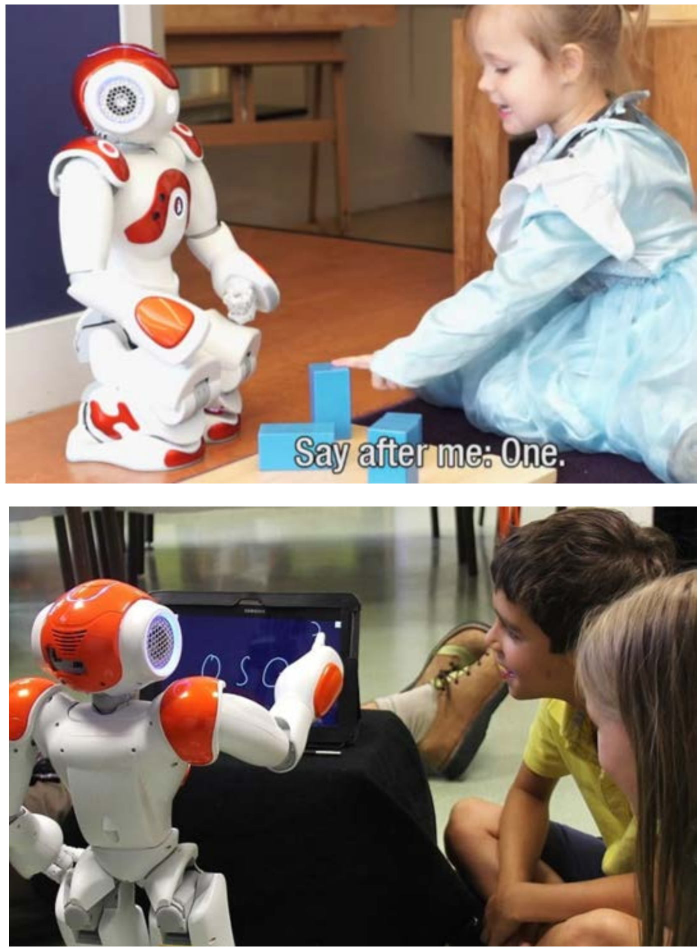


Figure 17 Robot in language education

The field of language learning with social robots is still in its early stages, and there is significant potential for growth and development. In the future, we can expect to see an increase in the use of social robots in language education, with more sophisticated robots and more advanced artificial intelligence algorithms. Additionally, there will be a growing focus on the integration of social robots into language education, creating a seamless and immersive learning experience. Finally, there will be a continued effort to evaluate the effectiveness of language learning with social robots, providing valuable insights for future development and improvement.

In conclusion, language learning with social robots is a promising approach to language education that has the potential to enhance student engagement, motivation and language proficiency. The field is rapidly evolving, and future developments are expected to bring new and exciting opportunities for language learning with social robots.

The research on the application of social robots in language learning mainly includes the following two perspectives:

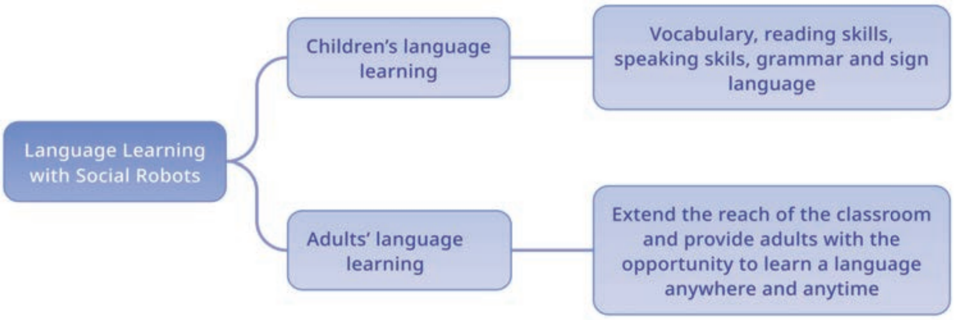


Figure 18 Language Learning with Social Robots

- Literature studies were conducted using different robots and methods for different languages, age groups and aspects of language, summarizing the findings and shortcomings of existing studies and looking at future research trends.
- Different forms of social robots for the development of children's language learning such as vocabulary, reading skills, speaking skills, grammar and sign language.
- Different forms of social robots to support second language learning in adults, which extend the reach of the classroom and provide adults with the opportunity to learn a language anywhere and anytime.

The application of social robots in language learning has been an active area of research.

Here are five representative studies that showcase the current state of research in this field:

The paper "Social Robots and Young Children's Early Language and Literacy Learning" reviewed 13 studies on social robots in language learning and found that social robots can assist with early language and literacy learning in typically developing children. However, very few studies were found that have examined the effects of social robots on early literacy learning.

The paper "Social Robots for Language Learning: A Review" reviewed 33 studies on social robots in language learning and found that too few studies have been conducted so far to conclude that robots are effective language tutors, and future studies will allow for firmer conclusions regarding robots' potential as language tutors.

The paper "Teaching and learning with children: Impact of reciprocal peer learning with a social robot on children's learning and emotive engagement" presented a novel active role-switching (ARS) policy trained using reinforcement learning, and shed light on how fixed role (tutor/tutee) and adaptive role (peer) agents support children's cognitive and emotional needs as they play and learn.

The paper "Guidelines for designing social robots as second language tutors" suggested that social robots can effectively serve as second language tutors, but their design should take into account several guidelines to maximize their effectiveness, including considering the robot's appearance, voice, behavior, and feedback mechanisms.

The paper "Intelligent personal assistants: can they understand and be understood by accented L2 learners?" investigated Echo's ability to recognize and process non-native accented speech at different levels of accentedness, based on the accuracy of its replies for a set of pre-established questions.

Topic 5. Teaching with Robotics in Classrooms

It is a challenge for teachers or professors who use traditional techniques (such as oral explanations, PowerPoint presentations, etc.) to provide students with a clear understanding of abstract theoretical concepts in K-12 and higher education. Therefore, a valuable topic is how to integrate robotics to complement traditional pedagogical practices in basic disciplines in K-12 and engineering courses in higher education, thereby solving the poor learning of traditional methods, improving students' understanding of abstract concepts and reinforcing students' system design skills, among other benefits.

Robotics is mainly used as tools, technologies or approaches to enhance traditional pedagogical practices in K-12 and higher education. In K-12 education, which mainly focuses on basic disciplines, integrating educational robots into mathematics or other subject areas may provide insights into new horizons. This study can encourage more teachers to visualize abstract knowledge with the tangible and manipulable nature of robots. In higher education, which mainly offers multidisciplinary engineering courses, robotics can be a valuable teaching tool for various engineering courses in the classroom because of its multidisciplinary nature. Thus, they can enhance the way the professors teach, reinforce students' theories and skills, etc. For example, 3D simulations can create virtual environments in robotics courses and robot prototypes can be designed as new technologies in mechatronics-related courses.

Figure 19 Integration of robotics in the classroom

The academic research on how to use robotics to complement traditional pedagogical practices is promising, but more rigorous research is needed. In K-12 education, several studies have shown that robotics generally plays an active role in mathematics and other fundamental disciplines. However, there is a lack of high-quality empirical research showing the influence of integrated robotics on academic performance. In some fields of science education, robots were seldom adopted in classrooms such as astronomy, chemistry, etc. In addition, the use of socially assistive robots in mathematics and science is very limited. In higher education, previous works have shown that the integration of robotics into traditional teaching practices provides teaching tools and technologies and has a positive influence on students. Nevertheless, there are no formal studies as of now that demonstrate the impact of using robotics on the academic performance of college students.

The academic research on how to integrate robotics to complement traditional pedagogical practices has developed the following scenarios:

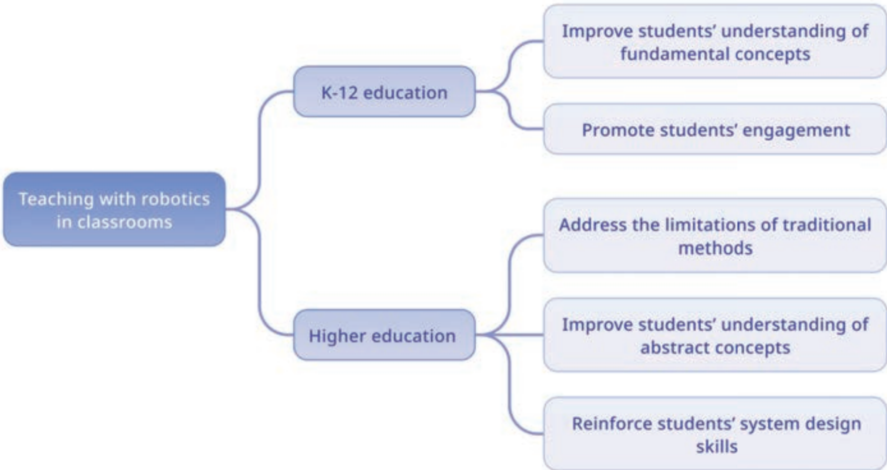


Figure 20 Teaching with robotics in classrooms

- In K-12 education, robotics is mainly used as tools or integrated as approaches in pedagogical practice, mostly applied in basic disciplines, to improve students' understanding of fundamental concepts, promote students' engagement, etc.
- In higher education, robotics is essentially utilized as tools or designed as technologies in pedagogical practice, mostly in multidisciplinary engineering courses, to address the limitations of traditional methods, improve students' understanding of abstract concepts, reinforce students' system design skills, etc.

The selected highly cited papers below are organized as follows:

The paper "The effect of programming on primary school students' mathematical and scientific understanding: educational use of mBot" detailed the implementation of programming and robotics, and emphasized the benefits acquired in mathematics, computational concepts and interactions in the classroom. This paper presented proposals for the integration of educational robotics with visual block programming in mathematics, especially in the subjects or didactic units related to coordinates and integers.

The paper "Exploring the evolution of two girls' conceptions and practices in computational thinking in science" explored the evolution of two elementary school girls' conceptions and practices of CT in science. The study provided a qualitative view of how elementary school girls' CT conceptions and practices evolved throughout a CT-integrated science module using robotics kits. The study also demonstrated instructional methods and integrated activities that future research can leverage in engaging girls in STEM learning opportunities.

The paper "A systematic review of the literature regarding socially assistive robots in pre-tertiary education" aimed to critically review the research on the use of Socially Assistive Robots (SARs) in pre-tertiary classrooms teaching mathematics and science. The study found that SARs can have positive effects on students' learning outcomes, engagement, motivation and social skills. The results indicated that the use of SARs in pre-tertiary education is promising, but studies focusing on mathematics and science are significantly under-represented. In addition, this study suggested that rigorous evidence is needed to assess SARs' promise in mathematics and science-inclusive teaching and learning.

The paper "Analysing the effect of the use of 3D simulations on the performance of engineering students in a robotics course: Findings from a pilot study" showed that simulations can help solve the poor learning of many traditional methods and provide a tool to improve the way in which professors teach. The test results demonstrated that the performance of the students in the group using the new teaching methods combining traditional methods together with the 3D simulations was better than that of the students in the group where only the traditional method was used. In this way, the students in the group using the new teaching method consequently reinforced their theoretical knowledge and practical skills to solve exercises.

Figure 21 Teaching with robots in the manufacturing hub

The paper "A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics-Related Courses" presented a robot prototype used for teaching in multidisciplinary engineering courses. Considering the student outcomes in terms of Accreditation Board for Engineering and Technology (ABET) criteria, it can be concluded that the prototype helps students to: improve their system design skills; acquire desired skills within realistic constraints; and learn to work in multidisciplinary teams. Furthermore, student portfolios from the laboratory activities will be useful in future ABET evaluations, to emphasize the contribution of the robot prototype to improving the student learning outcomes.

Topic 6. Robot-assisted Special Education

Social robots have received great acceptance from children and adults in the field of education. A recent study attributed the high acceptance and preference to many reasons: the childlike appearance which attracts attention; the patience and stability robots can provide in interaction; the multiple roles as tutor, assistant and peers. The advantages of using social robots in the educational process are even more valuable considering special education, where the children interacting with the robots have some impairments. Studies have been conducted for applying robots to children with different impairment types including autism spectrum disorder (ASD), attention deficit and hyperactivity disorder (ADHD), neurodevelopment disorders (NDD), hearing impairment, cerebral palsy, oncological disorders and down syndrome. Among these, robot intervention for children with ASD has drawn much more attention than other impairments.

ASD is a neurodevelopmental disorder that presents in the form of severe difficulties in social communication and interaction, along with repetitive behaviors and stereotypical interests. Individuals with ASD often perceive the world in a different way. They exhibit a spectrum of characteristics including unsuitable communication, inappropriate social interaction and repetitive and unusual stereotyped behaviors. Both the verbal and non-verbal communication skills, like conversation skills, narrative skills and gestural communication skills of children with ASD are generally quite low, and some never develop completely functional speech corresponding to their chronological age. In addition, children with ASD tend to respond negatively to change, in contrast to their peers of typical development who adjust relatively easily to new conditions. It is believed that some of the most common symptoms related to difficulties lie in attention and impairment in cognitive, sensory, motor and emotional functions since children with ASD often display difficulties in understanding feelings, motives and body language. Despite that some high-functional children with autism have a very high Intelligence Quotient (IQ), or are gifted in memorizing and mathematics, most children with autism have deficits in intelligence and motor function.

For the past century, the diagnostic criteria and screening tools for autism have evolved, and the definition has broadened. Meanwhile, people have become more aware and informed about autism through its widening definition. The above two factors lead to the fact that more and more children are diagnosed with ASD. According to the Morbidity and Mortality Weekly Report issued by the U.S. Department of Health and Human Services Centers for Disease Control and Prevention, the overall prevalence of ASD among the Autism and Developmental Disabilities Monitoring (ADDM) sites was 14.7 per 1,000 (one in 68) children aged 8 years in 2010. The ASD prevalence then rose to 18.5 per 1,000 (one in 54) in 2016 and 23 per 1,000 (one in 43) in 2018, which makes ASD a very common disorder among children. While autism is incurable, it is believed that early intervention programs are able to help them in improving their quality of life. However, despite the statistics reported in every continent, the numbers of medical personnel and occupational therapists (OT) are still limited which poses a challenge to cope with providing effective intervention programs. Thus, developing robotic tools for autism intervention programs are necessary so as to increase the capacity of medically trained people to provide effective intervention programs.

Figure 22 Interaction between robots and an autistic child

According to the social motivation theory of autism, individuals with ASD show deficits in orienting toward social stimuli, engaging with humans and maintaining social relations which leads to the fact that individuals with ASD tend to have low interest in other humans and have a weaker understanding of the interpersonal world than of the object-related world. They may find it challenging to pay attention to multiple cues during social interactions with humans, and thus are less sensitive to other people’s behaviors. The above factors build a natural barrier to learning social skills from people. In contrast, robot-enhanced therapy (RET) is a promising method for improving social skills and reducing behavioral symptoms of children with ASD, for it has been proven to have many potential benefits for overcoming the obstacles inherent to human-to-human interaction. While communication in the human world tends to be unpredictable, computer-programmed robots offer stability and do not exhibit emotional transitions in a way that a human partner would. Therefore, it establishes a more simplified and more predictable form of communication. Also, robots are operated within predictable and lawful systems and can focus on one task at a time thereby providing a highly structured learning environment and helping children with ASD to focus on the targeted stimuli. Moreover, a robot appears less intimidating to a child with ASD than a human, for its expressions and reactions are more limited and predictable. Nevertheless, children perceive robots as attractive or interesting and prefer to engage them in activities and interactions. Most children with ASD exhibit a clear preference for robots, rather than non-robotic toys, or even people, and they tend to respond faster to cues provided by a robotic partner than a human partner.

Many pilot studies have been made to investigate the effectiveness of RET for children with ASD, and most of them support the favorability in every aspect. Still, some findings are the opposite with no significant difference or poor performance using RET. To conclude, the research on RET for children with ASD mainly focuses on the following scenarios:

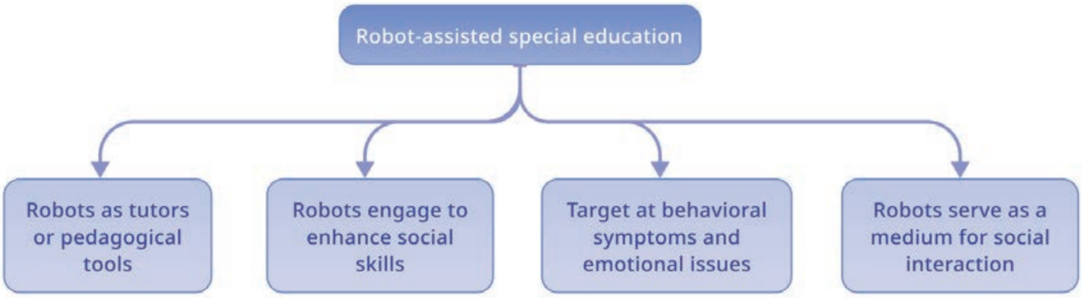


Figure 23 Robot-assisted special education

- Robots as a tutor or pedagogical tools to teach children with ASD certain abilities such as musical ability, drama play, etc., thus to develop basic skills for daily life.
- Robots engage to enhance social skills such as verbal/nonverbal communication, imitation skills, etc., so as to build interpersonal relationships.
- Using robots to target behavioral symptoms and emotional issues.
- Robotics serving as a platform or medium for social interaction between children with ASD and human instructors, thus enhancing effectiveness of human therapy.

The selected highly cited papers below are organized as follows:

The paper “Review of assistive technology in the training of children with autism spectrum disorders” presents, organizes and evaluates the most important features and results of 13 relevant scientific articles from the timeframe of 2008-2018. By analyzing the research findings, it was confirmed that robots can have positive immediate effects on the communication skills of children with ASD, and is promising for future research.

The paper “Utilizing social virtual reality robot (V2R) for music education to children with high-functioning autism” develops a virtual reality system based on the NAO robot, to conduct music education for four high-functioning and one low-functioning child with ASD. This is done in order to see whether robots can improve the musical ability and performance of children in playing melodies, as well as social and cognitive skills.

The paper "Who is a better teacher for children with autism? Comparison of learning outcomes between robot-based and human-based interventions in gestural production and recognition" compares the learning outcomes in children with ASD and intellectual disabilities from robot-based intervention on 14 gestural usages in daily communication to those used in human-based intervention.

The paper "Effects of a Robot-Enhanced Intervention for Children with ASD on Teaching Turn-Taking Skills" investigated the effectiveness of a robot-enhanced intervention on turn-taking abilities through five single-subject experiments with children with ASD aged between three and five years. The performance, social interaction and behavioral outcomes were measured.

The paper "Robotic Intervention Program for Enhancement of Social Engagement among Children with Autism Spectrum Disorder" used the NAO robot to assist in the teaching of 14 students with ASD in a structured interactive social game, a structured story-based activity and a structured singing and dancing activity. This was done to enhance the core components of social communication.

The paper "Robot-based play-drama intervention may improve the narrative abilities of Chinese-speaking preschoolers with autism spectrum disorder" and the paper "Robotic Intervention Program for Enhancement of Social Engagement among Children with Autism Spectrum Disorder" examined whether children with ASD who received a robot intervention program had better abilities than their peers who did not receive the intervention. They separately focused on narrative abilities and gestural communication, eye contact and verbal initiation.

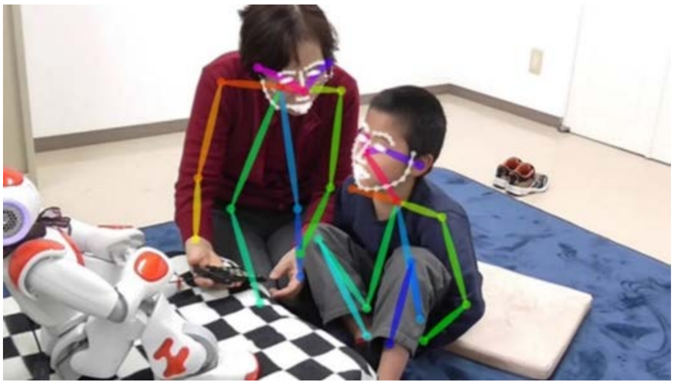


Figure 24 Robots to help autistic children

Topic 7. Robot-Based Cognitive Training for the Senior People with Special Needs

Cognitive training aims to maintain or improve cognitive functioning (e.g., memory or attention) through structured and guided activities carried out individually or in a group. The difficulty level of activities can be adapted to individual functioning. It has also been demonstrated that cognitive training can enhance the cognitive functioning of people with mild dementia.

In any aging society, some elderly people have memory or thinking problems which are called mild cognitive impairment, or mild cognitive impairment (MCI). MCI is a stage preceding dementia that does not meet the dementia criteria but already the person diagnosed has some symptoms in domains such as memory and language, compared with healthy individuals of the same age group. It is estimated that about 12% to 36% of older adults have MCI, and as the population of older adults increases, the prevalence of MCI will gradually increase. Approximately

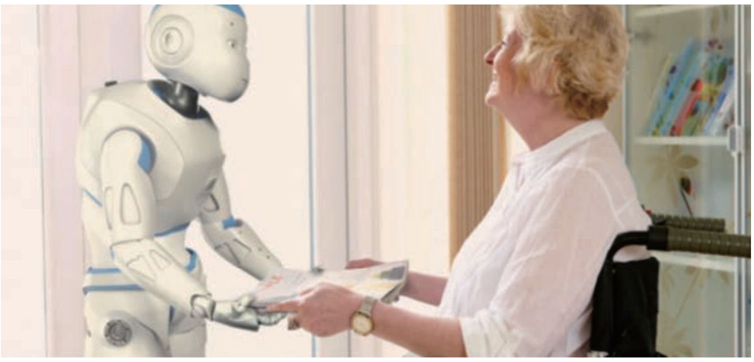


Figure 25 Robots supporting senior people

12% of older adults with normal cognitive functions but approximately 10-15% of those with MCI would show the development of Alzheimer's dementia.

With the rapid development of robotics and information and communications technology (ICT), cognitive training robotics have provided promising training and assistance approaches to mitigate cognitive deficits. Particularly due to the shortage of human caregivers and the high burden of caregiving, robots can provide care with high repeatability and without any complaints. Both human-like robots and animal-like robots are adopted to conduct cognitive training for the elderly person. Furthermore, social robots can improve an elderly person's social interaction, communication and depression to improve the effectiveness of cognitive training. Social interaction is the interaction of multiple individuals with each other such as gatherings, play, sports and other group activities. Studies have shown that active participation of older adults in face-to-face interaction online and offline can lead to a healthier lifestyle and improved cognitive function, while those who participate less in social activities may have a slow decline in cognitive function.

We selected five studies published in recent three years and these five studies conducted robot-assistive cognitive training research in two fields, namely:

- Robot-Assisted Intervention of cognitive training for the senior people.
- The interactions and acceptability of the robots for the senior people.

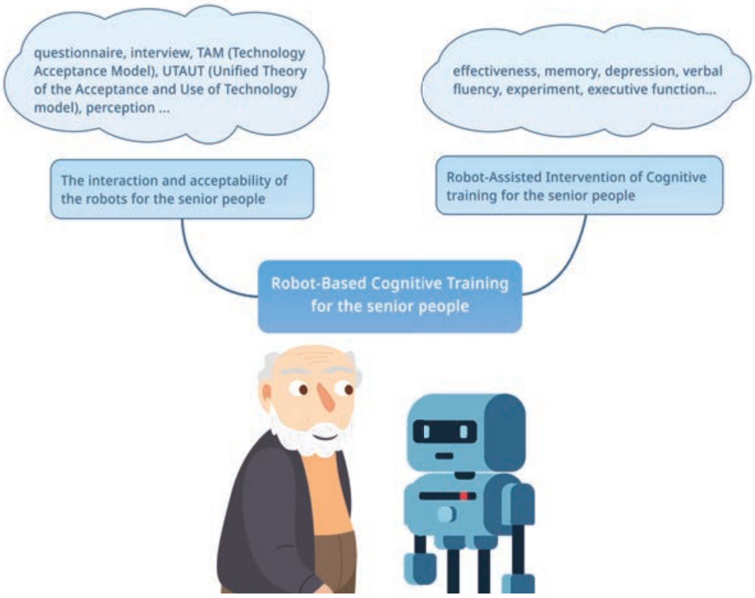


Figure 26 Robot-Based Cognitive Training for the Senior People with Special Needs

For Robot-Assisted Intervention, randomized controlled trials were conducted in these studies and participants' cognition, subjective memory complaints questionnaire and neuropsychological assessment were measured through these studies to test the effectiveness of SARs for the training of an elder's cognitive ability. Two studies used the humanoid robot, namely Sil-bot and NAO in interventions with participants with dementia or mild cognitive impairment.

Figure 27 Interaction between robots and senior people

The paper "The Humanoid Robot Sil-Bot in a Cognitive Training Program for Community-Dwelling Elderly People with Mild Cognitive Impairment during the COVID-19 Pandemic: A Randomized Controlled Trial" used a multi-domain cognitive training program in particular, robot-assisted training conducted 12 times, twice a week for six weeks. According to the results, cognitive function was improved and depression declined in community-dwelling older adults with mild cognitive impairment.

The paper "The Humanoid Robot NAO as Trainer in a Memory Program for Elderly People with Mild Cognitive Impairment" also revealed that memory training with NAO resulted in an increase of visual gaze from patients and reinforcement of therapeutic behavior reducing, in some cases, depressive symptoms.

For Interactions and Acceptability, the purpose of these studies was to assess how the elderly perceived the SARs in terms of usability, appearance and satisfaction through a questionnaire or Qualitative Content Analysis. Acceptability was often assessed with the Technology Acceptance Model (TAM) and Unified Theory of the Acceptance and Use of Technology model (UTAUT). Three studies focused on how the robots were used and how the elderly perceived them.

The paper "Mini: A New Social Robot for the Elderly" took the social robot Mini which supports elders and caregivers in cognitive and mental tasks as an example and described all aspects of the design including sensors, human-robot interaction and so on of a new social robot for older people. This study also evaluated how users perceived the robot based on participants reporting interesting results in terms of usability, appearance and satisfaction.

The paper "The Impact of Serious Games with Humanoid Robots on Mild Cognitive Impairment Older Adults" investigated how seniors with Mild Cognitive Impairments related to and perceived serious games accessed through humanoid robots, as part of a training program aimed to improve their cognitive status. The results showed that the robot was received with more enthusiasm by the older adults, thus improving their level of engagement.

The paper “The Usability and Impact of a Low-Cost Pet Robot for Older Adults and People With Dementia: Qualitative Content Analysis of User Experiences and Perceptions on Consumer Websites” used a novel methodology to analyze the information that was uploaded by reviewers of the JfA cat on the review sites to explore the usability and impact of the JfA robotic cat, as an example of a low-cost robot, based on perceptions and experiences of using the JfA cat for older adults and people with dementia.

From what can be deducted from the educational robotics scenarios and 100 influential academic articles, school systems can better improve through the incorporation of robotics in pedagogical practices. We found the studies presented very interesting and important for further discourse on educational robotics. We realized that different disciplines can apply specific and tailored-made educational robotics products to improve learning.

Postscript

We call for more rigorous research studies in the field of educational robotics. The discussions in this handbook can act as a springboard for further deliberations on solutions, mitigating factors, best practices, and prospects of educational robotics.

A collective effort by research organizations and governments can help advance the call for the optimal use of robotics in education. Future research directions could range from human-robot collaboration, robotics for personalized and adaptive learning, equity issues in robotics such as inclusion and access, educational robotics for social and emotional learning, effectiveness and evaluation of educational robotics, implementing educational robotics in deprived regions, and designing robots for multiple disciplines.

Recommendations

1. Explore the mechanism of human-machine collaboration and build an intelligent education ecosystem.

With the rise of artificial intelligence technologies (robots, intelligent tutoring systems, chatbots, metaverse, etc.), studying human-machine collaboration in education has become extremely important. It is vital to focus on how to improve the role of teachers and achieve collaborative teaching between teachers and machines while addressing ethical issues. Theoretical research, platform and guidance are needed to support and strengthen the practice of human-machine teaching in primary and secondary schools and universities.

2. Develop e-pedagogy and revise the direction of education reform to adapt to the age of intelli2. gence.

The age of intelligence will introduce a large number of artificial intelligence technologies into education, most of which are double-edged swords, such as ChatGPT. It is not wise to ban these technologies because of the drawbacks. Instead, we need to change our education to meet the needs of education in the age of intelligence. This includes teaching philosophy, e-learning, digital resources, assessment methods, etc.

3. Rethink the key competencies of students, teachers, and citizens of the intelligence age.

The age of intelligence demands more than just ICT skills. New abilities, such as psychology and communication, are needed so that users can communicate and collaborate with machines in education. it is important to study how to achieve "collaborative intelligence" (i.e., design strategies, required abilities, etc.) to ensure that human teachers and machines (i.e., information technology systems, ChatGPT, robots) can share their intelligence and work together effectively to achieve the desired educational goals.

4. Keep up with the pace of open science development and embrace the international open-source movement.

Openness can promote access to education and support innovation when users (such as students, teachers, and administrators) can access, modify, and reuse tools/content in their environment. Therefore, it is crucial to conduct research on open science and develop relevant policies to support education and innovation in the age of intelligence. The open science includes various elements such as open-source policies, open educational resources, open data, open methods, open peer review, and open access.

5. Initiate social experiments on AI and education on a large scale, and ensure healthy and sustainable digital transformation.

Social experiments have less control over the process and provide a path to study the real impact of artificial intelligence technology in real and natural education processes. It also provides a practical basis and data support for extending public service in education, which is a crucial part of a country's digital transformation in education, as it helps achieve education fairness, scaled education, and personalized learning, improve the quality of digital education, and promote the achievement of UNESCO Sustainable Development Goal 4.

List of 100 Influential Academic Articles of Educational Robots (in alphabetical order)

[1] Ahumada-Newhart, V., & Olson, J.S. (2019). Going to School on a Robot. ACM Transactions on Computer-Human Interaction (TOCHI), 26, 1 - 28. https://doi.org/10.1145/3325210
Keywords: Telepresence robots, Inclusion, Education, Communication, Identity, Social norms, Schools, Appearance
Citation:15

[2] Alemi, M., Meghdari, A.F., Basiri, N.M., & Taheri, A. (2015). The Effect of Applying Humanoid Robots as Teacher Assistants to Help Iranian Autistic Pupils Learn English as a Foreign Language. International Conference on Software Reuse. https://doi.org/10.1007/978-3-319-25554-5_1
Keywords: Humanoid robot, Autism, High-functioning, Foreign language education, RALL
Citation:36

[3] Alemi, M., Meghdari, A.F., & Ghazisaedy, M. (2015). The Impact of Social Robotics on L2 Learners' Anxiety and Attitude in English Vocabulary Acquisition. International Journal of Social Robotics, 7, 523-535. https://doi.org/10.1007/s12369-015-0286-y
Keywords: Social robotics, RALL, Anxiety, Attitude, EFL learners
Citation:79

[4] Arastoopour Irgens, G., Dabholkar, S., Bain, C., Woods, P., Hall, K.C., Swanson, H., Horn, M.S., & Wilensky, U. (2020). Modeling and Measuring High School Students' Computational Thinking Practices in Science. Journal of Science Education and Technology, 29, 137-161. https://doi.org/10.1007/s10956-020-09811-1
Keywords: Computational thinking, Learning analytics, Assessment, Biology, Science learning
Citation:28

[5] Atmatzidou, S., Demetriadis, S.N., & Nika, P. (2018). How Does the Degree of Guidance Support Students' Metacognitive and Problem Solving Skills in Educational Robotics? Journal of Science Education and Technology, 27, 70-85. https://doi.org/10.1007/s10956-017-9709-x
Keywords: Educational robotics, Metacognition, Problem solving, Teacher guidance
Citation:29

[6] Aydın, Ö., & Karaarslan, E. (2022). OpenAI ChatGPT Generated Literature Review: Digital Twin in Healthcare. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4308687

Keywords: OpenAI, ChatGPT, Artificial Intelligence, Digital twin, Healthcare, ChatGPT revolution, Academic Publishing

[7] Barak, M., & Assal, M. (2016). Robotics and STEM learning: students' achievements in assignments according to the P3 Task Taxonomy—practice, problem solving, and projects. International Journal of Technology and Design Education, 28, 121 - 144. https://doi.org/10.1007/s10798-016-9385-9
Keywords: Robotics, STEM, Task taxonomy
Citation:52

[8] Barnes, J.A., Park, C.H., Howard, A.M., & Jeon, M.P. (2020). Child-Robot Interaction in a Musical Dance Game: An Exploratory Comparison Study between Typically Developing Children and Children with Autism. International Journal of Human–Computer Interaction, 37, 249- 266. https://doi.org/10.1080/10447318.2020.1819667
Citation:11

[9] Baxter, P.E., Ashurst, E.J., Read, R., Kennedy, J., & Belpaeme, T. (2017). Robot education peers in a situated primary school study: Personalisation promotes child learning. PLoS ONE, 12. https://doi.org/10.1371/journal.pone.0178126
Citation:82

[10] Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. Science Robotics, 3. https://doi.org/10.1126/scirobotics.aat5954
Citation:445

[11] Benotti, L., Martínez, M.C., & Schapachnik, F. (2018). A Tool for Introducing Computer Science with Automatic Formative Assessment. IEEE Transactions on Learning Technologies, 11, 179-192. https://doi.org/10.1109/TLT.2017.2682084
Keywords: Interactive learning environments, K-12 education, Computer science education, Automatic formative assessment
Citation:24

[12] Bers, M.U., Flannery, L.P., Kazakoff, E.R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. Computers & Education, 72, 145-157. https://doi.org/10.1016/j.compedu.2013.10.020
Keywords: Elementary education, Interactive learning environments, Pedagogical issues, Teaching/learning strategies, Robotics, Programming, Early childhood
Citation:360

[13] Bers, M.U., González-González, C.S., & Armas-Torres, M.B. (2019). Coding as a playground: Promoting positive learning experiences in childhood classrooms. Computers & Education, 138, 130-145. https://doi.

org/10.1016/j.compedu.2019.04.013
Keywords: Cooperative/collaborative learning, Teaching/learning strategies, Improving classroom teaching, Elementary education
Citation:74

[14] Burleson, W., Harlow, D.B., Nilsen, K.J., Perlin, K., Freed, N., Jensen, C.N., Lahey, B., Lu, P., & Muldner, K. (2018). Active Learning Environments with Robotic Tangibles: Children's Physical and Virtual Spatial Programming Experiences. IEEE Transactions on Learning Technologies, 11, 96-106. https://doi.org/10.1109/TLT.2017.2724031
Keywords: Robots, Computers, Electronic mail, Programming profession, Education, Context
Citation:17

[15] Çetin, M., & Demircan, H.Ö. (2018). Empowering technology and engineering for STEM education through programming robots: a systematic literature review. Early Child Development and Care, 190, 1323 - 1335. https://doi.org/10.1080/03004430.2018.1534844
Keywords: Early childhood education, Robotics, Programming, STEM education, Technology, Engineering
Citation:21

[16] Chang, C., & Chen, Y. (2020). Using mastery learning theory to develop task-centered hands-on STEM learning of Arduino-based educational robotics: psychomotor performance and perception by a convergent parallel mixed method. Interactive Learning Environments, 30, 1677 - 1692. https://doi.org/10.1080/10494820.2020.1741400
Keywords: Educational robotics, Psychomotor, Hands-on task, Task-Centered learning
Citation:10

[17] Chen, C., Yang, C., Huang, K., & Yao, K. (2020). Author response for "Augmented reality and competition in robotics education: Effects on 21st century competencies, group collaboration and learning motivation". https://doi.org/10.1111/jcal.12469
Keywords: 21st century competencies, Augmented reality, Competition, Learning motivation, Robotics education
Citation:16

[18] Chen, H., Park, H., & Breazeal, C.L. (2020). Teaching and learning with children: Impact of reciprocal peer learning with a social robot on children's learning and emotive engagement. Computer & Education, 150, 103836. https://doi.org/10.1016/j.compedu.2020.103836
Keywords: Intelligent tutoring systems, Interactive learning, Environments, Evaluation of CAL systems, Cooperative/collaborative learning
Citation:45

[19] Cheng, Y., Wang, Y., Yang, Y., Yang, Z., & Chen, N. (2020). Designing an authoring system of robots and IoT-based toys for EFL teaching and learning. Computer Assisted Language Learning, 34, 6 - 34. https://doi.

org/10.1080/09588221.2020.1799823
Keywords: Authoring system, IoT-based toys, Pedagogical needs, Robot-assisted language learning, System usability
Citation:20

[20] Chevalier, M., Giang, C., Piatti, A., & Mondada, F. (2020). Fostering computational thinking through educational robotics: a model for creative computational problem solving. International Journal of STEM Education, 7, 1-18. https://doi.org/10.1186/s40594-020-00238-z
Keywords: Computational thinking, Educational robotics, Instructional intervention, Problem solving, Trial-and-error
Citation:38

[21] Chung, E.Y. (2019). Robotic Intervention Program for Enhancement of Social Engagement among Children with Autism Spectrum Disorder. Journal of Developmental and Physical Disabilities, 31, 419-434. https://doi.org/10.1007/s10882-018-9651-8
Keywords: Human robotic interaction, Robotics, ASD, Social engagement
Citation:16

[22] Cotton, D.R., Cotton, P.A., & Shipway, J.R. (2023). Chatting and cheating: Ensuring academic integrity in the era of ChatGPT. Innovations in Education and Teaching International. https://doi.org/10.1080/14703297.2023.2190148
Keywords: Machine-generated writing, Plagiarism, Higher education, Detection and prevention

[23] Crompton, H., Gregory, K., & Burke, D. (2018). Humanoid robots supporting children's learning in an early childhood setting. British Journal of Educational Technology, 49(5), 911-927. https://doi.org/10.1111/bjet.12654
Citation:19

[24] Crossman, M.K., Kazdin, A.E., & Kitt, E.R. (2018). The Influence of a Socially Assistive Robot on Mood, Anxiety, and Arousal in Children. Professional Psychology: Research and Practice, 49, 48–56. https://doi.org/10.1037/pro0000177
Keywords: Anxiety, Mood, Socially, Assistive robot, Intervention
Citation:28

[25] Cukurbas, B., & Kiyici, M. (2018). High School Students' Views on the PBL Activities Supported via Flipped Classroom and LEGO Practices. J. Educational Technology & Society, 21, 46-61.http://www.jstor.org/stable/26388378
Keywords: Flipped classroom, LEGO, Robotic, Algorithm instruction, Problem-based learning
Citation:20

[26] Cutumisu, M., Adams, C., & Lu, C. (2019). A Scoping Review of Empirical Research on Recent Computational Thinking Assessments. Journal of Science Education and Technology, 28, 651 - 676. https://doi.org/10.1007/s10956-019-09799-3

Keywords: Computational thinking, Computational literacy, Coding, K-12 education, Learning and assessment, Programming and programming languages

Citation:31

[27] David, D.O., Costescu, C.A., Matu, S., Szentágotai, A., & Dobrean, A. (2020). Effects of a Robot-Enhanced Intervention for Children With ASD on Teaching Turn-Taking Skills. Journal of Educational Computing Research, 58, 29 - 62. https://doi.org/10.1177/0735633119830344

Keywords: Turn-taking, Assistive technology, Autism spectrum disorder, Social skills, Social

Citation:20

[28] Dawe, J.P., Sutherland, C.J., Barco, A., & Broadbent, E. (2019). Can social robots help children in healthcare contexts? A scoping review. BMJ Paediatrics Open, 3. https://doi.org/10.1136/bmjpo-2018-000371

Keywords: Psychology, Technology, Multidisciplinary team-care

Citation:48

[29] El-Hamamsy, L., Chessel-Lazzarotto, F., Bruno, B., Roy, D., Cahlikova, T., Chevalier, M., Parriaux, G., Pellet, J., Lanarès, J., Zufferey, J.D., & Mondada, F. (2020). A computer science and robotics integration model for primary school: evaluation of a large-scale in-service K-4 teacher-training program. Education and Information Technologies, 26, 2445 - 2475. https://doi.org/10.1007/s10639-020-10355-5

Keywords: Computer science education, Professional development, Elementary school curriculum, Computer science unplugged, Educational robotics, Curriculum implementation

Citation:14

[30] Gao, C.A., Howard, F.M., Markov, N.S., Dyer, E.C., Ramesh, S., Luo, Y., & Pearson, A.T. (2022). Comparing scientific abstracts generated by ChatGPT to original abstracts using an artificial intelligence output detector, plagiarism detector, and blinded human reviewers. bioRxiv. https://doi.org/10.1101/2022.12.23.521610

[31] García-Valcárcel-Muñoz-Repiso, A., & Caballero-González, Y. (2019). Robotics to develop computational thinking in early Childhood Education. Comunicar. https://doi.org/10.3916/C59-2019-06

Keywords: Childhood education, Robotics, Computational thinking, Educational innovations, Skills development, Creative thinking, Active learning, Quantitative analysis

Citation:45

[32] Garduño-Aparicio, M., Rodríguez-Reséndiz, J., Macias-Bobadilla, G., & Thenozhi, S. (2018). A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics-Related Courses. IEEE Transactions on Education, 61, 55-62. https://doi.org/10.1109/TE.2017.2741446

Keywords: ABET accreditation, Design practice, Engineering technology, Higher education, Interdisciplinary, Indus-

trial robotics, Project-based learning
Citation:49

[33] Gilson, A., Safranek, C.W., Huang, T., Socrates, V., Chi, L., Taylor, R.A., & Chartash, D. (2023). How Does ChatGPT Perform on the United States Medical Licensing Examination? The Implications of Large Language Models for Medical Education and Knowledge Assessment. JMIR Medical Education, 9. https://doi.org/10.2196/45312
Keywords: Natural language processing, NLP, MedQA, Generative pre-trained transformer, GPT, Medical education, Chatbot, Artificial intelligence, Education technology, ChatGPT, Conversational agent, Machine learning

[34] González, M.Á., Rodríguez-Sedano, F.J., Llamas, C.F., Gonçalves, J., Lima, J., & García-Peñalvo, F.J. (2020). Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review. Computer Applications in Engineering Education, 29, 46 - 65. https://doi.org/10.1002/CAE.22354
Keywords: Challenge-based learning, Mechatronics, Physical devices, Problem-based learning, Project-based
Citation:30

[35] Green, C.A., Mahuron, K.M., Harris, H.W., & O'Sullivan, P.S. (2019). Integrating Robotic Technology Into Resident Training: Challenges and Recommendations From the Front Lines. Academic Medicine. https://doi.org/10.1097/ACM.0000000000002751
Citation:16

[36] Hsiao, H., Lin, Y., Lin, K., Lin, C., Chen, J., & Chen, J. (2019). Using robot-based practices to develop an activity that incorporated the 6E model to improve elementary school students' learning performances. Interactive Learning Environments, 30, 85 - 99. https://doi.org/10.1080/10494820.2019.1636090
Keywords: Robot-based practices, Interdisciplinary projects, Programming and programming languages, Computational thinking ability, Hands-on ability
Citation:19

[37] Hsu, T., Chang, S., & Hung, Y. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. Computers & Education, 126, 296-310. https://doi.org/10.1016/j.compedu.2018.07.004
Keywords: Applications in subject areas, Pedagogical issues, Programming and programming languages, Teaching/learning strategies
Citation:204

[38] Iio, T., Maeda, R., Ogawa, K., Yoshikawa, Y., Ishiguro, H., Suzuki, K., Aoki, T., Maesaki, M., & Hama, M. (2018). Improvement of Japanese adults' English speaking skills via experiences speaking to a robot. J. Comput. Assist. Learn., 35, 228-245. https://doi.org/10.1111/jcal.12325

Keywords: Language learning, Robot-assisted learning, Second language, Speaking skills, Tutoring robot
Citation:11

[39] Ioannou, A., & Makridou, E. (2018). Exploring the potentials of educational robotics in the development of computational thinking: A summary of current research and practical proposal for future work. Education and Information Technologies, 23, 2531-2544. https://doi.org/10.1007/s10639-018-9729-z
Keywords: Computational thinking, Educational robotics, Robotics in education
Citation:49

[40] Ismail, L.I., Verhoeven, T., Dambre, J., & Wyffels, F. (2018). Leveraging Robotics Research for Children with Autism: A Review. International Journal of Social Robotics, 11, 389-410. https://doi.org/10.1007/s12369-018-0508-1
Keywords: Human–robot interaction, Robotics, Children with autism
Citation:36

[41] Jawaid, I., Javed, M.Y., Jaffery, M.H., Akram, A., Safder, U., & Hassan, S. (2020). Robotic system education for young children by collaborative-project-based learning. Computer Applications in Engineering Education, 28, 178 - 192. https://doi.org/10.1002/cae.22184
Keywords: Cognitive development, Collaborative learning (CL), Integrated learning, Open-source platform, Project-based learning (PBL), Robotics
Citation:13

[42] Jung, S.E., & Won, E. (2018). Systematic Review of Research Trends in Robotics Education for Young Children. Sustainability, 10, 905. https://doi.org/10.3390/su10040905
Keywords: Educational robotics, Robotics for early childhood education, Educational technology
Citation:75

[43] Kanaki, K., & Kalogiannakis, M. (2018). Introducing fundamental object-oriented programming concepts in preschool education within the context of physical science courses. Education and Information Technologies, 23, 2673-2698. https://doi.org/10.1007/s10639-018-9736-0
Keywords: Computational thinking, Object-oriented programming, Physical science, Game-based learning, Early childhood education
Citation:19

[44] Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G.L., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Stadler, M., Weller, J., Kuhn, J., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences. https://doi.org/10.1016/j.lindif.2023.102274
Keywords: Large language models, Artificial intelligence, Education, Educational technologies

[45] Kennedy, J., Baxter, P.E., & Belpaeme, T. (2015). The Robot Who Tried Too Hard: Social Behaviour of a Robot Tutor Can Negatively Affect Child Learning. 2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 67-74. https://doi.org/10.1145/2696454.2696457

Keywords: Robot Tutor, Social HRI, Child-Robot Interaction, Social Behaviour

Citation:145

[46] Kennedy, J., Baxter, P.E., Senft, E., & Belpaeme, T. (2016). Social robot tutoring for child second language learning. 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 231-238. https://doi.org/10.1109/HRI.2016.7451757

Keywords: Human-robot interaction, Robot tutors, Second language learning, Social availability, Immediacy

Citation:82

[47] Kert, S.B., Erkoç, M.F., & Yeni, S. (2020). The effect of robotics on six graders' academic achievement, computational thinking skills and conceptual knowledge levels. Thinking Skills and Creativity, 38, 100714. https://doi.org/10.1016/j.tsc.2020.100714

Keywords: Programming education, Robotics, Block-based programming, Computational thinking, Conceptual knowledge level

Citation:15

[48] Koh, W.Q., Whelan, S., Heins, P., Casey, D., Toomey, E.C., & Dröes, R.M. (2021). The Usability and Impact of a Low-Cost Pet Robot for Older Adults and People With Dementia: Qualitative Content Analysis of User Experiences and Perceptions on Consumer Websites. JMIR Aging, 5. https://doi.org/10.2196/29224

Keywords: Social robot, Pet robots, Low-cost robot, Dementia, Older adults, Qualitative research, Qualitative content analysis

Citation:4

[49] Konijn, E.A., & Hoorn, J.F. (2020). Robot tutor and pupils' educational ability: Teaching the times tables. Computers & Education, 157, 103970. https://doi.org/10.1016/j.compedu.2020.103970

Keywords: Social robots, Robot tutor, Multiplication tables, Primary school, Tutoring, Capacity issues

Citation:20

[50] Kumazaki, H., Muramatsu, T., Yoshikawa, Y., Corbett, B.A., Matsumoto, Y., Higashida, H., Yuhi, T., Ishiguro, H., Mimura, M., & Kikuchi, M. (2019). Job interview training targeting nonverbal communication using an android robot for individuals with autism spectrum disorder. Autism, 23, 1586 - 1595. https://doi.org/10.1177/1362361319827134

Keywords: Android robot, Autism spectrum disorder, Cortisol, Job interview, Nonverbal communication

Citation:18

[51] Kumazaki, H., Warren, Z., Swanson, A.R., Yoshikawa, Y., Matsumoto, Y., Takahashi, H., Sarkar, N., Ishig-

uro, H., Mimura, M., Minabe, Y., & Kikuchi, M. (2018). Can Robotic Systems Promote Self-Disclosure in Adolescents with Autism Spectrum Disorder? A Pilot Study. Frontiers in Psychiatry, 9. https://doi.org/10.3389/fpsyt.2018.00036

Keywords: Autism spectrum disorder, Self-disclosure, Robotics, Android robot, Simplistic humanoid

Citation:23

[52] Kuo, H., Tseng, Y., & Yang, Y.C. (2019). Promoting college student's learning motivation and creativity through a STEM interdisciplinary PBL human-computer interaction system design and development course. Thinking Skills and Creativity. https://doi.org/10.1016/j.tsc.2018.09.001

Keywords: STEM education, Project-based learning (PBL), Human-Computer interaction (HCI) system, Creativity, Engineering education

Citation:59

[53] Kuo, W.C., & Hsu, T. (2020). Learning Computational Thinking Without a Computer: How Computational Participation Happens in a Computational Thinking Board Game. The Asia-Pacific Education Researcher, 29, 67-83. https://doi.org/10.1007/s40299-019-00479-9

Keywords: Computational thinking, Computational participation, Unplugged, Board game

Citation:24

[54] Lei, M., Clemente, I.M., & Hu, Y. (2019). Student in the shell: The robotic body and student engagement. Computers & Education, 130, 59-80. https://doi.org/10.1016/j.compedu.2018.11.008

Keywords: Robots, Embodiment, Social presence, Student engagement, Synchronous learning

Citation:15

[55] Leonard, J., Mitchell, M.B., Barnes-Johnson, J.M., Unertl, A., Outka-Hill, J., Robinson, R., & Hester-Croff, C. (2018). Preparing Teachers to Engage Rural Students in Computational Thinking Through Robotics, Game Design, and Culturally Responsive Teaching. Journal of Teacher Education, 69, 386 - 407. https://doi.org/10.1177/0022487117732317

Keywords: Computational thinking, Culturally responsive teaching, Self-efficacy, Robotics, Game design, Equitable teaching

Citation:28

[56] Logan, D.E., Breazeal, C.L., Goodwin, M.S., Jeong, S., O'Connell, B., Smith-Freedman, D., Heathers, J.A., & Weinstock, P. (2019). Social Robots for Hospitalized Children. Pediatrics, 144. https://doi.org/10.1542/peds.2018-1511

Citation:40

[57] Loreto-Gómez, G., Rodríguez-Arce, J., Gonzalez-Garcia, S., & Montaño-Serrano, V.M. (2018). Analysing the effect of the use of 3D simulations on the performance of engineering students in a robotics course: Findings from a pilot study. International Journal of Electrical Engineering & Education, 56, 163 - 178.

https://doi.org/10.1177/0020720918790113
Keywords: Virtual laboratories, Educational platforms, Teaching experiment, 3D simulations
Citation:11

[58] Luo, F., Antonenko, P.D., & Davis, E.C. (2020). Exploring the evolution of two girls' conceptions and practices in computational thinking in science. Computers & Education, 146. https://doi.org/10.1016/j.compedu.2019.103759
Keywords: Computational thinking integration, Elementary education, Science education, Robotics, Girls in STEM
Citation:22

[59] Mahmoudi Asl, A., Molinari Ulate, M., Franco Martin, M., & van der Roest, H.G. (2022). Methodologies Used to Study the Feasibility, Usability, Efficacy, and Effectiveness of Social Robots For Elderly Adults: Scoping Review. Journal of Medical Internet Research, 24. https://doi.org/10.2196/37434
Keywords: Aged, Dementia, Social robots, Pet-bots, Community settings, Long-term care, Methods, Scoping review
Citation:3

[60] Manca, M., Paternò, F., Santoro, C., Zedda, E., Braschi, C., Franco, R., & Sale, A. (2021). The impact of serious games with humanoid robots on mild cognitive impairment older adults. International Journal of Human-Computer Studies, 145, 102509. https://doi.org/10.1016/j.ijhcs.2020.102509
Keywords: Mild cognitive impairment, Serious games, Interactive technologies, Humanoid robots
Citation:23

[61] Moussalli, S., & Cardoso, W. (2020). Intelligent personal assistants: can they understand and be understood by accented L2 learners? Computer Assisted Language Learning, 33, 865 - 890. https://doi.org/10.1080/09588221.2019.1595664
Keywords: Intelligent personal assistants, L2 speech, Human-machine interaction
Citation:29

[62] Nam, K., Kim, H.J., & Lee, S. (2019). Connecting Plans to Action: The Effects of a Card-Coded Robotics Curriculum and Activities on Korean Kindergartners. The Asia-Pacific Education Researcher, 1-11. https://doi.org/10.1007/s40299-019-00438-4
Keywords: Early-childhood education, Kindergarten, Programming, Robotics, Sequencing
Citation:15

[63] Neumann, M.M. (2020). Social Robots and Young Children's Early Language and Literacy Learning. Early Childhood Education Journal, 48, 157-170. https://doi.org/10.1007/s10643-019-00997-7
Keywords: Social robots, Language, Literacy, Young children, Education
Citation:19

[64] Noh, J., & Lee, J. (2020). Effects of robotics programming on the computational thinking and creativity

of elementary school students. Educational Technology Research and Development, 68, 463-484. https://doi.org/10.1007/s11423-019-09708-w
Keywords: Elementary education, Robotics programming, Computational thinking, Creativity, Prior skill, Gender difference
Citation:44

[65] Novak, E., & Wisdom, S. (2018). Effects of 3D Printing Project-based Learning on Preservice Elementary Teachers' Science Attitudes, Science Content Knowledge, and Anxiety About Teaching Science. Journal of Science Education and Technology, 27, 412-432. https://doi.org/10.1007/s10956-018-9733-5
Keywords: Science education, 3D printing, Science self-efficacy, Science teaching anxiety, Interest in science, Preservice elementary teachers
Citation:30

[66] Odry, Á., Fuller, R., Rudas, I.J., & Odry, P. (2020). Fuzzy control of self-balancing robots: A control laboratory project. Computer Applications in Engineering Education, 28, 512 - 535. https://doi.org/10.1002/cae.22219
Keywords: Arduino, Embedded control system, Experiment-based teaching, Fuzzy control, Self-balancing robot
Citation:17

[67] Olmo-Muñoz, J.D., Cózar-Gutiérrez, R., & González-Calero, J.A. (2020). Computational thinking through unplugged activities in early years of Primary Education. Computers & Education, 150, 103832. https://doi.org/10.1016/j.compedu.2020.103832
Keywords: Computational thinking, Elementary education, Evaluation methodologies, Gender studies, Teaching/learning strategies
Citation:56

[68] Pala, F.K., & Türker, P.M. (2019). The effects of different programming trainings on the computational thinking skills. Interactive Learning Environments, 29, 1090 - 1100. https://doi.org/10.1080/10494820.2019.1635495
Keywords: Computational thinking, Computational thinking skills, Programming training, Arduino, C ++
Citation:18

[69] Papadopoulos, I., Lazzarino, R., Miah, S., Weaver, T., Thomas, B., & Koulouglioti, C. (2020). A systematic review of the literature regarding socially assistive robots in pre-tertiary education. Computers & Education, 155, 103924. https://doi.org/10.1016/j.compedu.2020.103924
Keywords: Early years education, Elementary education, Secondary education, Improving classroom teaching, Socially assistive robots
Citation:24

[70] Papakostas, G.A., Sidiropoulos, G.K., Papadopoulou, C.I., Vrochidou, E., Kaburlasos, V.G., Papadopoulou,

M., Holeva, V., Nikopoulou, V.A., & Dalivigkas, N. (2021). Social Robots in Special Education: A Systematic Review. Electronics. https://doi.org/10.3390/ELECTRONICS10121398
Keywords: Social robots, Child-robot interaction, Special education, Robot-assisted learning, Systematic review
Citation:10

[71] Park, E., Jung, A., & Lee, K. (2021). The Humanoid Robot Sil-Bot in a Cognitive Training Program for Community-Dwelling Elderly People with Mild Cognitive Impairment during the COVID-19 Pandemic: A Randomized Controlled Trial. International Journal of Environmental Research and Public Health, 18. https://doi.org/10.3390/IJERPH18158198
Keywords: Mild cognitive impairment (MCI), Humanoid robots, Randomized controlled trial, Cognition, Depression
Citation:5

[72] Pérez, E.S., & López, F.J. (2019). An ultra-low cost line follower robot as educational tool for teaching programming and circuit's foundations. Computer Applications in Engineering Education, 27, 288-302. https://doi.org/10.1002/cae.22074
Keywords: Arduino, Computational thinking, Digital fabrication, Low-cost, Maker, STEM
Citation:16

[73] Pino, O., Palestra, G., Trevino, R., & Carolis, B.D. (2020). The Humanoid Robot NAO as Trainer in a Memory Program for Elderly People with Mild Cognitive Impairment. International Journal of Social Robotics, 12, 21-33. https://doi.org/10.1007/s12369-019-00533-y
Keywords: Mild Cognitive Impairment, Social robot, Elderly people
Citation:36

[74] Qadir, J. (2022). Engineering Education in the Era of ChatGPT: Promise and Pitfalls of Generative AI for Education (Version 1). TechRxiv. https://doi.org/10.36227/techrxiv.21789434.v1
Keywords: Natural language processing, NLP, MedQA, Generative pre-trained transformer, GPT, Medical education, Chatbot, Artificial intelligence, Education technology, ChatGPT, Conversational agent, Machine learning

[75] Ramachandran, A., Huang, C., & Scassellati, B. (2017). Give Me a Break! Personalized Timing Strategies to Promote Learning in Robot-Child Tutoring. 2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI, 146-155). https://doi.org/10.1145/2909824.3020209
Keywords: Child-robot Interaction, Personalization, Education
Citation:31

[76] Rudovic, O., Lee, J., Dai, M., Schuller, B., & Picard, R.W. (2018). Personalized machine learning for robot perception of affect and engagement in autism therapy. Science Robotics, 3. https://doi.org/10.1126/scirobotics.aao6760
Citation:112

[77] Sáez-López, J., Sevillano-García, M.L., & Vázquez-Cano, E. (2019). The effect of programming on primary school students' mathematical and scientific understanding: educational use of mBot. Educational Technology Research and Development, 1-21. https://doi.org/10.1007/s11423-019-09648-5
Keywords: Computational thinking, Elementary education, Programming and programming languages, Robotics, Teaching/learning strategies
Citation:35

[78] Salichs, M.A., Castro-González, Á., Salichs, E., Fernández-Rodicio, E., Maroto-Gómez, M., Gamboa-Montero, J.J., Marques-Villarroya, S., Castillo, J.C., Alonso-Martín, F., & Malfaz, M. (2020). Mini: A New Social Robot for the Elderly. International Journal of Social Robotics, 12, 1231 - 1249. https://doi.org/10.1007/s12369-020-00687-0
Keywords: Robots for elderly, Healthcare robotics, Human-robot interaction, HRI, Social robotics, Assistive robotics
Citation:18

[79] Scassellati, B., Boccanfuso, L., Huang, C., Mademtzi, M., Qin, M., Salomons, N., Ventola, P., & Shic, F. (2018). Improving social skills in children with ASD using a long-term, in-home social robot. Science Robotics, 3. https://doi.org/10.1126/scirobotics.aat7544
Citation:112

[80] Shahab, M., Taheri, A., Mokhtari, M., Shariati, A., Heidari, R., Meghdari, A.F., & Alemi, M. (2021). Utilizing social virtual reality robot (V2R) for music education to children with high-functioning autism. Education and Information Technologies, 27, 819-843. https://doi.org/10.1007/S10639-020-10392-0
Keywords: Social virtual reality robots (V2R), Music education, Autism spectrum disorders (ASD), Imitation, Joint attention, Cognitive skills
Citation:16

[81] Sinoo, C., van der Pal, S.M., Blanson Henkemans, O., Keizer, A., Bierman, B.P., Looije, R., & Neerincx, M.A. (2018). Friendship with a robot: Children's perception of similarity between a robot's physical and virtual embodiment that supports diabetes self-management. Patient education and counseling, 101 7, 1248-1255. https://10.1016/j.pec.2018.02.008
Keywords: Social robot, Embodied conversational agent, Virtual avatar, Diabetes self-management, Friendship, Motivation, Usability
Citation:25

[82] So, W.C., Cheng, C., Lam, W., Wong, T., Law, W., Huang, Y., Ng, K., Tung, H., & Wong, W. (2019). Robot-based play-drama intervention may improve the narrative abilities of Chinese-speaking preschoolers with autism spectrum disorder. Research in developmental disabilities, 95, 10351. https://doi.org/10.1016/j.ridd.2019.103515
Keywords: Autism, Socially assistive robots, Intervention, Early childhood,Narrative

Citation:15

[83] So, W.C., Wong, M.K., Lam, W., Cheng, C., Ku, S., Lam, K., Huang, Y., & Wong, W.L. (2019). Who is a better teacher for children with autism? Comparison of learning outcomes between robot-based and human-based interventions in gestural production and recognition. Research in developmental disabilities, 86, 62-75. https://doi.org/10.1016/j.ridd.2019.01.002
Keywords: Intransitive gestures, Children with ASD, Robot-based intervention, Human-based intervention
Citation:19

[84] Sullivan, A., & Bers, M.U. (2018). Dancing robots: integrating art, music, and robotics in Singapore's early childhood centers. International Journal of Technology and Design Education, 28, 325-346. https://doi.org/10.1007/s10798-017-9397-0
Keywords: Robotics, Early childhood, STEAM, Programming
Citation:59

[85] Sullivan, A., & Bers, M.U. (2018). Investigating the use of robotics to increase girls' interest in engineering during early elementary school. International Journal of Technology and Design Education, 1-19. https://doi.org/10.1007/s10798-018-9483-y
Keywords: Gender, Girls, Programming, Robotics, Stereotypes, STEM, Education
Citation:42

[86] Syriopoulou-Delli, C.K., & Gkiolnta, E. (2020). Review of assistive technology in the training of children with autism spectrum disorders. International Journal of Developmental Disabilities, 68, 73 - 85. https://doi.org/10.1080/20473869.2019.1706333
Keywords: Autism spectrum disorder, Robotics, Social robotics, Social skills
Citation:22

[87] Tanaka, F., Isshiki, K., Takahashi, F., Uekusa, M., Sei, R., & Hayashi, K. (2015). Pepper learns together with children: Development of an educational application. 2015 IEEE-RAS 15th International Conference on Humanoid Robots (Humanoids), 270-275. https://doi.org/10.1109/HUMANOIDS.2015.7363546
Keywords: Education, Tactile sensors, Wireless sensor networks, Robot kinematics, Airplanes
Citation:81

[88] Taylor, K., & Baek, Y. (2018). Collaborative Robotics, More Than Just Working in Groups. Journal of Educational Computing Research, 56, 1004 - 979. https://doi.org/10.1177/0735633117731382
Keywords: Collaborative robotics, Learning motivation, Collaborative problem-solving, Science process skills
Citation:16

[89] Taylor, M.S. (2018). Computer Programming With Pre-K Through First-Grade Students With Intellectual Disabilities. The Journal of Special Education, 52, 78 - 88. https://doi.org/10.1177/0022466918761120

Keywords: Intellectual disabilities, Elementary, Technology, Computer programming, Robotics
Citation:19

[90] Tlili, A., Shehata, B., Adarkwah, M.A., Bozkurt, A., Hickey, D.T., Huang, R., & Agyemang, B. (2023). What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education. Smart Learning Environments, 10. https://doi.org/10.1186/S40561-023-00237-X
Keywords: Generative AI, ChatGPT, Chatbots, Education, Artificial intelligence, Human-machine collaboration

[91] van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., van der Ven, S.H., & Leseman, P.P. (2018). Social Robots for Language Learning: A Review. Review of Educational Research, 89, 259 - 295. https://doi.org/10.3102/0034654318821286
Keywords: Robot-assisted language learning, Human-robot interaction, First and second-language learning, Motivation, Novelty effect
Citation:110

[92] Xia, L., & Zhong, B. (2018). A systematic review on teaching and learning robotics content knowledge in K-12. Computers & Education, 127, 267-282. https://doi.org/10.1016/j.compedu.2018.09.007
Keywords: Elementary education, Secondary education, Improving classroom teaching, Pedagogical issues, Teaching/learning strategies
Citation:63

[93] Xu, Y., Wang, D., Collins, P., Lee, H.O., & Warschauer, M. (2021). Same benefits, different communication patterns: Comparing Children's reading with a conversational agent vs. a human partner. Computers & Education, 161, 104059. https://doi.org/10.1016/j.compedu.2020.104059
Keywords: Conversational agents, Language development, Storybook reading, Communication, Young children
Citation:24

[94] Yang, G., Bellingham, J., Dupont, P.E., Fischer, P., Floridi, L., Full, R.J., Jacobstein, N., Kumar, V.R., McNutt, M., Merrifield, R.D., Nelson, B.J., Scassellati, B., Taddeo, M., Taylor, R.H., Veloso, M.M., Wang, Z., & Wood, R. (2018). The grand challenges of Science Robotics. Science Robotics, 3. https://doi.org/10.1126/scirobotics.aar7650
Citation:488

[95] Zhang, B. Preparing Educators and Students for ChatGPT and AI Technology in Higher Education. https://doi.org/10.13140/RG.2.2.32105.98404

[96] Zheng, Z., Zhao, H., Swanson, A.R., Weitlauf, A.S., Warren, Z., & Sarkar, N. (2018). Design, Development, and Evaluation of a Noninvasive Autonomous Robot-Mediated Joint Attention Intervention System for Young Children With ASD. IEEE Transactions on Human-Machine Systems, 48, 125-135. https://doi.org/10.1109/THMS.2017.2776865

Keywords: Children with autism spectrum disorder (ASD), Joint attention, Robot-assisted intervention
Citation:30

[97] Zhong, B., & Li, T. (2020). Can Pair Learning Improve Students' Troubleshooting Performance in Robotics Education? Journal of Educational Computing Research, 58, 220 - 248. https://doi.org/10.1177/0735633119829191
Keywords: Robotics education, Troubleshooting, Pair learning, Individual learning
Citation:17

[98] Zhong, B., & Wang, Y. (2019). Effects of roles assignment and learning styles on pair learning in robotics education. International Journal of Technology and Design Education, 31, 41-59. https://doi.org/10.1007/s10798-019-09536-2
Keywords: Cooperative learning, Pair programming, Robotics education, Pair learning, Roles assignment, Learning style
Citation:12

[99] Zhong, B., & Xia, L. (2018). A Systematic Review on Exploring the Potential of Educational Robotics in Mathematics Education. International Journal of Science and Mathematics Education, 18, 79-101. https://doi.org/10.1007/s10763-018-09939-y
Keywords: Educational robotics, Mathematics education, Teaching/learning strategies, Transdisciplinary issues
Citation:45

[100] Zuschnegg, J., Paletta, L., Fellner, M., Steiner, J., Pansy-Resch, S., Jos, A., Koini, M., Prodromou, D., Halfens, R.J., Lohrmann, C., & Schüssler, S. (2021). Humanoid socially assistive robots in dementia care: a qualitative study about expectations of caregivers and dementia trainers. Aging & Mental Health, 26, 1270 - 1280. https://doi.org/10.1080/13607863.2021.1913476
Keywords: Dementia, Robotics, Informal Caregivers, Nurses, Activities of daily living
Citation:3

Reference

[1] Aris, N., & Orcos, L. (2019). Educational Robotics in the Stage of Secondary Education: Empirical Study on Motivation and STEM Skills. Education Sciences.https://doi.org/10.3390/educsci9020073

[2] Atmatzidou, S., Demetriadis, S.N., & Nika, P. (2018). How Does the Degree of Guidance Support Students' Metacognitive and Problem Solving Skills in Educational Robotics? Journal of Science Education and Technology, 27, 70-85.https://doi.org/10.1007/s10956-017-9709-x

[3] Chen, G., Shen, J., Barth-Cohen, L.A., Jiang, S., Huang, X., & Eltoukhy, M. (2017). Assessing elementary students' computational thinking in everyday reasoning and robotics programming. Comput. Educ., 109, 162-175.https://doi.org/10.1016/j.compedu.2017.03.001

[4] Daniela, L., & Strods, R. (2019). Educational Robotics for Reducing Early School Leaving from the Perspective of Sustainable Education. Smart Learning with Educational Robotics.https://doi.org/10.1007/978-3-030-19913-5_2

[5] Di Lieto, M.C., Castro, E., Pecini, C., Inguaggiato, E., Cecchi, F., Dario, P., Cioni, G., & Sgandurra, G. (2020). Improving Executive Functions at School in Children With Special Needs by Educational Robotics. Frontiers in Psychology, 10.https://doi.org/10.3389/fpsyg.2019.02813

[6] Evripidou, S., Georgiou, K., Doitsidis, L., Amanatiadis, A.A., Zinonos, Z., & Chatzichristofis, S.A. (2020). Educational Robotics: Platforms, Competitions and Expected Learning Outcomes. IEEE Access, 8, 219534-219562.https://doi.org/10.1109/ACCESS.2020.3042555

[7] Germany (2018). Artificial Intelligence Strategy. German Federal Government. https://www.ki-strategie-deutschland.de/home.html?file=files/downloads/Nationale_KI-Strategie_engl.pdf

[8] Littman, M.L., Ajunwa, I., Berger, G., Boutilier, C., Currie, M.E., Doshi-Velez, F., Hadfield, G.K., Horowitz, M.C., Isbell, C., Kitano, H., Levy, K.E., Lyons, T., Mitchell, M., Shah, J.A., Sloman, S.A., Vallor, S., & Walsh, T. (2022). Gathering Strength, Gathering Storms: The One Hundred Year Study on Artificial Intelligence (AI100) 2021 Study Panel Report. ArXiv, abs/2210.15767.https://doi.org/10.48550/arXiv.2210.15767

[9] Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A.N. (2017). Programming experience promotes higher STEM motivation among first-grade girls. Journal of experimental child psychology, 160, 92-106 .https://doi.org/10.1016/j.jecp.2017.03.013

[10] Miao, F., Wayne, H., Huang, R., & Zhang, H. (2021). AI and education Guidance for policymakers. Paris : UNESCO

[11] Ministry of Education and other six departments of China. The Ministry of Education and other six departments on promoting the construction of new education infrastructure and building a high-quality education support system [EB/OL]. http://www.moe.gov.cn/srcsite/A16/s3342/202107/t20210720_545783.html

[12] Ministry of Education of the People's Republic of China. Notice of the Ministry of Education on the issuance of the Action Plan for Education Informatization 2.0[EB/OL].http://www.moe.gov.cn/srcsite/A16/s3342/201804/t20180425_334188.html?from=timeline&isappinstalled=0

[13] Ministry of Industry and Information Technology. The notice of the fifteenth department on the issuance of the "14th Five-Year Plan" robot industry development plan[EB/OL].https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2021/art_14c785d5a1124f75900363a0f45d9bbe.html

[14] Nemiro, J.E., Larriva, C., & Jawaharlal, M. (2017). Developing Creative Behavior in Elementary School Students with Robotics. Journal of Creative Behavior, 51, 70-90.https://doi.org/10.1002/jocb.87

[15] S.1260-United States Innovation and Competition Act of 2021. https://www.congress.gov/bill/117th-congress/senate-bill/1260/text

[16] State Council of China.The State Council on issuance of the development plan of the new generation of artificial intelligence[EB/OL].http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm

[17] UK Ministry of Defence. Defence artificial intelligence strategy[EB/OL].2022-06.https://www.gov.uk/government/publications/defence-artificial-intelligence-strategy/defence-artificial-intelligence-strategy

[18] UNESCO. Beijing Consensus on Artificial Intelligence and Education[EB/OL]. 2019-05.https://unesdoc.UNESCO.org/ark:/48223/pf0000368303

[19] UNESCO. K-12 AI curricula:A mapping of government-endorsed AI curricula[R/OL].https://unesdoc.unesco.org/ark:/48223/pf0000380602/PDF/380602eng.pdf.multi

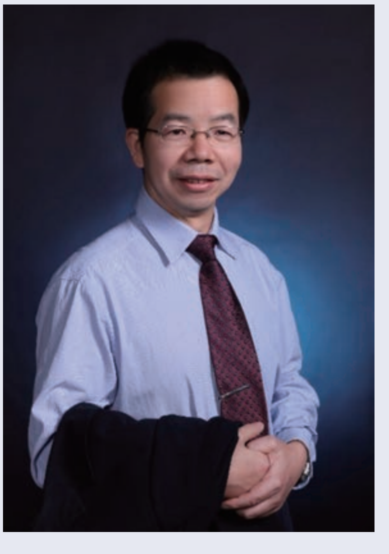
UNESCO has approved the establishment of a UNESCO chair on Artificial Intelligence in Education at Beijing Normal University in November 2022. The Chair will investigate the use of artificial intelligence in education as a driver and component of solutions and strategies to support the attainment of the Sustainable Development Goals (SDGs).

The goal of the Chair is to foster an integrated system of education-related artificial intelligence research, training, information, and documentation. It will facilitate collaboration between high-level, internationally-recognized researchers and teaching staff of the University and other institutions in China, as well as elsewhere in Asia, Africa, Latin America, and in other regions of the world.

The Chair works on the missions to:

- Improve the capabilities of educators and education managers to use Artificial Intelligence (AI) ethically and effectively in education;
- Promote international policy dialogue with an emphasis on artificial intelligence in education and the utilization of AI to enable digital transformation in education;
- Facilitate technical innovation on trustworthy, safe, transparent, explainable, and robust AI algorithms, AI tools, and evidence-based, effective models of employing AI in education;
- Support the development of AI talents and high-level graduates of higher education institutions;
- Cooperate closely and actively with concerned entities of UNESCO, and existing Chairs and Networks of UNESCO on relevant programs and activities.

Prof. HUANG Ronghuai, who has lead research on smart learning environments, artificial intelligence in education, educational technology, and knowledge engineering, takes on the role of Chairholder.



United Nations Educational, Scientific and Cultural Organization
International Research and Training Centre for Rural Education

The UNESCO International Research and Training Centre for Rural Education (UNESCO INRULED) was established by UNESCO and the Chinese government in 1994 with a mandate to promote sustainable socio-economic development in rural areas. As a Category II center under the auspices of UNESCO, INRULED's research and training activities concentrate on education for rural transformation. The Center has moved to Beijing Normal University in 2008 for better coordination and connectivity. Through research and publicity, education and training, knowledge management and distribution, UNESCO INRULED works in the area of rural education, aiming to bring about positive changes in the thinking and behaviour of rural people, and to achieve the social, economic and ecological development of the rural areas that contribute to the realisation of the SDG4 and the 2030 Agenda. UNESCO INRULED's mission is "Education for Rural Transformation".

北京师范大学智慧学习研究院
Smart Learning Institute of Beijing Normal University

The UNESCO International Research and Training Centre for Rural Education (UNESCO INRULED) was established by UNESCO and the Chinese government in 1994 with a mandate to promote sustainable socio-economic development in rural areas. As a Category II center under the auspices of UNESCO, INRULED's research and training activities concentrate on education for rural transformation. The Center has moved to Beijing Normal University in 2008 for better coordination and connectivity. Through research and publicity, education and training, knowledge management and distribution, UNESCO INRULED works in the area of rural education, aiming to bring about positive changes in the thinking and behaviour of rural people, and to achieve the social, economic and ecological development of the rural areas that contribute to the realisation of the SDG4 and the 2030 Agenda. UNESCO INRULED's mission is "Education for Rural Transformation".

Highlights

1. The development trend for AI Generated Content (AIGC) and Large Language Models (LLMs) is towards increased sophistication, efficiency, and integration with other AI technologies. These advancements will have a significant impact on education, enabling personalized and adaptive learning experiences, automated grading and assessment, and the creation of high-quality educational materials. However, there are also concerns about the potential for bias, cheating, lack of transparency, exacerbation of issues of equitability, and the need to ensure the ethical and responsible use of these technologies in education.

2. As one of the pilot AIGC projects, ChatGPT and GPT-4 are revolutionary and upgraded versions of conversational agents. To achieve the proper use of AI technology in education like ChatGPT, the focus on critical thinking becomes more important, to filter out inaccurate information ChatGPT generates. Clear guidelines are needed to clarify the acceptable and non-acceptable use of such tools.

3. The robotics manufacturing industry is moving in a direction that prioritizes higher levels of automation, enhanced precision and accuracy, improved efficiency, and the use of advanced technologies such as artificial intelligence and machine learning. This will have a significant impact on educational equipment, as they provide innovative and engaging tools for students to learn and interact with technology.

4. The development of educational robots is influenced by a series of factors, including the open-source movement, market demand, industry drive, and capital pressure. These factors raise ethical and moral concerns, safety concerns, issues of human dignity, and the cost of computing power.

5. Robotics has become more and more popular in facilitating STEM education, as it provides an engaging and hands-on learning experience for students, and stimulates cooperative learning, which has positive effects on student motivation and science process skills. A keen focus is needed on creating a constructive environment, exploring learning patterns, and breaking technological and economic barriers by providing low-cost STEM education solutions.

6. Robot-oriented programming is an effective mode for all age groups, as to develop computational thinking, problem-solving skills, and creativity, and promotes learner engagement and cooperation. However, the main problems of current robot-oriented programming education include the lack of necessary equipment, shortage of qualified teachers, and the need for related teaching materials to meet the demand for students of all grade levels.

7. Language Learning with Social Robots is a rapidly expanding field that has the potential to transform language education for both children and adults. With studies exploring different robots and methods for various languages and aspects of language, social robots have shown promise in developing children's language skills, supporting second language learning in adults. It is needed to explore effective roles, groups and contexts to meet the diverse needs of students beyond traditional classroom settings.

8. Robotics can augment conventional pedagogical practices and have a great potential to improve students' understanding of fundamental concepts, reinforce system design skills, and promote engagement and motivation, particularly in mathematics and multidisciplinary engineering courses. However, more rigorous research is needed such as empirical studies that demonstrate the impact of integrating robotics on the academic performance of students.

9. In the field of special education, particularly for children with autism spectrum disorder, social robots are preferred due to their childlike appearance, patience, stability, and ability to perform multiple roles. Though robot-enhanced therapy for children with ASD is a research field still in its infancy, it has shown promising potential for future development, as it enhances communication and social interaction, and reduce behavioral symptom. More focus is needed on long-term in-home robotic therapy, and ways to transfer acquired skills to everyday life. More appropriate clinical guidance is also needed.

10. Cognitive training robotics have provided promising training and assistance approaches to mitigate cognitive deficits, especially for senior people with special needs. Robotics can improve several aspects of mild cognitive impairment, such as cognitive function, memory, executive function, etc. Meanwhile, stakeholders have a high level of acceptance of robotics in the elderly population. However, there is still a long way to go before robots are routinely used in the home, hospital and care settings.

AIED UNESCO CHAIR ON AI IN EDUCATION

unesco Chair

United Nations Educational, Scientific and Cultural Organization · International Research and Training Centre for Rural Education

北京师范大学智慧学习研究院
Smart Learning Institute of Beijing Normal University

Website: http://sli.bnu.edu.cn/en/

Address: 12F, Block A, Jingshi Technology Building, No. 12 Xueyuan South Road, Haidian District, Beijing, China

Email: unescochair.aied@bnu.edu .cn

Phone: +86 10-58807219

Postcode: 100091

http://sli.bnu.edu.cn/en