Online-Journals.org

iJOE International Journal of Online and Biomedical Engineering

iJOE | eISSN: 2626-8493 | Vol. 19 No. 18 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijoe.v19i18.43893

PAPER

# Exploring the Learning Gains of Implementing Teacher Humanoid Robots in STEM Education: A Systematic Review

**Vasiliki Mertzani[1], Athanasios Drigas[2](✉)**

[1]Metropolitan College of Greece, Athens, Greece

[2]Demokritos Institute of Informatics and Telecommunications – Net Media Lab Mind – Brain R&D IIT – N.C.S.R. "Demokritos", Athens, Greece

dr@iit.demokritos.gr

**ABSTRACT**

Educational (or pedagogical) robotics has received increased attention over the last few years based on its effectiveness on the learning process. Humanoid robots have been recently introduced in school settings to mainly support teaching of curriculum-based subjects. However, humanoid robots' benefits on STEM education in typical classroom settings are less examined by the research literature. Instead, most research studies take place in non-typical school or classroom settings (such as laboratories). The main goal of the current review is to sum up results of relevant research studies about the positive impact of teacher humanoid robots on STEM education. The learning benefits in STEM subjects, programming and reasoning skills are examined too. Sample subject of this review are mainstream students aged 4 to 18 years old and research studies are grouped based on their commonalities such as common learning areas and results.

**KEYWORDS**

teacher humanoid robots, STEM education, learning gains, programming and coding, reasoning and problem-solving skills

## 1 INTRODUCTION

STEM education has emerged as a pedagogical approach that brings together science, technology, engineering, and mathematics in school settings as integrating diverse learning fields [9]. Based on STEM's interdisciplinary nature, collaborative learning, critical thinking and reflective skills can be promoted through investigation, planning and programming [42], which constitute critical and necessary skills for a range of curriculum subject-areas [11].

Educational robotics has been an inherently interdisciplinary field that introduces students to robotic platforms, robotic kits, and programmable robots for engaging them with coding, programming, and planning [15]. The integration of

Mertzani, V., Drigas, A. (2023). Exploring the Learning Gains of Implementing Teacher Humanoid Robots in STEM Education: A Systematic Review. *International Journal of Online and Biomedical Engineering (iJOE)*, 19(18), pp. 18–30. https://doi.org/10.3991/ijoe.v19i18.43893

Article submitted 2023-08-08. Revision uploaded 2023-10-20. Final acceptance 2023-10-26.

educational robotics in the learning process promotes students' motivation and interest for science and technology-oriented subjects (such as mathematics, science), hence complicated concepts can be more accessible to them [8]. Several recent studies [16, 44, 47] provide strong evidence for robotics' positive role on STEM education, improving students' digital literacy, creation of hypotheses and problem-solving skills. As a result, students, instead of simply receiving information and knowledge, can play an active role in the learning process as creators of their knowledge [20]. In STEM, educational, robotics can be applied for "hands-on-activities" but also with the use of programmable humanoid robots [22].

Humanoid robots replicate human form and its movement; however, they are polymorphic, and they can differ in terms of size, shape, and structure according to the task [41]. Their introduction in school settings is relatively new with the main goal being personalizing student support [3] or being applied for the whole class [19]. The increased educational interest for robotics in school is a result of their humanoid social characteristics with which those students can find common ground [32], but also as a result of their evidence-based effect on the teaching process. Research literature highlights robotics' effectiveness on students' motivation for learning [23] and the change of attitudes for robotics [13], but also the development of their critical thinking, problem-solving as skills that can be developed in STEM education too [24]. Hence, there is evidence to suggest that humanoid robots can be considered as a critical tool to promote STEM education [8].

However, most studies examine the effectiveness of educational robotics in students' oral language, reading skills and their engagement in literacy-oriented subjects [24]. Additionally, research literature focuses on teacher social robots' role in vocabulary development, enhancement of writing, reading, oral language [10], social skills and motivation for learning [36]. Consequently, fewer studies investigate the use of humanoid robots in STEM education and thus there is gap in the existing literature regarding STEM and humanoid robots.

Based on the increased attention and interest for integrating robotics in classroom settings, its effective on the learning process and the necessity for more research and empirical evidence, the current systematic literature review aims to provide a synthesis of relevant studies about robotics' effect on STEM education. The current systematic review intends to answer the following research question:

- Efficacy: Which are the learning gains from implementing humanoid robots in STEM education in classroom settings?

## 2 METHODOLOGY

Systematic literature review is defined as a method of collecting, evaluating, studying and reflecting on available research studies with quantitative and qualitative data relevant to specific research questions and research fields [6]. In the current systematic literature review, this method consisted of two phases: a. investigation of relevant research literature, b. examination of studies against certain inclusion criteria.

### 2.1 Phase 1

In the first phase upon search of available literature, several research papers were collected relevant to the effectiveness of humanoid robots in STEM education.

A variety of accessible web search engines were used such as “Science Direct”, “Springer Link”, “ERIC”, “Web of science”, “Oxford Journals Online”, “Sage Journals Online” and several key-words were also applied such as “humanoid robots”, “STEM subjects”, “STEM in school”. The research papers that were studied and included in the current literature review have been conducted between 2011 and 2022.

### 2.2 Phase 2

In the second phase, the research studies were carefully reviewed by examining the abstract, research goal, sample, study settings but most importantly, specific criteria were set for determining whether the studies were suitable or not for this study. These criteria were:

- The study is not a systematic literature review
- The study focuses on the use of teacher humanoid robots in STEM education
- The study has been conducted in classroom settings and not in laboratories
- The sample of the study is mainstream students aged 4–18 years old
- The study has been conducted between 2011 and 2022

Because of the above inclusion criteria, duplicates and several studies were excluded such as the study [7] which took place in lab settings. As a result of this review process, 20 in total research studies were included in this study. Following that, the studies were coded as a helpful process for the analysis, interpretation of their results, and generation of relevant themes. In this phase, six themes were created as they are presented: 1. Author/s, 2. Research Design, 3. Sample size, 4. Sample age, 5. Educational Level, 6. Results. The results were categorized into three broad categories too: learning gains in STEM subjects, programming, coding, and reasoning skills.

## 3 RESULTS

In total 20 research articles relevant to the use of humanoid robots in STEM in classroom settings were reviewed and coded. Following this coding process, three main themes were generated: a. Learning gains in STEAM subjects, b. Programming, c. Reasoning skills. In the following section, an analysis and interpretation of the results/themes is provided.

### 3.1 Learning gains in STEM subjects

Upon analysis, it was concluded that humanoid robots are used mostly in mathematics, science, and geography subjects as against other STEM subjects, programming, and coding trainings.

**Mathematics and Geometry.** Most experimental studies focus on robots’ role in teaching instructional mathematical areas (Numeracy, Operations, Spatial Sense, Measurement, Geometry). Specifically, the comparative study [40] indicates the effectiveness of NAO social robot in teaching/learning numeracy to elementary students. A total of 38 students (10–11 years old) participated in 2 experimental conditions: a. perform the experiment with the teacher, b. perform the experiment with the robot-tutor. According to the post-test findings, the students who interacted with the robot achieved better scores in all mathematical questions and demonstrated academic improvement. Similarly, the mixed-method and multi-scenario study [33] provides strong evidence for implementing NAO robot to promote learning new mathematical concepts (number fractions, metric system). Different educational scenarios were implemented for three educational levels: elementary (28 students aged 8–11 years old), secondary (25 students aged 11–14 years old), high school (entire classrooms). Based on the post-tests, the results of the experimental groups were higher than the ones for control groups and hence learning gains in math were found.

Regarding operations, the experimental study [31] with a sample of 86 elementary students (8–10 years old) investigated the effectiveness of humanoid robots in teaching multiplications. A NAO robot-teacher was used, and the sample randomly participated in two experimental conditions: a. neutral robot-teacher, b. social robot-teacher (verbal language) with the completion of mathematics summative tests about multiplication tables. Post-assessment, students' ability on time-tables was enhanced (from $M = 55.73$ to $M = 62.12$) independently through the robots' behavioural role. The positive role of NAO robot has been evidenced for other instructional mathematical concepts such as prime numbers. The study [27] provides strong evidence for the effectiveness of robots in fostering conceptual teaching in elementary classrooms. A random sample of 22 students (8–9 years old) participated in two experimental conditions: a. robot-teacher compared to b. human-teacher. The post-test emphasized the helpful role of the robot-teacher, however no significant difference was evident between both conditions. The same researchers [26] one year before had conducted one more experimental study with the use of the same type of robot to exclusively examine its effectiveness in introducing the concept of prime numbers to 45 students aged 5 years old. Across the four experimental conditions: a. instruction, b. instruction with digital materials, c. instruction with neutral robot, and d. instruction with social robot, it was evidenced that students showed important progress with the neutral robot-teacher.

In terms of spatial sense, the experimental study [29] investigated the impact of a Kindergarten Assistive Robotics System (KAR) on early childhood children's geometrical thinking and spatial cognition. A total of 9 children aged 3–4 years old participated in different play-based activities with the presence of NAO robot. Children's visuospatial perception and spatial navigation were examined with the post-test results to indicate the positive role of the robot on students' geometrical thinking skills.

Regarding teaching and learning of geometry, Kennedy et al. [25] examined the impact of NAO robot on teaching and learning about geometrical shapes for 28 elementary students 8 years old. Two experimental conditions were applied: a. physical presence of robot, b. virtual robot on i-Pad screen. It is important to note that for both conditions, an improved performance was evidenced. Similarly, the experimental study [37] indicates the effective role of NAO robot in enabling 52 students (11–12 years old) solve perimeter practice problems. A "between subject design" was applied with two experimental conditions: a. robot-teacher presence, b. robot-teacher programmable to follow the "Thinking Aloud" learning strategy (reflection, revisions). Based on post-test results, the initial hypothesis about the positive role of the robot was confirmed, compared to the hypothesis about the second condition as the most effective, which was not finally confirmed.

Nevertheless, the comparative study [5] provides mixed results with reference to the effectiveness of NAO robot as a mathematics tutor. A total of 14 students aged 8–9 years old were randomly assigned in two comparative experimental conditions: a. robot-mathematics tutor, b. human-mathematics tutor and robot; were taught novel algebra concepts. Based on the post-test, although an improvement was found for the group taught by the robot, no statistically significant difference between the robot and the human teacher was evidenced.

**Geography and science.** In geography and science learning areas, fewer and smaller-scale studies about the use of humanoid robots have been found and reviewed.

The study [21] investigated the use of NAO robot in reading and interpreting geographical maps. A sample of 24 students (10–12 years old) participated in two experimental conditions: a. robot-teacher provides guidance, b. robot-teacher promotes inquiry-based learning. Positive results were highlighted for both conditions in reference to students' performance, reading and identification of maps. Regarding the science and engineering areas of study [18] examined the role of an Android robot-teacher (SAYA type), established by the University of Tokyo, on teaching and learning about Lever law. A total of 45 students (11–12 years old) randomly assigned in two groups participated in a series of tutorials, experiments, and formative test. Based on the post-test, a significant improvement of both groups' understanding, knowledge and performance was evidenced. For early childhood education level, the experimental study of [28] with a sample of 17 students (4–5 years old) investigated the impact of a robotic social system (Kindsar) on sample's learning about the 4 seasons of the year and development of geometric thinking (generating 3D shapes). Positive results were evidenced for both learning areas with slightly better students' performance on science learning.

**Environmental education.** With reference to the use of humanoid robots in Environmental Education, fewer and mainly action research studies were collected following the review process.

Ziouzios et al. [46] designed the EI-EDUROBOT with neutral robot assets to investigate its effectiveness on the development of environmental empathy and environmental knowledge for a sample of 50 students (12 years old). A series of educational scenarios with robot's narrations, interactions, and students' collaborative activities took place. According to the post-test, the role of the robot was significantly helpful to enhance students' competency for environmental issues and foster their positive attitudes towards environment. However, the research hypothesis about the positive impact of NAO robot on the development of environmental empathy as generated by Alves-Oliveiro et al. [1] in their study was not finally supported. In more detail, two studies with different duration took place with educational scenarios about energy consumption and collaborative student games. A sample of 63 students (14 years old) and 20 students (14 years old) was randomly assigned in two experimental conditions: a. robot-teacher with empathy, b. robot-teacher without empathy. Both post-tests indicated lower empathy scores compared to the pre-test scores.

### 3.2 Programming and coding

For the development of programming and coding skills, pilot projects were mainly found with significant evidence of robots' effectiveness in STEM.

The action research [34] investigated the way that NAO robot can foster students' programming, coding skills and their familiarization with Artificial Intelligence. A total of 24 students (11–16 students) from different elementary and secondary schools participated in a series of trainings "designing, experimenting, innovation", "Programming, Robotics". Positive results were indicated with most students demonstrating good knowledge of robotic parts system, operations (eg., end effectors) and give motion and verbal behaviour to robots with the software Choreographie. Likewise, the pilot research project "Robotikum" [43] studied the role of NAO robot in familiarization of study's sample with robotic platforms and development of programming, coding skills. Several training projects with three different sample groups took place (9 students 7–10 years old, 14 students 11–14 years old, 8 students 12 years old) from different socio-economic backgrounds. Based on the final evaluation and students' self-reports, the robot significantly contributed to students' understanding and basic knowledge of programming and coding processes.

In the light of STEM education, Ko et al. [30] established a "robot-theatre project" with music, theatrical, robotic components. Four different programme-trainings took place with three aged sample groups: 1st group-12 students (6 years), 2nd group-25 students (8 years), 3rd group-40 students (16 years) and different robots were used (NAO, Pepper, Darwin). Each sample group participated in writing plenary tasks with robot characters and programming robots with verbal language and motion. The positive impact of robots was highlighted for all the sample-groups; however, lower performance was evidenced for the younger students. One more STEM "robot-theatre project" was conducted [2] with a sample of 37 students (7–9 years old) and the use of different robots (NAO, Darwin types). Same research methodology process (design, programming trainings) with the study [30] was followed and it was concluded that the combination of robotics and art was effective for students' programming and coding competencies.

### 3.3 Reasoning and problem-solving skills

Besides the studies about the use of humanoid robots in STEM subjects and trainings for programming and coding, existing literature provides evidence for robots' positive impact on reasoning and problem-solving as relevant skills to STEM education.

The experimental study [38] with a sample of 25 students (12–15 years old) highlighted the positive role of NAO robot on students' reasoning skills in a LEGO building task. Two experimental comparative conditions were implemented: a. human-teacher intervention, b. robot-teacher intervention. Among those, the second condition with the presence of the robot was alluded to as the most effective.

Similarly, the pilot project conducted by the United Robotics Group in collaboration with the Association of Independent Schools of Australia from 2015 to 2017 [39] involved 19 classrooms with students aged 4–15-year-old, provides empirical evidence for NAO robot's effective role in problem-solving, critical thinking and coding skills. The students were introduced to Python programming language and were taught how to programme NAO robots. According to the qualitative findings, all the students significantly developed their problem-solving skills, creativity, and programming skills.

## 4 DISCUSSION

A total of 20 studies were included in the current literature review, which had been conducted from 2011 to 2022 and were categorized based on their commonalities.

### 4.1 Efficacy of humanoid robots in STEM education

The results of the study focus on the learning domain and they are classified as: a. learning gains in STEM subjects, b. programming, c. reasoning skills as they are presented in Figure 1.

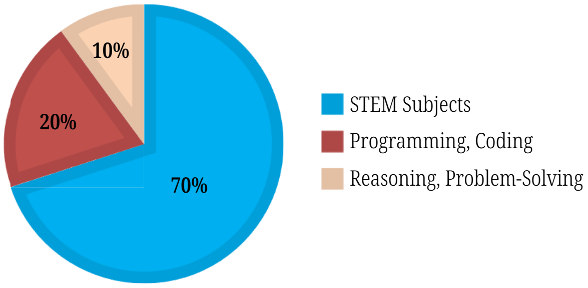


**Fig. 1.** Use of humanoid robots and learning gains

In terms of learning gains, the very high percentage of 70% out of 20 studies examined the effectiveness of humanoid robots on learning gains in relevant STEM subjects such as mathematics and science, followed by 20% of the studies investigating the role of robots in teaching/learning programming and finally 10% focussed on problem-solving and reasoning skills. Interpreting these percentages with most studies focusing on the learning gains in STEM subjects, there is evidence to suggest that humanoid robots can be critical for teaching curriculum, technology-oriented subjects. Nevertheless, the application of robots for the development of programming skills, problem-solving, and mainly for the change of secondary students' attitudes towards robotics is less studied, a conclusion which is consistent with the existing literature [12].

### 4.2 Educational levels

It is also important to note that the comparative study of [5] and the study [1] did not support the initial hypotheses for robots' effectiveness in STEM, possibly because their experimental conditions differentiate from the other studies (eg, involvement of both human-mathematics tutor and robot-tutor in one experimental condition). Therefore, this different variable can affect the effectiveness of the robot, a conclusion that agrees with the existing literature (Figure 2) [17].

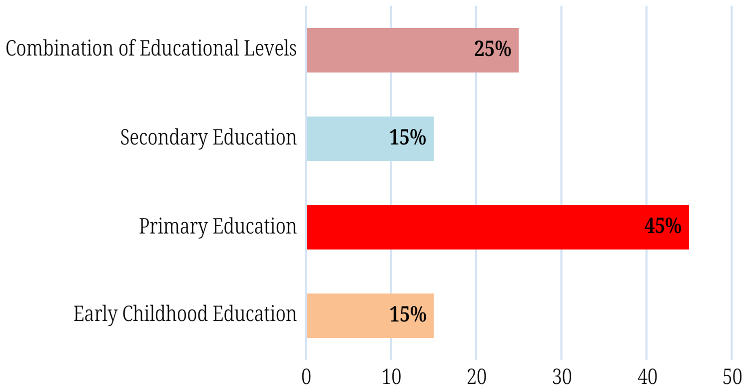


**Fig. 2.** Use of humanoid robots in education levels

Regarding the use of humanoid robots in school settings, it was evidenced that the significant percentage of 45% of studies took place in elementary educational level, followed by 25% of big-scale studies conducted in a combination of education levels and finally 15% of studies took place in kindergarten and 15% in secondary education, respectively. Hence, humanoid robots are used mainly in primary educational level to foster elementary students' reasoning, programming skills and promote their learning in STEM education compared to the other education levels. Existing literature suggests too that humanoid robots can be applied across all the education levels based on their effect on the learning process, but more important contribution is evidenced for elementary students [45].

## 5 CONCLUSION

In conclusion, we emphasize the importance of all digital technologies in the field of education and STEM training. These technologies are highly effective and productive and facilitate and improve assessment, intervention, and educational procedures through mobile devices that bring educational activities anywhere [48–49], various ICTs applications that are the main supporters of education [50–51], and games [52] that raise educational procedures to new performance levels. In addition, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the development of emotional intelligence [53–64], accelerate and improve educational practices and results more than those, especially in STEM education domain and its practices like assessment and intervention.

More specifically from the results of this study, the following conclusions can be drawn:

**a)** Humanoid robot can significantly enhance the learning process and particularly promote learning gains in STEM subjects (such us mathematics), which is also supported by other authors [35] who highlighted the positive impact of humanoid robots on students' performance in STEM oriented subjects. Moreover, the physical presence of robots can foster students' programming, coding, problem-solving and reasoning skills as well as increase their engagement in STEM education, which is similarly alluded by existing literature [6].

**b)** Humanoid robots are mostly used in Elementary Education and effectively support elementary students based on their need for a more directive teaching style as it is indicated by research literature [14]. The same conclusion is also supported by [4] in their systematic review. Finally, robots can foster students' self-esteem, critical thinking and inquiry skills, which is in line with the study [31].

## 6 REFERENCES

[1] P. Alves-Oliveira, P. Sequeira, F. S. Melo, G. Castellano, and A. Paiva, "Empathic robot for group learning: A field study," *ACM Transactions on Human-Robot Interaction (THRI),* vol. 8, no. 1, pp. 1–34, 2019. https://doi.org/10.1145/3300188

[2] J. Barnes, S. M. FakhrHosseini, E. Vasey, C. H. Park, and M. Jeon, "Child-robot theater: Engaging elementary students in informal STEAM education using robots," *IEEE Pervasive Computing*, vol. 19, no. 1, pp. 22–31, 2017. https://doi.org/10.1109/MPRV.2019.2940181

[3] T. Belpaeme, P. Baxter, R. Read, R. Wood, H. Cuayáhuitl, B. Kiefer, S. Racioppa, I. Kruijff-Korbayová, G. Athanasopoulos, V. Enescu, and R. Looije, "Multimodal child-robot interaction: Building social bonds," *Journal of Human-Robot Interaction*, vol. 1, no. 2, pp. 33–53, 2012. https://doi.org/10.5898/JHRI.1.2.Belpaeme
[4] T. Belpaeme, J. Kennedy, A. Ramachandran, B. Scassellati, and F. Tanaka, "Social robots for education: A review," *Science Robotics*, vol. 3, no. 21, p. 5954, 2018. https://doi.org/10.1126/scirobotics.aat5954
[5] A. Bhat, A. Chojnacki, and E. Knapp, "The future is nao: Teaching mathematics to young schoolchildren using humanoid robots," in *New Friends 2016 2nd International Conference on Social Robots in Therapy and Education*, Barcelona, Spain, 2016.
[6] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *Journal of Engineering Education*, vol. 103, no. 2, pp. 220–252, 2014. https://doi.org/10.1002/jee.20040
[7] W. Budiharto and A. D. Cahyani, "Behavior-based humanoid robot for teaching basic mathematics," *Internetworking Indonesia*, vol. 9, no. 1, pp. 33–37, 2017.
[8] W. Budiharto, A. D. Cahyani, P. C. Rumondor, and D. Suhartono, "EduRobot: Intelligent humanoid robot with natural interaction for education and entertainment," *Procedia Computer Science*, vol. 116, pp. 564–570, 2017. https://doi.org/10.1016/j.procs.2017.10.064
[9] M. Çetin and H. Ö. Demircan, "Empowering technology and engineering for STEM education through programming robots: A systematic literature review," *Early Child Development and Care*, vol. 190, no. 9, pp. 1323–1335, 2020. https://doi.org/10.1080/03004430.2018.1534844
[10] C. Chalmers, T. Keane, M. Boden, and M. Williams, "Humanoid robots go to school," *Education and Information Technologies*, vol. 27, no. 6, pp. 7563–7581, 2022. https://doi.org/10.1007/s10639-022-10913-z
[11] J. D. Chesloff, "STEM education must start in early childhood," *Education Week*, vol. 32, no. 23, pp. 27–32, 2013.
[12] J. DeWitt, J. Osborne, L. Archer, J. Dillon, B. Willis, and B. Wong, "Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable," *International Journal of Science Education*, vol. 35, no. 6, pp. 1037–1063, 2013. https://doi.org/10.1080/09500693.2011.608197
[13] M. Donnermann, M. Lein, T. Messingschlager, A. Riedmann, P. Schaper, S. Steinhaeusser, and B. Lugrin, "Social robots and gamification for technology supported learning: An empirical study on engagement and motivation," *Computers in Human Behavior*, vol. 1, no. 121, p. 106792, 2021. https://doi.org/10.1016/j.chb.2021.106792
[14] S. Ekström and L. Pareto, "The dual role of humanoid robots in education: As didactic tools and social actors," *Education and Information Technologies*, vol. 27, no. 9, pp. 12609–12644, 2022. https://doi.org/10.1007/s10639-022-11132-2
[15] S. Evripidou, K. Georgiou, L. Doitsidis, A. A. Amanatiadis, Z. Zinonos, and S. A. Chatzichristofis, "Educational robotics: Platforms, competitions and expected learning outcomes," *IEEE Access*, vol. 8, pp. 219534–219562, 2020. https://doi.org/10.1109/ACCESS.2020.3042555
[16] Q. Hanif, C. W. Budiyanto, and R. A. Yuana, "Abstract thinking skills of high school students in STEM learning: Literature review," in *Journal of Physics: Conference Series*, vol. 1808, no. 1, p. 12019, 2021. https://doi.org/10.1088/1742-6596/1808/1/012019
[17] P. A. Hancock, D. R. Billings, K. E. Schaefer, J. Y. Chen, E. J. De Visser, and R. Parasuraman, "A meta-analysis of factors affecting trust in human-robot interaction," *Human Factors*, vol. 53, no. 5, pp. 517–527, 2011. https://doi.org/10.1177/0018720811417254
[18] T. Hashimoto, I. M. Verner, and H. Kobayashi, "Human-like robot as teacher's representative in a science lesson: An elementary school experiment," in *Robot Intelligence Technology and Applications 2012: An Edition of the Presented Papers from the 1st International Conference on Robot Intelligence Technology and Applications Springer Berlin Heidelber*g, 2013, pp. 775–786. https://doi.org/10.1007/978-3-642-37374-9_74

[19] J. N. Hughes and O. M. Kwok, "Classroom engagement mediates the effect of teacher–student support on elementary students' peer acceptance: A prospective analysis," *Journal of School Psychology*, vol. 43, no. 6, pp. 465–480, 2006. https://doi.org/10.1016/j.jsp.2005.10.001

[20] M. Jeon, M. FakhrHosseini, J. Barnes, Z. Duford, R. Zhang, J. Ryan, and E. Vasey, "Making live theatre with multiple robots as actors bringing robots to rural schools to promote STEAM education for underserved students," in *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, IEEE, pp. 445–446, 2016. https://doi.org/10.1109/HRI.2016.7451798

[21] A. Jones and G. Castellano, "Adaptive robotic tutors that support self-regulated learning: A longer-term investigation with primary school children," *International Journal of Social Robotics*, vol. 10, pp. 357–370, 2018. https://doi.org/10.1007/s12369-017-0458-z

[22] M. Kalaitzidou and T. P. Pachidis, "Recent robots in STEAM education," *Education Sciences*, vol. 13, no. 3, p. 272, 2023. https://doi.org/10.3390/educsci13030272

[23] T. Kanda, R. Sato, N. Saiwaki, and H. Ishiguro, "A two-month field trial in an elementary school for long-term human–robot interaction," *IEEE Transactions on Robotics*, vol. 23, no. 5, pp. 962–971, 2007. https://doi.org/10.1109/TRO.2007.904904

[24] T. Keane, C. Chalmers, M. Boden, and M. Williams, "Humanoid robots: Learning a programming language to learn a traditional language," *Technology, Pedagogy and Education*, vol. 28, no. 5, pp. 533–546, 2019. https://doi.org/10.1080/1475939X.2019.1670248

[25] J. Kennedy, P. Baxter, and T. Belpaeme, "Comparing robot embodiments in a guided discovery learning interaction with children," *International Journal of Social Robotics*, vol. 7, pp. 293–308, 2015b. https://doi.org/10.1007/s12369-014-0277-4

[26] J. Kennedy, P. Baxter, and T. Belpaeme, "The robot who tried too hard: Social behaviour of a robot tutor can negatively affect child learning," in *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction*, 2015a, pp. 67–74. https://doi.org/10.1145/2696454.2696457

[27] J. Kennedy, P. Baxter, E. Senft, and T. Belpaeme, "Heart vs hard drive: Children learn more from a human tutor than a social robot," in 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI), IEEE, 2016, pp. 451–452. https://doi.org/10.1109/HRI.2016.7451801

[28] G. Keren and M. Fridin, "Kindergarten social assistive robot (KindSAR) for children's geometric thinking and metacognitive development in preschool education: A pilot study," *Computers in Human Behavior*, vol. 35, pp. 400–412, 2014. https://doi.org/10.1016/j.chb.2014.03.009

[29] G. Keren, A. Ben-David, and M. Fridin, "Kindergarten assistive robotics (KAR) as a tool for spatial cognition development in pre-school education," in *2012 IEEE/RSJ international conference on intelligent robots and systems*, IEEE, 2012, pp. 1084–1089. https://doi.org/10.1109/IROS.2012.6385645

[30] S. Ko, H. Swaim, H. Sanghavi, J. Dong, C. Nadri, and Jeon, M. "Robot-theater programs for different age groups to promote STEAM education and robotics research," in *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 2020, pp. 299–301. https://doi.org/10.1145/3371382.3378353

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

[32] H. Kose-Bagci, E. Ferrari, K. Dautenhahn, D. S. Syrdal, and C. L. Nehaniv, "Effects of embodiment and gestures on social interaction in drumming games with a humanoid robot," *Advanced Robotics*, vol. 23, no. 14, pp. 1951–1996, 2009. https://doi.org/10.1163/016918609X12518783330360

[33] E. Lopez-Caudana, M. S. Ramirez-Montoya, S. Martínez-Pérez, and G. Rodríguez-Abitia, "Using robotics to enhance active learning in mathematics: A multi-scenario study," *Mathematics*, vol. 8, no. 12, p. 2163, 2020. https://doi.org/10.3390/math8122163

[34] G. Majgaard, "Multimodal robots as educational tools in primary and lower secondary education," in *I The 9th International Conference on Interfaces and Human Computer Interaction*, vol. 22, 2015, p. 24.

[35] P. N. Mwangi, C. M. Muriithi, and P. B. Agufana, "Exploring the benefits of educational robots in STEM Learning: A systematic review," *International Journal of Engineering and Advanced Technology*, vol. 11, no. 6, pp. 5–11, 2022. https://doi.org/10.35940/ijeat.F3646.0811622

[36] M. Pedaste and H. Altin, "Does inquiry-based education using robots have an effect on learners' inquiry skills, subject knowledge and skills, and motivation?," *International Journal on Advanced Science Engineering and Information Technology,* vol. 10, no. 4, pp. 1403–1409, 2020. https://doi.org/10.18517/ijaseit.10.4.12766

[37] A. Ramachandran, C. M. Huang, E. Gartland, and B. Scassellati, "Thinking aloud with a tutoring robot to enhance learning," in *Proceedings of the 2018 ACM/IEEE international conference on human-robot interaction*, 2018, pp. 59–68. https://doi.org/10.1145/3171221.3171250

[38] S. Serholt, C. A. Basedow, W. Barendregt, and M. Obaid, "Comparing a humanoid tutor to a human tutor delivering an instructional task to children," in 2014 IEEE-RAS International Conference on Humanoid Robots, 2014, pp. 1134–1141. https://doi.org/10.1109/HUMANOIDS.2014.7041511

[39] S. D. Sood, "How NAO is impacting students' problem-solving skills," Aldebaran, United Robotics Group, Sep. 24, 2020. [Online]. Available: https://www.aldebaran.com/en/blog/news-trends/how-nao-impacting-students-problem-solving-skills [Accessed Jun. 12, 2023].

[40] E. Vrochidou, A. Najoua, C. Lytridis, M. Salonidis, V. Ferelis, and G. A Papakostas, "Social robot NAO as a self-regulating didactic mediator: A case study of teaching/learning numeracy," in *2018 26th IEEE international conference on software, telecommunications and computer networks (SoftCOM)*, 2018, pp. 1–5. https://doi.org/10.23919/SOFTCOM.2018.8555764

[41] B. SicIliano and O. Khatib, "Humanoid robots: Historical perspective, overview and scope," in Humanoid robotics: A reference, A. Goswami and P. Vadakkepat, Eds., Springer Dordrecht: Netherlands, 2019, pp. 3–8. https://doi.org/10.1007/978-94-007-6046-2_64

[42] B. Zan, "Introduction: Why STEM? Why early childhood? Why now? In STEM learning with young children: Inquiry teaching with ramps and pathways," New York: Teachers College Press, pp. 1–9, 2016.

[43] S. Zeaiter, "Using humanoid robots as tools for the promotion of STEM-education in schools (RoboPraX)," in Pioniergeist, Ausdauer, Leidenschaft, E. Festschrift and H., Eds., Philipps-Universität: Marburg, 2020. pp. 279–320.

[44] Y. Zhang, R. Luo, Y. Zhu, and Y. Yin, "Educational robots improve K-12 students' computational thinking and STEM attitudes: Systematic review," *Journal of Educational Computing Research*, vol. 59, no. 7, pp. 1450–1481, 2021. https://doi.org/10.1177/0735633121994070

[45] J. Zhou, X. Chen, U. Chang, J. T. Lu, C. C. Y Leung, Y. Chen, Y. Hu, and Z. Wang, "A soft-robotic approach to anthropomorphic robotic hand dexterity," *Ieee Access*, vol. 7, pp. 101483–101495, 2019. https://doi.org/10.1109/ACCESS.2019.2929690

[46] D. Ziouzios, D. Rammos, T. Bratitsis, and M. Dasygenis, "Utilizing educational robotics for environmental empathy cultivation in primary schools," *Electronics*, vol. 10, no. 19, pp. 2389, 2021. https://doi.org/10.3390/electronics10192389

[47] R. Zviel-Girshin, A. Luria, and C. Shaham, "Robotics as a tool to enhance technological thinking in early childhood," *Journal of Science Education and Technology*, vol. 29, pp. 294–302, 2020. https://doi.org/10.1007/s10956-020-09815-x

[48] Stathopoulou, et all, "Mobile assessment procedures for mental health and literacy skills in education," *International Journal of Interactive Mobile Technologies (IJIM),* vol. 12, no. 3, pp. 21–37, 2018. https://doi.org/10.3991/ijim.v12i3.8038

[49] A. Stathopoulou, Z. Karabatzaki, D. Tsiros, S. Katsantoni, and A. Drigas, "Mobile apps the educational solution for autistic students in secondary education," *Journal of Interactive Mobile Technologies (IJIM),* vol. 13, no. 2, pp. 89–101, 2019. https://doi.org/10.3991/ijim.v13i02.9896

[50] A. Drigas and A. Petrova, "ICTs in speech and language therapy," *International Journal of Engineering Pedagogy (iJEP),* vol. 4, no. 1, pp. 49–54, 2014. https://doi.org/10.3991/ijep.v4i1.3280

[51] M. Xanthopoulou, G. Kokalia, and A. Drigas, "Applications for children with autism in preschool and primary education," *Int. J. Recent Contributions Eng. Sci. IT (IJES),* vol. 7, no. 2, pp. 4–16, 2019. https://doi.org/10.3991/ijes.v7i2.10335

[52] C. Kefalis, E. Z. Kontostavlou, and A. Drigas, "The effects of video games in memory and attention," *Int. J. Eng. Pedagog. (IJEP),* vol. 10, no. 1, pp. 51–61, 2020. https://doi.org/10.3991/ijep.v10i1.11290

[53] E. Mitsea, N. Lytra, A. Akrivopoulou, and A. Drigas, "Metacognition, mindfulness and robots for autism inclusion," *Int. J. Recent Contributions Eng. Sci. IT (IJES),* vol. 8, no. 2, pp. 4–20, 2020. https://doi.org/10.3991/ijes.v8i2.14213

[54] C. Papoutsi, A. Drigas, and C. Skianis, "Virtual and augmented reality for developing emotional intelligence skills," *Int. J. Recent Contrib. Eng. Sci. IT (IJES),* vol. 9, no. 3, pp. 35–53, 2021. https://doi.org/10.3991/ijes.v9i3.23939

[55] S. Kapsi, S, Katsantoni, and A. Drigas, "The role of sleep and impact on brain and learning," *Int. J. Recent Contributions Eng. Sci. IT (IJES),* vol. 8, no. 3, pp. 59–68, 2020. https://doi.org/10.3991/ijes.v8i3.17099

[56] A. Drigas, E. Mitsea, and C. Skianis, "The role of clinical hypnosis and VR in special education," *International Journal of Recent Contributions from Engineering Science & IT (IJES),* vol. 9, no. 4, pp. 4–17, 2021. https://doi.org/10.3991/ijes.v9i4.26147

[57] I. Chaidi and A. Drigas, "Parents' involvement in the education of their children with autism: Related research and its results," *International Journal of Emerging Technologies in Learning (IJET),* vol. 15, no. 14, pp. 194–203 2020. https://doi.org/10.3991/ijet.v15i14.12509

[58] A. Drigas, E. Mitsea, and C. Skianis, "Clinical hypnosis & VR, Subconscious restructuring-brain rewiring & the entanglement with the 8 pillars of metacognition X 8 layers of consciousness X 8 intelligences," *International Journal of Online & Biomedical Engineering (IJOE),* vol. 18, no. 1, 2022. https://doi.org/10.3991/ijoe.v18i01.26859

[59] A. Drigas and M. Karyotaki, "Attention and its role: Theories and models," *International Journal of Emerging Technologies in Learning (IJET),* vol. 14, no. 12, pp. 169–182, 2019. https://doi.org/10.3991/ijet.v14i12.10185

[60] A. Drigas and M. Karyotaki, "Executive functioning and problem solving: A bidirectional relation," *International Journal of Engineering Pedagogy (iJEP),* vol. 9, no. 3, 2019. https://doi.org/10.3991/ijep.v9i3.10186

[61] L. Bakola and A. Drigas, "Technological development process of emotional Intelligence as a therapeutic recovery implement in children with ADHD and ASD comorbidity," *International Journal of Online & Biomedical Engineering, (IJOE),* vol. 16, no. 3, pp. 75–85 2020. https://doi.org/10.3991/ijoe.v16i03.12877

[62] A. Drigas and L. Bakola, "The 8x8 layer model consciousness-intelligence-knowledge pyramid, and the platonic perspectives," *International Journal of Recent Contributions from Engineering, Science & IT (iJES),* vol. 9, no. 2, pp. 57–72, 2021. https://doi.org/10.3991/ijes.v9i2.22497

[63] A. Drigas and C. Papoutsi, "Nine layer pyramid model questionnaire for emotional intelligence," *International Journal of Online & Biomedical Engineering (IJOE),* vol. 17, no. 7, 2021. https://doi.org/10.3991/ijoe.v17i07.22765

[64] A. Drigas, C. Papoutsi, and Skianis, "Metacognitive and metaemotional training strategies through the nine-layer pyramid model of emotional intelligence," *International Journal of Recent Contributions from Engineering, Science & IT (iJES),* vol. 9, no. 4, pp. 58–76, 2021. https://doi.org/10.3991/ijes.v9i4.26189

## 7 AUTHORS

**Vasiliki Mertzani** a PhD candidate in the University of Glasgow investigating the effectiveness of Educational Robotics and AI for children with Special Educational Needs. She works as a lecturer in Research Methodologies modules and a programme leader for Early Childhood Education and Special Educational Needs undergraduate programmes at the Metropolitan College of Greece (E-mail: vmertzani@mitropolitiko.edu.gr).

**Athanasios Drigas** is the Research Director at I.I.T – N.C.S.R. 'Demokritos', Institute of Informatics and Telecommunications – Net Media Lab & Mind – Brain R&D (E-mail: dr@iit.demokritos.gr).