Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva / Italian Journal of Health Education, Sports and Inclusive Didactics - Anno 5 n. 2 - ISSN 2532-3296 ISBN 978-88-6022-411-8 - aprile - giugno 2021 - CC BY-NC-ND 3.0 IT - https://doi.org/10.32043/gsd.v5i2.390

# ROBOTICA EDUCATIVA TRA NEUROSCIENZA E INTELLIGENZA ARTIFICIALE: UN'ANALISI SISTEMATICA

# EDUCATIONAL ROBOTICS BETWEEN NEUROSCIENCES AND ARTIFICIAL INTELLIGENCE: A SYSTEMATIC ANALYSIS

**Chiara Panciroli**[1]
Department of Education Studies "Giovanni Maria Bertin"
chiara.panciroli@unibo.it

**Manuela Fabbri**
Department of Education Studies "Giovanni Maria Bertin"
m.fabbri@unibo.it

**Anita Macauda**
Department of Education Studies "Giovanni Maria Bertin"
anita.macauda@unibo.it

## Abstract

The paper focuses on research on educational robotics, neuroscience and artificial intelligence, in relation to the development of learning processes and the relationship between body, mind and knowledge construction. The first part of the contribution defines the theoretical frameworks of reference on neuroscience and artificial intelligence on the one hand and on educational robotics on the other. In the second part, the first results of a systematic analysis of the contributions published over 2010-2020 are presented. In fact, in recent years, many initiatives have involved primary and secondary schools in innovative projects for the application of robotics, especially in the STEM disciplines. These projects show how robotic technology is able to support the development of students' cognitive, socio-relational and aesthetic-emotional processes. In fact, the younger generations are offered the possibility through robotics to experiment with new spaces of action / communication between the different areas of knowledge.

Il paper focalizza l'attenzione sulle ricerche riguardanti robotica educativa, neuroscienze e intelligenza artificiale, in relazione allo sviluppo dei processi di apprendimento e al rapporto tra corpo, mente e costruzione della conoscenza. Nella prima parte del contributo vengono definite le cornici teoriche di riferimento su neuroscienze e intelligenza artificiale da un lato e su robotica educativa dall'altro. Nella seconda parte, vengono presentati i primi risultati di un'analisi sistematica dei contributi pubblicati nell'arco del 2010-2020. In questi anni, infatti, molte iniziative hanno coinvolto le scuole primarie e secondarie in progetti innovativi di applicazione della robotica, in particolar modo nelle discipline STEM. Questi progetti mostrano come la tecnologia robotica è in grado di supportare lo sviluppo dei processi cognitivi, socio relazionali ed estetico-emotivi degli studenti. Alle giovani generazioni, infatti, viene offerta la possibilità attraverso la robotica di sperimentare nuovi spazi di azione / comunicazione tra le diverse aree della conoscenza.

## Keywords
Educational robotics, Neuroscience, Artificial Intelligence, Learning, Educational Technologies
Robotica educativa, Neuroscienze, Intelligenza artificiale, Apprendimento, Tecnologie educative

---

1 This contribution, developed and shared jointly by the three authors, was drawn up as follows: paragraph 1 by Chiara Panciroli; paragraph 2 by Manuela Fabbri; paragraph 3 by Anita Macauda. The paragraph "Conclusions" was developed together by the three authors.

## 1. Theoretical Context between Neuroscience and Artificial Intelligence

The scientific literature highlights how the field of neuroscience and that of artificial intelligence (AI) show more and more elements of contact that need to be investigated and deepened (Marblestone et al., 2016; Ullman, 2019). Specifically, it is emphasized that a greater understanding of biological brains plays a central role in the construction of increasingly intelligent machines (Hassabis et al., 2017). In fact, the study of human capacities concerning generalization, reasoning, the discovery of meanings and ways of learning from past experiences can underlie the processes that direct the development of algorithms and computerized systems (Castelvecchi, 2016).

Inspired by the way neural networks communicate with each other in the human brain, artificial intelligence takes a similar approach to identify and extract from huge amounts of data the patterns that lead to speech recognition, image categorization, and speech processing. language (Hof, 2013). When in a 1950 article the mathematician Turing asked the question "Can machines think?" ushering in artificial intelligence research, the only known systems that performed complex calculations were biological nervous systems. As a result, scientists working in the nascent field of AI turned to brain circuits to design brain-like circuits capable of performing intelligent calculations.

In its current form, known as the "deep network" (or deep net) architecture, this brain-inspired model is built from successive layers of neuron-like elements. In particular, the application of deep networks and methods related to artificial intelligence systems is of a transformative nature and impacts computer vision, speech recognition (spoken and written) and the production / reproduction of complex interactions. Ullman further points out how additional aspects of brain circuits can drive network models to broader aspects of cognition and general AI (2019).

In support of the theories that argue that the development of artificial intelligence resulting from an accurate study of biological intelligence is significant, the research shows that, on the one hand, neuroscience provides a rich source of inspiration for new types of algorithms, while on the other it can validate already existing artificial intelligence techniques (Hassabis et al. 2017).

Hassabis et al., however, note how the interaction between neuroscience and artificial intelligence has become less significant, in respect to the consolidation of their disciplinary boundaries. Nevertheless, it is important to study this relationship not as a one-way but as a two-way flow: on the one hand, the importance of neuroscience in generating ideas that accelerate and drive AI research is recognized (Ullman, 2019), on the other, it is underlined how the construction of intelligent algorithms is able to offer new ideas on the aspects concerning intelligence in the brain of human beings.

These aspects are of particular importance when artificial intelligence is used in teaching and learning (Pearson, 2019). Today, one of the most popular applications of AI in school is about personalized learning that refers to education that focuses on students' individual learning needs in relation to their interests (Pane, Steiner, Baird, Hamilton, & Pane, 2017). Starting from a one-size-fits-all approach, personalized learning prioritizes the needs of each student, allowing for a differentiated and flexible pace.

Specifically, an AI-based tutoring system that also takes students' emotions into consideration is particularly significant in the learning processes (Yuksel, Collisson & Czerwinski, 2017). A study by Woolf et al., 2009 reported that students' pass rates in learning tests after a week of lessons with the AI-based tutor were 10% higher than those of peers who they spent the same amount of time in a normal class. Furthermore, the artificial intelligence-based tutor was used for detecting the emotional states of students through hundreds of sensors, both those embedded in computers to record physiognomic aspects related to their degree of interest and concentration, and those worn on the wrist to record stress levels. Indeed, it has been found that an emotionally sentient mentoring system could function as a pedagogical conversation agent, providing students with social and emotional support and improving the effectiveness of human-computer interaction (McDuff & Czerwinski, 2018). Recently, robots in the UK, such as those that can engage in a conversation with humans, recognize faces and make eye contact, have been used to help students with special needs (Wakefield, 2018). By 2030, AI is expected to automate 40% of the activities carried out by primary school teachers, with particular reference to monitoring student progress (Herold, 2019). Furthermore, teaching activities could be redesigned by classroom management tools based on artificial intelligence tutors that provide personalized and adaptive instruction (Etzioni & Schoenick, 2018; Sparks, 2017).

## 2. Theoretical Context of Educational Robotics

Contemporary society is structurally based on models and tools for the construction and dissemination of knowledge. Technologies support the growth of the scientific community at an international level, conveying the social peripheralization of knowledge and re-establishing training scenarios. There are several legislative measures and recommendations from the bodies of the European Union (Council of Europe, 2018; European Commission, 2010; Redecker & Punie, 2017) that intend to plan and implement initiatives to improve citizens' digital skills, promoting their digital Citizenship: «Digital citizenship and engagement involves a wide range of activities, from creating, consuming, sharing, playing and socializing, to investigating communicating, learning and working. Competent digital citizens are able to respond to new and everyday challenges related to learning, work, employability, leisure, inclusion and participation in society, respecting human rights and intercultural differences" (Richardson & Milovidov, 2019, p. 12).

The Digital Competence Framework for Citizens (Carretero, Vuorikari, & Punie, 2017) includes problem-solving and critical thinking among the different types of skills. The aptitude for analysis and critical, systematic and logical reflection on the different everyday problem situations refers to the broader concept of Computational Thinking (CT) (Bocconi, Kampylis & Punie, 2012; Bocconi et al., 2016) of thought, developed in the IT field, relating to the conceptualization of knowledge, which includes moments of abstraction, decomposition, formalization not necessarily linked to the use of digital media (Wing, 2006; 2017). Over the last decade this construct and the terms related to it - robotics, coding, programming - have gained space in the debate on the implementation of 21st century skills in school curricula.

The current international scientific literature on Educational Robotics (ER) (Benitti, 2012; Cheng, Su & Chen, 2018; Toh et al., 2016) identifies with this construct "a field of study that aims to improve the learning experience of people through the creation, implementation, improvement and validation of pedagogical activities, tools (e.g. guidelines and templates) and technologies, where robots play an active role and pedagogical methods inform each decision" (Angel-Fernandez & Vincze, 2018, p. 41). Educational Robotics and the implementation of physical and digital school environments represent an interesting research sector of technologies to support learning processes: "The incorporation of new technologies in the classroom and educational robotics seek to improve interdisciplinary learning environments where students and teachers can structure their research and solve problem situations in a concrete way; developing new skills and abilities [...] contributing to the development of student's creativity and cognitive capacity "(Sanchez, Martìnez & Gonzàlez, 2019, p. 2).

In recent years, many initiatives have involved schools and universities in innovative projects that apply ER as a key element to significantly affect student learning (Lepuschitz, Merdan & Koppensteiner, 2018), particularly within STEM (Science, Technology, Engineering and Mathematics) disciplines (Nugent, Barker & Grandgenett in Nugent et al., 2012; Scaradozzi, 2019; Taylor, 2016). Catlin & Woollard (2014) underline the symbiotic relationship existing between CT and ER: teaching activities with educational robots would stimulate CT, as well as disciplinary and interdisciplinary skills, thus building new spaces for action and communication between the different areas of knowledge. ER stimulates interest and motivation towards knowledge, enhancing the playful, fun and engaging dimension of the teaching experience (González & Muñoz-Repiso, 2017; Resnick, 2017); the immediate feedback - tactile, visual, sound - provided by robots would also develop regulatory and self-evaluative skills in students. Social skills are also developed, specifically communicative, relational, metacognitive, creative, collaborative, problem-solving skills: through collaborative activities, students build and manipulate robots, prepare programming algorithms, solve authentic problems, analyze and evaluate their own learning process, developing reflexivity, critical and creative thinking through constructive knowledge negotiation with the peer group.

The methodologies used within these projects (e.g. Game-Based learning, Problem-Based Learning, Inquiry-Based Learning, Project-Based Learning) refer to active teaching of Deweyan origin (Dewey, 1938), to learning by doing, for which the long-lasting learning is inextricably linked to concrete, active, first-person experience, and to reflection on it.

We find a common theoretical framework at the basis of the different educational robotics frameworks (EARLY, Lye, Wong & Chiou, 2013; Educational Robotics in Early Childhood Education, Misirli & Komis, 2014; ERA, Catlin & Blamires, 2010; ER4STEM, Angel-Fernandez, 2021; Framework of Educational Scenarios as a Basis for Planning and Organizing Educational Robotics Activities, Komis, Romero & Misirli, 2016; TERECOP, Alimisis et al., 2007; The Roberta initiative, Bredenfel & Leimbach, 2010), which in recent years has sought to support teachers and educators in design of RE didactic activities within school curricula of all types and levels and which explain the connections between Active Learning, disciplinary knowledge and social skills with different nuances: constructivism / social constructionism.

The constructivist perspective (Bruner, 1997; Piaget, 1970), which considers the active student as the builder of his/her own knowledge through interaction with the environment, represents the first ER pedagogic approach that historically analyzes the educational role of robots in teaching. Secondly, Papert's constructionism (1980; 1993), creator of the Logo and precursor of educational robotics, interprets learning as a process that is built in a situation through the performance of practical and meaningful activities; the collaborative creation of concrete artifacts through the resolution of authentic, real problems, with multiple solutions, related to everyday life, involves the development of concepts and the organization and construction of one's knowledge. A similar context of discovery learning fosters students' critical thinking and creativity, supporting the socio-constructivist conception of Vygotsky matrix of learning (Jonassen, 1994; Pontecorvo, Ajello & Zucchermaglio, 1995), which sees in interactions with the peer group and in the active construction of meanings by the students, the essential components for the achievement of educational success both on an individual and social level. Neuroscience reaffirms the ecological, relational, systemic nature of learning (Rivoltella, 2014; Rossi, 2011), interpreting it as a cognitive process interrelated with the sensory-motor and emotional dimensions and arising from being in a specific physical, social and cultural environment (Damiani, Santaniello & Gomez Paloma, 2015).

## 3. A Systematic Review

### 3.1. The methodology

The initial phase of a systematic analysis of the scientific literature at national and international level is presented here, aimed at investigating research and experiments on Educational Robotics (ER), in relation to the field of neuroscience and AI. Systematic analysis as research synthesis (McKibbon, 2006; Machi, McEvoy, 2016), was built on the observation of single contributions in order to assemble and synthesize the results of primary studies according to an integrated approach and identify relevant research in relation to particular questions and themes responding to the research question that guided the selection and directed the analysis itself: what are the contributions of neuroscience and AI to ER?

It is an analysis: *i.*qualitative in nature that combines the information gathered from the different studies and describes the results in a narrative form; *ii.* based on an emergent method in which the various phases of the analysis that emerge during the course, in constant dialogue with the literature examined, resulted in ongoing changes with respect to the selection of the analysis criteria and the planning of the phases to be followed; *iii.* aimed at producing new knowledge starting from the integration of single studies, in view, on the one hand, of the growing availability and accessibility to studies, and on the other, of the fragmentation of research and as such, capable of integrating the results and evidence emerging in the different contributions on educational robotics.

The research was conducted both on Google Scholar and on online databases accessible through the Library System of the University of Bologna: ScienceDirect - All Content; Education Source Product (EBSCO) (XML); eBook Collection (EBSCO); PsycINFO (EBSCO); SCOPUS (Elsevier API). The criterion chosen for the selection of the sources was to consider the articles and scientific contributions that would return the state of the art of the studies of the last decade 2010-2020, recalled by querying the databases with the following two strings: Educational robotics AND artificial intelligence; Educational robotics AND neuroscience. The research was refined by selecting the contributions aggregated according to the following categories: Education; Robotics; Learning; Children; Robots; Educational Technology; Teaching Methods. The following were included in the analysis: theoretical, empirical or hybrid research articles; qualitative and quantitative research; articles that report both the results of experiments that directly involved students, and reflections on teachers' professionalism.

### 3.2. Construction of the instrument

The tool built for the analysis of the studies consists of a category scheme that highlights different aspects of the articles and the research described therein. It has already been the subject of several revisions that have made it possible to refine it both with respect to the wealth of significant dimensions that emerged in the dialogue with literature, and with respect to the objective of the SR that has been defined in more detail.

The analysis scheme, in its current version, comprises 10 categories:

1. Reference discipline of the proposed study
2. Type of approach to neuroscience and/or artificial intelligence
3. Origin of the researchers who conducted the study
4. Type of research conducted (i.e. theoretical, empirical, hybrid)
5. Focus of interest of the contribution
6. Goals
7. Research setting / age range of the subjects involved
8. Technologies
9. Didactic strategies
10. Results

Not all the dimensions described by the scheme used have been made explicit in all the articles analyzed. In these cases, the abbreviation NE (not explicit) has been placed in the category section.

### 3.3. Data analysis

The analysis led to the identification of 97 contributions from which only those with a pedagogical-educational focus oriented to neuroscience and AI were selected. Five systematic analyses were also excluded in order to focus attention on primary sources of a theoretical and / or empirical nature (Benitti, 2012; Liying & Baichang, 2018; Anwar et al. 2019; Frison, 2019; Papadopoulos et al., 2020). The analysis was thus limited to 45 contributions.

The review highlighted how the selected articles refer mainly to empirical studies (only five are theoretical); the empirical contributions traced are geographically placed as follows: USA (Cambridge, Boston), Europe (Italy, France, Austria), Malaysia, Russia, Pakistan, Chile, Salamanca. The experiments proposed and analyzed in these contributions, moreover, focus more on the target 3-6 and 7-12 years.

The issues mainly concern:

- Robots and artificial intelligence (Salas-Pilco, 2020; Kerimbayev et al., 2020)
- Robots in STEM disciplines (Rappaport et al. 2018)
- Independent robot teachers, embodied pedagogical agents (Edwards et al. 2018).

- AI and robotics in learning development projects (Ospennikova et al. 2015).
- Knowledge of the principles and concepts of artificial intelligence and robotics as key skills for the 21st century (Eguchi, 2013).
- Educational robotics integrated in a school environment for the achievement of curricular objectives and the development of programming skills and computational thinking (Datteri et al, 2012)
- Educational robotics and development of the cognitive functions (Bargagna et al. 2018; La Paglia et al. 2019; Di Lieto et al., 2020)
- Robotic kits as tools for developing mathematical and metacognitive skills (La Paglia et al. 2018)
- Robots and socio-cognitive conflicts (Castiglioni et al., 2012; Benvenuti et al. 2018)
- Educational robotics as a viable rehabilitation tool for children with special needs (Di Lieto, 2020).
- Collaborative process of explaining the robot behavior (Mitnick et al, 2009).

With reference to these issues, most of the contributions focus on the impact of ER on the learning process of boys and girls, with the exception of three studies that focus on teachers, in service or in training. A clear prevalence of research and experimentation has also emerged in which ER is oriented towards the enhancement of higher cognitive processes and the design of stimulating learning environments. Conversely, there are still a small number of initiatives in which ER is connected to AI literacy and education (Kandhofer et al. 2016; 2019; Ferrari et al. 2020).

**Conclusions**

With reference to the AI and Neuroscience studies analyzed, we can highlight how the robotics experience in formal learning contexts is characterized as a methodological experimentation aimed at the following objectives: strengthening of higher cognitive processes; design and implementation of analog models of complex systems based on the visualization of topological, functional, relationship and logical sequencing relationships; enhancement of the technological tool as a means for new and more stimulating learning; literacy and AI education in order to introduce students to the logic underlying intelligent technologies; use of didactic strategies such as guided discovery, problem-solving, cooperative learning, storytelling and project-based learning (Fridin, 2014; Kandhofer et al. 2016; Kory-Westlund et al. 2017).

The experiences proposed in the individual studies show how students who use robotic activity obtain a significant increase in their knowledge interpretation and construction skills, especially through the inclusion of chatbots that help each student to organize their own study path (Edwards, & Cheok, 2018). Therefore, a widespread experimentation of robotics can develop efficient methodological solutions for a wider dissemination in school contexts, also contributing to the acquisition of digital skills (Ospennikova, Ershovb & Iljina, 2015).

**References**

Alimisis, D., Moro, M., Arlegui, J., Pina, A., Frangou, S., & Papanikolaou, K. (2007). Robostics & constructivism in education: the TERECoP project. In *Proceedings of the 11th European Logo Conference*. Comenius University, Bratislava.

Angel-Fernandez, J.M. (2021). *ER3STEM Framework: final version. European Commission*. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5be02c668&appId=PPGMS

Angel-Fernandez, J.M., & Vincze, M. (2018). Towards a Definition of Educational Robotics. In P. Zech & J. Piater (Eds). *Proceedings of the Austrian Robotics Workshop 2018*. Innsbruck: Innsbruck University Press.

Angeli, C., Valanides, N. (2020). Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. *Computers in Human Behavior*, 105, 105954. Doi: 10.1016/j.chb.2019.03.018

Anwar, S., Bascou, N.A., & Menekse, M. (2019). A Systematic Review of Studies on Educational Robotics. *Journal of Pre-College Engineering Education Research (J-PEER*), 9(2), doi: 10.7771/2157-9288.1223

Bargagna, S., Castro, E., Cecchi, F., Cioni, C., ·Dario, P… Sgandurra, G. (2019). Educational Robotics in Down Syndrome: A Feasibility Study. *Technology, Knowledge and Learning*, 24, 315-323. doi: 10.1007/s10758-018-9366-z

Benitti, F.B.V. (2012). Exploring. The Educational Potential of Robotics in Schools: A Systematic Review. *Computers and Education*, *58*, 978-988.

Benvenuti, M. Piobbico, G., & Mazzoni, E. (2017). Robots and Socio Cognitive Conflict Enhance Wayfinding in Children. Annual Review of Cybertherapy and Telemedicine, 15, 33-38.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). *Developing Computational Thinking in Compulsory Education. Implication for policy and practice*. European Commission-Joint Research Centre. Luxembourg: Pubblications Office of the European Union.

Bocconi S., Kampylis P., & Punie Y. (2012), *Innovating Learning: Key Elements for Developing Creative Classrooms in Europe*, in http://publications.jrc.ec.europa.eu/repository/bitstream/JRC72278/jrc72278.pdf

Bredenfel, A. & Leimbach, T. (2010). The Roberta Initiative. *Proceedings of SIMPAR 2010 Workshops* (pp. 558-567). Darmstadt.

Bruner, J. (1997). Celebrating divergence: Piaget and Vygotsky. *Human Development*, *40*(2), 63-73. http://dx.doi.org/10.1159/000278705

Carretero, R., Vuorikari, R., & Punie, Y. (2017). *DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use*, Luxembourg: Publications Office of the European Union.

Castelvecchi, D. (2016). Can we open the black box of AI?, *Nature*, 538(7623), 20–23.

Castiglioni, M., Datteri, E., Zecca, L., Businaro, N., & Laudisa, F. (2012). Do socio-cognitive conflicts enhance metacognitive skills? A pilot study in educational robotics. In *Metacognition 2012 – Proceedings of the 5th Biennial Meeting of the EARLI Special Interest Group 16 Metacognition* (pp. 184-185). Milano, EDUCat.

Catlin, D. & Woollard, J. (2014). Educational robots and computational thinking. *Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education*, Padova.

Catlin, D. & Blamires, M. (2010). The Principles of Educational Robotics Applications (ERA): A framework for understanding and developing educational robots and their activities. In *The 12th EuroLogo Conference*. Paris.

Cheng, A.W., Su, P.C., & Chen, N.S. (2018). The Essential Applications of Educational Robot: Requirement Analysis from the Perspectives of Experts, Researchers and Instructors, *Computers & Education*, *126*, 399-416.

Cichy, R.M., Pantazis, D., & Oliva, A. (2014). Resolving human object recognition in space and time. *Nat. Neurosci*. 17, 455–462.

Conti, D., Di Nuovo, S., Buono, S. &· Di Nuovo, A. (2017). Robots in Education and Care of Children with Developmental Disabilities: A Study on Acceptance by Experienced and Future Professionals. *Int J of Soc Robotics*, 9, 51-62. doi 10.1007/s12369-016-0359-6

Damiani, P., Santaniello, A., & Gomez Paloma, F. (2015). Ripensare la Didattica alla luce delle Neuroscienze. Corpo, abilità visuospaziali ed empatia: una ricerca esplorativa, *Giornale Italiano della Ricerca Educativa*, *14*, 83-105.

Datteri, E., Zecca, L., Laudisa, F., Castiglioni, M. (2012). Educational robotics and science education in primary schools. In *Metacognition 2012 – Proceedings of the 5th Biennial Meeting of the EARLI Special Interest Group 16 Metacognition* (pp. 185-186). Milano, EDUCat.

Dewey J. (1938). Experience and education. New York: Macmillan.
Di Lieto, M. C., Castro, E., Pecini, C. Inguaggiato, E., Cecchi, F., Sgandurra, G. (2020). Improving Executive Functions at School in Children with Special Needs by Educational Robotics. *Front. Psychol.,* 10., 2813, doi: 10.3389/fpsyg.2019.02813
Di Lieto, M. C., Castro, E., Pecini, C. Inguaggiato, E., Cecchi, F., Sgandurra, G. (2020). Empowering executive functions in 5- and 6-year-old typically developing children through educational robotics: An RCT study. *Front. Psychol.,* 10., 3084, doi: 10.3389/fpsyg.2019.03084
Di Lieto, M. C., Inguaggiato, E., Castro, E., Cecchi, F.,…Dario, P. (2017). Educational Robotics intervention on Executive Functions in preschool children: A pilot study. *Computers in Human Behavior*, 71, 16-23. doi: 10.1016/j.chb.2017.01.018
Edwards, B. I., & Cheok, A. D. (2018). Why not robot teachers: Artificial intelligence for addressing teacher shortage. *Applied Artificial Intelligence*. oi: 10.1080/08839514.2018.1464286
Eguchi, A. (2013). Educational Robotics for Promoting 21st Century Skills. *Journal of Automation, Mobile Robotics & Intelligent Systems*, 8(1), 5-11. doi: 10.14313/JAMRIS_1-2014/1
Eguchi, A. (2014). Robotics as a learning tool for educational transformation. In Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education (pp. 27-34), Padova.
European Commission (2010). *Europe 2020. A strategy for smart, sustainable and inclusive growth*. Luxembourg: Publications Office of the European Union.
Ferrari, L., Macauda, A., Soriani, A., & Russo, V. (2020). Educational robotics and artificial intelligence education: what priorities for schools?. *Form@*re, 20, 68-85.
Fridin, M. (2014). Storytelling by a kindergarten social assistive robot: A tool for constructive learning in preschool education. *Computers & Education*, 70, 53-64.
Frison, D. (2019). La robotica educativa nei servizi educativi 0-6: un'analisi sistematica della
Letteratura. *Form@re.* 19(1), 30-46. doi : 10.13128/formare-24937
Gaudiello, I., & Zibetti, E. (2012). La robotique éducationnelle : état des lieux et perspectives. *Psychologie Française*, 58(1), 17-40. doi: 10.1016/j.psfr.2012.09.006
Glasser, M.F., Smith, S.M., Marcus, D.S., Andersson, J.L., Auerbach, E.J., Behrens, T.E., Coalson, T.S., Harms, M.P., Jenkinson, M., Moeller, S., et al. (2016). The Human Connectome Project's neuroimaging approach. *Nat. Neurosci*. 19, 1175–1187.
González, Y.A.C., & Muñoz-Repiso, A.G.V. (2017). Educational robotics for the formation of programming skills and computational thinking in childish. *Computers in Education* (*SIIE*), 1-5.
Hassabis, D., Kumaran, D., Summerfield, C., & Botvinick, M. (2017). Neuroscience-Inspired Artificial Intelligence. *Neuron*, 95, 245-258. http://dx.doi.org/10.1016/j.neuron.2017.06.011
Hof, R. D. (2013). *Deep learning*. Retrieved from. MIT Technology Review https://www.technologyreview.com/s/513696/deep-learning/.
Jonassen, D.H. (1994). Thinking Technology: Toward a Constructivist Design Model, *Educational Technology*, *34*(4), 34-37.
Kandlhofer, M., Hirschmugl-Gaisch, S., & Huber, P. (2016). Artificial Intelligence and Computer Science in Education: From Kindergarten to University. *2016 IEEE Frontiers in Education Conference* (pp. 1-9). doi: 10.1109/FIE.2016.7757570.
Kandlhofer, M., Steinbauer, G., Laßnig, J.P., Bauman, W., Plomer, S., Ballagi, S., & Alfoldi, I. (2019). Enabling the Creation of Intelligent Things: Bringing Artificial Intelligence and Robotics to Schools. In *2019 IEEE Conference on Frontiers in Education* (pp. 1-5) doi: 10.1109/FIE43999.2019.9028537
Komis, V, Romero, M., & Misirli, A. (2016). A scenario-based approach for designing educational robotics activities for co-creative problem solving. *International Conference EduRobotics 2016*, Athens.
Kerimbayev, N., Beisov, N., Kovtun, A., & Nurym, N., & Akramova, A. (2020). Robotics in the international educational space: Integration and the experience. *Education and Information* Technologies, 25, 5835-5851.

Kory Westlund, J., Jeong, S., Park, H. W., Ronfard, S., Adhikari, A., Harris, P. L., DeSteno, D., & C. L. Breazeal (2017). Flat vs. Expressive storytelling: Young children's learning and retention of a social robot's narrative. Frontiers in Human Neuroscience, 11. doi:10.3389/fnhum.2017.00295

Kriegeskorte, N., Kievit, R.A. (2013). Representational geometry: integrating cognition, computation, and the brain. *Trends Cogn. Sci*. 17, 401-412

Jdeed, M., Schranz, M., & Elmenreicha, W. (2020). A study using the low-cost swarm robotics platform spiderino in education. *Computers and Education Open*, 1, 100017. doi: 10.1016/j.caeo.2020.100017

La Paglia, F., Francomano, M., Riva, G., & La Barbera, D. (2019). Educational Robotics to develop of executive functions visual spatial abilities, planning and problem solving. *Annual Review of CyberTherapy and Telemedicine*, 16, 80-86.

La Paglia, F., La Cascia, C., Francomano, M., & La Barbera, D.. (2017). Educational Robotics to Improve Mathematical and Metacognitive Skills. *Annual Review of CyberTherapy and Telemedicine*. 15.

Lepuschitz, W., Merdan, M., & Koppensteiner, G. (2018) (Eds.). *Robotics in Education: Methods and Applications for Teaching and Learning*, Cham: Springer.

Liying, X., & Baichang, Z. (2018). A systematic review on teaching and learning robotics content

knowledge in K-12. *Computers & Education*, 127, 267-282.

Lye, N.C., Wong, K.W., & Chiou, A. (2013). Framework for educational robotics: a multiphase approach to enhance user learning in a competitive arena, *Interactive Learning Environments*, 142-155.

Machi, L., & McEvoy, B. (2008). *The Literature Review: Six Steps to Success*. Newbury Park: Corwin Press

Marblestone, A.H.,Wayne, G., & Kording, K.P. (2015). Toward an integration of deep learning and neuroscience. *Frontiers in Computational Neuroscience*, 10(94)

McKibbon K.A. (2006). Systematic reviews and librarians. *Library trend*s, 55, 1, 202-215.

Misirli, A. & Komis, V. (2014). Robotics and programming concepts in early childhood education: A conceptual framework for designing educational scenarios. *Research on e-Learning and ICT in Education*, 99-118.

Mitnik, R., Recabarren, M., Nussbaum, M., & Soto, A. (2009). Collaborative robotic instruction: A graph teaching experience. *Computers & Education,* 53, 330-342.

Nugent, G., Barker, B.S., & Grandgenett N. (2012). The impact of educational robotics on student STEM learning, attitudes, and workplace skills. In B.S. Barker, G. Nugent, N. Grandgenett, & V.I. Adamchuk (Eds.), *Robotics in K-12 education: A new technology for learning* (pp. 186-203). Hershey, PA: IGI Global.

Ospennikova E., Ershovb M., Iljina I. (2015). Educational Robotics as an Innovative Educational Technology. In *Procedia - Social and Behavioral Sciences*, 214, 18-26. doi: 10.1016/j.sbspro.2015.11.588

Pane, J. F., Steiner, E. D., Baird, M. D., Hamilton, L. S., & Pane, J. D. (2017). *Informing progress: Insights on personalized learning implementation and effects*. Retrieved from Santa Monica, CA: RAND Corporation https://www.rand.org/pubs/research_reports/RR2042.html.

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*, 55. doi: 10.1016/j.compedu.2020.103924

Received 30 September 2019; Received in revised for

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. New York, NY: Basic Books.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. NewYork, NY: Basic Books.

Pearson (2019). The global learner survey. Retrieved from; https ://www.pearson.com/content/dam/one-dot-com/one-dot-com/global/Files/news /gls/Pearson_Global_Learner_Survey_2019.pdf.
Petre, M., & Price, B. (2004). Using Robotics to Motivate 'Back Door' Learning. *Education and Information Technologies*, 9(2), 147-158.
Piaget, J. (1970). *Genetic epistemology*. New York: Columbia University Press.
Pontecorvo, C., Ajello, A.M., & Zucchermaglio, C. (1995). *I contesti sociali dell'apprendimento*. Milano: LED.
Rappaport, J. M., Richter, S. B., & Kennedy, D. T. (2018). A Strategic Perspective on Using Symbolic Transformation in STEM Education: Robotics and Automation. *International Journal of Strategic Decision Sciences*, 7(1), 39-40. doi 10.4018/IJSDS.2016010103
Redecker, C,. & Punie, Y. (2017). *DigCompEdu. Proposal for a European Framework for the Digital Competence of Educators*, Luxembourg: Publications Office of the European Union.
Richardson, J., & Milovidov, E. (2019). *Digital Citizenship education Handbook. Being online, Well-being online, Rights online*. Strasbourg: Council of Europe Committee of Ministers Publishing.
Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passions, peers, and play*, Cambridge, MA: MIT Press.
Rivoltella, P.C. (2014). *La previsione. Neuroscienze, apprendimento, didattica*. Brescia: La Scuola.
Rossi, P.G. (2011). *Didattica enattiva. Complessità, teoria dell'azione, professionalità docente*. Roma: Carocci.
Salas-Pilco, S. Z. (2020). The impact of AI and robotics on physical, social-emotional and intellectual learning outcomes: An integrated analytical framework, *British Journal of Educational Technology, 51*(5) 1808–1825; doi:10.1111/bjet.12984
Sanchez, H., Martìnez, L.S., & Gonzàlez, J.D. (2019). Educational Robotics as a Teaching tool in higher education institutions: A bibliographical analysis. *Journal of Physics: Conference Series*, Vol. 1391, pp. 1-6.
Scaradozzi, D., Screpanti, L., Cesaretti, L., Storti, M., & Mazzieri, E. (2019). Implementation and assessment methodologies of Teachers' training courses for STEM activities. *Technology, Knowledge and Learning*, *24*(2), 247-268. https://doi.org/10.1007/s10758-018-9356-1.
Stone, A., & Farkhatdinov, I. (2017). Robotics Education for Children at Secondary School Level and Above. Conference Paper in Lecture Notes in Computer Science. doi: 10.1007/978-3-319-64107-2_47
Taylor, P.C. (2016). Why is a STEAM Curriculum Perspective Crucial to the 21st Century? 14th Annual conference of the Australian Council for Educational Research, 7-9 August 2016, Brisbane: Murdoch University Research.
Toh, L.P.E., Causo, A., P.W., Tzuo, P.W., Chen, I.M., Yeo, S.H. (2016). A Review on the Use of Robotics, Education and Young Children. *Educational Technology & Society*, *19*(2), 148-163.
Ullman, S. (2019). Using neuroscience to develop artificial intelligence. *Science*, 363(6428), 692-693. DOI: 10.1126/science.aau6595
Verner, I. M. (2004). Robot Contest as a Laboratory for Experiential Engineering Education. *ACM Journal on Educational Resources in Computing*, 4(2).
Wing, J.M. (2006). Computational Thinking. *Communications of the ACM*, *49*(3), 33-35.
Wing, J.M. (2017). Computational thinking's influence on research and education for all. *Italian Journal of Educational Technology*, *25*(2), 7-14.