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EDUCATIONAL ROBOTICS: A NEW ARENA IN CLASSROOM TEACHING

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Abstract

Robotics activities give abundant educational opportunities, but its impact and reach have defined by the conventional way in which it has been introduced. While projects including cars, vehicles and mobile robots are evidently appealing to young people, many other young people do not become fully engaged in these types of projects where development and usage of Educational Robotics (ER) are involved. By offering alternate pathways into robotics that can gain student's attention, we have a chance to engage a wider and more different people in new learning experiences. This paper explores approaches for exposing students to robotic technologies and ideas and explains the significance of implementing multiple ways into robotics, to ensure that there are entry points to engage people with diverse interests and learning styles.

Key Words: Educational Robotics, STEM, Constructionism

Introduction

Though a technology can be anything from a pencil to a virtual environment, the modern history of technology in education has been shaped in large part by development in digital technologies such as computers. The history of digital technologies is followed by a description of what we have learned from the past that can help us become more effective technology users today. In today’s technology driven society, a new technology tools and new versions of older tools are emerging at a dizzying rate. Taking advantage of the power of these tools requires both up-to-date information on their features and capabilities as well as overarching guidelines and procedures for analysing and matching them to educational problems and needs. Technology integration strategies require a combination of hardware or equipment and software or programs written to perform various functions. Even today's mobile devices or portable handheld computer equipment such as MacBook, i-pads, tablets or cell phones have this combination of hardware and software. Sometimes software and data must be stored outside of the hardware using CDs, DVDs or various types of hard drives. These are thought of as storage media. However, a growing trend is toward using online storage, referred to as cloud computing, which is using software stored outside one's own computer on servers that are accessed through the Internet.

Although most people acknowledge the importance of students having a knowledge base of specific skills and information, it is also becoming evident that our world is too complex and technical for students to learn ahead of time everything they may need for the future. Thus, our society is beginning to place a high value on the ability to solve novel problems in creative ways. If students are conscious of the procedures they use to solve problems, they often can more easily improve on their strategies and become more effective, creative problem solvers. Consequently, teachers often try to present students with novel problems to solve them. Resources such as problem solving courseware and multimedia applications are often considered ideal environments for getting students to think about how they think and for offering opportunities to challenge their creativity and problem solving abilities. The problem of inert knowledge is believed to arise when students learn skills in isolation from problem applications. When students later encounter problem that require the skills, they do not realize how the skills could be relevant. Problem solving materials in highly visual formats (such as Robots) allow students to build rich mental models of problems to be solved. Technology integration strategies support a variety of teaching and learning needs ranging from providing efficient practice in basic skills to constructivist activities such as fostering group cooperation skills. Efficient technology integration depends upon up-to-date resources.

There is a common belief that in the process of learning, robots can be a useful teaching aid to increase the student's engagement, their motivation level and the improvement of skills instead of just focussing on robotics itself. Robotics, as a subject is useful in imparting skills to students and has been examined and found to be encouraging (Cielniak *et al*., 2013). The positive effect on student's engagement to a large extent is gained from the physical presence of robots, which make the results of programming very clear and immediately available, providing a regular formative assessment of learning process and motivation to students. Pursuing these ideas, selected institutions in developing countries have lately made some efforts to break the traditional way of teaching and introduced robotic activities to improve the quality of education and learning (Mills *et al*., 2007).

The recent years have observed a growing interest in the educational use of robotics. International competitions such as RoboCup, FIRST LEGO League (2006), and RoboFesta have attracted children and young adults around the world to compete in different challenges. Several universities and schools have been endeavouring summer camps on use of robotics and enhancement programs to K–12 students. The investment market of educational robotics is also growing. Recent research by Japan Robotics Association, United Nations Economic Commission, and the International Federation of Robotics shows that the market growth for personal robots, comprising of those used for entertainment and educational purposes, has been enormous. This trend may last for the next several decades. Research in the area of educational robotics has for years laid emphasis on the contribution of different technologies and the development of innovative ways of learning: new pedagogical ideas can lead to new technologies and vice-versa. Since the late 1960's, research has been advanced for robotic construction kits for children focusing on the invention of building tools and programming devices that children will discover easy to learn and master. Thus, children becoming active participants in their training and creators of their technological artefacts instead of being just users of tools those others have made for them.

One of the practices that have been identified particularly, in computer science, and promoted by many of the western higher education institutions (Yerion & Rinehart, 1995) to effectively improve teaching and learning involves hands-on experiences and collaborative learning. Students receive and remember more information when they actively engage in the learning process and when they can associate to what is being taught (Akey, 2006). Therefore, attempts to improve the quality of teaching and learning by the adoption of practices that promote more engagement, higher motivation and active participation of students are to be encouraged. Educational theorists such as S. Papert (1993) observe that robotic activities have remarkable potential to enhance classroom teaching. They argue that students can achieve a sense of power over technology by constructing a setting where they can program computers and robots (Nourbakhsh *et al*., 2005). Other studies have also recognised the real nature of robots as having significant advantages when used as a learning tool. For example, students can learn abstract concepts and achieve a more functional level of understanding when they learn with robots (Nourbakhsh *et al*., 2005). However, it is necessary to emphasise that the robot is just a different tool, and it is the educational theory that will determine the learning impact of robotic applications. Alignment with theories of learning, proper educational philosophy, well-designed curricula and supportive learning environments are some of the important elements that can make any educational innovation, including robotics, successful (Alimisis, 2012). Activities with educational robotics can serve learning objectives from a wide range of disciplines from technology and design to mathematics and science education. They are hands-on activities with significant experimentation features (Frangou *et al*., 2008). From this point of view educational robotics creates an active, cooperative learning environment which emphasises on students' participation. So incorporating robotic technologies into the curriculum can enrich teaching with a large impact in addressing teaching objectives from different disciplines having an innovative approach. This fact is backed up by research which suggests that robots tie into a variety of subjects (Barker, 2007). A robot is constructed of parts of motors, sensors and software. Each of these parts depends on diverse fields of expertise such as engineering, electronics, and computer science. This interdisciplinary nature of robots indicates that when students master to engineer robots, they will necessarily learn about the many other systems that robotics utilise (Rogers & Portsmore, 2004).

Educational Robotics has been introduced as a powerful, flexible teaching/learning tool stimulating learners to control the behaviour of physical models using specific programming languages (graphical or textual) and involving them actively in authentic problem-solving activities. It is necessary to start projects which include training of teachers for how to use educational robotics in the classroom. It is the necessity of the hour that teachers should take actions in proposing new technological tools in their classroom. This technique will help the students to enhance their engagement. Nowadays, the younger generation is exposed to technology from their childhood. Learning through new technology will increase interest as well as the participation of the students. Educational robotics involves hands-on activities which help a student to engage them emotionally, cognitively and behaviourally.

In India, the use of educational robotics has not been so much as compared with western countries. There are some engineering colleges in which the courses in robotics have been introduced. The CEO and founder of Omnipresent Robot Tech, Aakash Sinha feels that India is at the apex of a build-up of next-level technology driven by robotics. Nirmal Gadde, Jedi Trooper of Systems Engineering of Team Indus accepts that robotics is making a difference in fields like automotive, electrical and the Fast Moving Consumer Goods (FMCG), significantly by automating the manufacturing process. He implies that there is a lot to be done in the public domain. But much can be done in the educational field as well. There is a plenty of research being conducted in other areas that are tangled in the day-to-day lives of people. Many start-ups are developing robotics in India confirming to be the means for the robotic revolution. In light of this, the educational robotics should be used in the classroom as a teaching and learning tool for increasing the interest of children towards their curricular and co-curricular activities.

Seymour Papert's Mindstorms made a seminal contribution to the field of educational technology. It stimulates research into the potential role of the computer in learning that has embraced programming, microworlds and educational robotics. By building in Piaget's pedagogical theory of constructivism and Papert's constructionism, contemporary technologies such as digital fabrication and robotics can promote skills in creative thinking, collaboration and problem-solving in Science, Technology, Engineering, Arts and Mathematics (STEAM). Papert envisaged how ubiquitous computing and an increasing disillusion with traditional education could come together in a way that would be excellent for children, for parents and for learning through the construction of educationally powerful computational environments that will provide alternatives to traditional classrooms and traditional instruction.

Underlying Theories for Designing Robots

Constructionism is a learning and instructional approach found in the philosophical idea of constructivism, which specifies the active part of the learner in collaboratively constructing learning in a contented setting (Duffy & Cunningham, 1996). Papert (1991) describes the association between constructionism and constructivism:

Constructionism…shares constructivism's meaning of learning as "creating knowledge structures" irrespective of the conditions of the learning. It then continues the concept that this happens particularly felicitously in a setting where the learner is consciously involved in constructing a public actuality, whether it's a sand building on the shore or a theory of everything.

Constructionism shares connection with other constructivist theories such as conventional knowledge (Brown *et al*., 1989) and cognitive flexibility theory (Spiro *et al*., 1988). Though, constructionism is different in that it indicates "learning by creation" as the significant features of the learning activity. The articles to be generated are "objects to think with" (Papert, 1993). They contribute considerable means for learners to evaluate and modifiy their understanding of science concepts while working together in designing, building, evaluating, and modifying objects meaningful to them (Puntambekar & Kolodner, 2005). Knowledge gets constructed when learners are involved in the development of making objects and interactive about their design. Constructionism has familiarity with a set of studies in which technology is used to form a context that accelerates 'learning by doing' and 'learning by design'. Research designs in this area comprise those that use Logo programming in teaching mathematics (Papert, 1993), include children in generating computer games (Kafai, 1996), involve fragments of a practical similarity to develop objects and space (Bruckman & Resnick, 1996), and assist learning with programmable blocks (Sargent *et al*., 1996). Research on programmable blocks has pointed to the commercial product of LEGO Mindstorms robots (LEGO Group, 2006).

Froebel developed kindergarten in the 1800s and introduced a series of gifts to teach children about size, number and shape. Robotics also involves young children in using their hands for developing abilities. Robotics also invites children to participate in social communications and conversations while 'playing to learn' and 'learning to play' (Resnick, 2003). Learning how to work in the social world is an essential developmental task that young children need to achieve. Despite all of the potential advantages of robotics in education, research has shown the challenges of introducing new technologies in schools (Cuban, 2001). The challenges of incorporating technology in education are that on the one hand, teachers are not well- prepared to understand the possibilities of new technologies. On the other hand, teachers have issues regarding the developmental suitability of introducing technology and engineering in the start of grades. Most teachers are trained to a Piagetian idea of developmental stages that advises that children start the concrete operational stage at the age of six or seven. Therefore, according to Piaget, only at this age, a child obtains the capability to perform mental processes and also to modify those operations. As a consequence, a concrete operational child has a more complicated understanding of number, can imagine the world from views other than his or her own, can systematically analyse, sort, and classify objects, and can explain notions of time and causality (Piaget, 1971).

Scope of Educational Robotics

The utilisation of multimedia tools in education has become familiar in 21st century with the fast development of technology. Despite their applications in engineering, robots are being used by teachers in schools. According to Beran *et al.*, (2011), children are also playing more with technologically advanced devices during their playtime. Studies were carried to explore the use of the influence of robot on cognition of children (Wei *et al.*, 2011), language of children (Kozima & Nakagawa, 2007), interaction of children (Shimada, Kanda & Koizumi, 2012), social and moral development (Kahn *et al.*, 2012). Studies showed that the use of robot promotes interactive learning, making children more interested in their learning activities (Wei, Hung, Lee & Chen, 2011; Highfield, 2010). Research on robot application needs the systematic look to elucidate a roadmap for future studies. Robots are ubiquitous in our lives; educational robotic kits are an attractive means to provide our children with new opportunities to learn how to construct their robots (Resnick, 1998). Several colleges today have a long lasting belief of involving students in robotic experiments and competitions - events where robots have to accomplish a given task (usually to outperform another robot). Robotics creates learning experiences for children about sensors, motors, and the digital domain. Playing with motors, gears, sensors, levers and programming loops will help children to become engineers and as well as storytellers by designing their projects that move in response to their surroundings. Robotics can help children to learn about related mathematical concepts, the scientific method of inquiry and problem-solving.

Robotics is defined as the branch of science that studies those machines that can replace humans in performing the task, which combines physical activity with the decision-making process (Doulgeri, 2007). However, robotics has been used in education since the late 80's starting outside India, both as a teaching subject and also as an auxiliary tool in teaching various concepts of topics such as Mathematics Science, Engineering ae well as technology and computer Science (Karatrantou & Panagiatakopoulos, 2011). Apart from teaching certain concepts, robotics is used to achieve skills such as problem-solving ability, specific and abstract reasoning, critical thinking and active cooperation (Alimisis, 2009). For a robotic system to be functional, two types of activities are required: the construction and programming. In this way, cognitive processes are developed, and skills such as computational thinking are emerging, supporting students to solve authentic problems in the school environment as well as in real life (Karatrantou & Panagiatakopoulos, 2011; Karatrantou & Panagiatakopoulos, 2008). Problem-solving is a demanding process which invites the students to deal with logic, semantics and sometimes with abstract thinking to conceive and solve the problem. Moreover, the construction process of the robotic system and its programming contribute to the socialisation of the student through cooperation for the implementation of the activities (Karatrantou & Panagiatakopoulos, 2011; Alimisis, 2009).

Educational robotics is the process during which students assemble and program them to perform the certain behaviour for educational purposes. Therefore, educational robotics from a pedagogical perspective is considered to be grounded in the theories of classic Constructivism (Piaget, 1972) and in particular that of the constructionism (Papert, 1993). The learning environment provides activities embedded in problem-solving procedures, and thus, learners build an adequate knowledge as they are involved actively in the design and construction (manual and digital) of real objects that have to mean for them in a more natural way.

Educational Robotics combines game with learning, and thus, learning becomes a fun activity that is easier, enjoyable and its objectives is achieved more efficiently (Eguchi, 2014). The aspect of a game that robotic constructions involve is an important and decisive factor of individual action and motivation (Panagiatakopoulos, 2011). The development of research interest is promoted, and children are enabled to act like scientists and inventors and discover their original ideas and solutions thus enhancing their self-efficacy (Barker, 2012). By solving authentic problems students are actively involved and support their exploratory attitude having incentives to study science and technology. Students are also involved in situations that require from them to use and apply their knowledge from Mathematics, Science, Technology and Engineering (Alimisis *et al*., 2008) gaining the opportunity to develop a strong conceptual basis for the reconstruction of their knowledge at a later time (Eguchi, 2014).

Educational robotics allows students to express themselves freely and promotes the development of creativity and imagination, as it invites students to envision what they will make and what goal they want to achieve through the programming of their constructions (Mubin *et al*., 2013). Also, the construction of their robotics is a problem-solving situation that provides instant feedback promotes a multidisciplinary and interdisciplinary approach (Arlegui, 2008). At the same time, educational robotics activities are based on cooperation and interaction of individuals and groups, promoting thinking through conflicts in cognitive and social level as children are required to explain ideas, opinions and thoughts and justify their answers (Kiriakidi *et al*., 2012). Additionally, students need to analyse, plan and implement their work which constitutes high-level mental skills. Such activities with younger ages pose some rate of failure, since, according to Piaget, they are in concrete thinking, help children familiarise and deal with abstract concepts (e.g., speed, time, variable), having; as a result, their better preparation for the next cognitive stage (Feldman, 2009)

Educational robotics contributes in learning programming and helps students familiarise with the basic principles of programming (Papadanelis *et al*.,2012). Programming robotic constructions create an entirely new learning environment which is highly motivating. Furthermore, it supports metacognitive learning processes since students need to think about the way they thought and acted (Alimisis *et al*.,2010).

Robotics in STEM (Science, Technology, Engineering and Mathematics)

Robots now a days have the opportunity to become the next step in education. This is because of their innovative nature, the hands-on experience it offer and the enthusiasm it can cause, make children more receptive to learning stimuli. Apart from this, however, robots have a lot to offer and become a significant educational tool in the STEM approach (Barker, 2012).

The field of robotics, primarily provides learning incentives because it brings together many areas of the curriculum (Johnson,2003). Learning is fun and students engage in activities that sharpen their thinking and imagination through observation, design, calculation, measurement and the chance to test their projects in a real life context while usually developing their social skills and team spirit (Sullivan, 2008). The application of educational robotics has yielded significant positive results in the development of technology literacy and the ability to solve problems (Anagnostakis & Michaelides, 2006). Sullivan (2008) describes improved observational skills, the capacity to make appropriate calculations, creativity building and the intuitive assessment of hypotheses and variables. More so, positive results are observed in the social skills of children and the development of team spirit and mutual collaboration

(Mitnik *et al.*, 2008, Nuget *et al.*, 2009 & Owens *et al.*, 2008). However, it seems that educational robotics are not often utilised as a cognitive tool in specific subjects, especially at younger ages, Barak & Zadok (2009) note that the benefits of educational technology, as they are strongly associated with problem-solving. Milkropoulos and Bellou (2013) have also proposed educational robotics as mind tools in Physics and Computer Science education through meaningful learning activities.

Inquiry skills comprise the capabilities to control and comprehend scientific inquiry, comprising probing questions, planning and conducting studies, adopting appropriate tools and techniques to collect data, thinking critically and logically about connections between evidence and explanations, creating and analysing alternative explanations, and reporting scientific arguments" (National Research Council, 1996). Robotics activities are perfect for teaching scientific inquiry skills. In inquiry-based learning, students require a rich context to investigate questions and develop scientific argumentation abilities (Baumgartner & Reiser, 1998; Kolodner *et al.*, 2003). This setting is usually not available in the traditional classroom. Robotics activities may be a promising alternative. They may provide a rich context needed for students to identify and investigate problems, generate hypotheses, collect and analyse data, and to prepare findings and understand results. Also, constructing robots may provide a chance for learners to obtain science content knowledge since mathematics and physics are the foundations of engineering and programming, which are needed in robotics development.

Beyond the direct relationship that seems to be more obvious between robotics and technology and engineering; as robots are a technological tool and a product of engineering and technology. Studies in schools have reported that robots helped significantly for developing skills with fractions and proportions to be improved as well as learning of decimal and ratios to be more enjoyable and fruitful. A largescale study in Peru showed improvements in problem-solving skills and expertise of quantity and amount recognitions (Karim, 2015).

Robots were used to orient the principles of classical Physics. It is noted to have been used to study the relationship between distance, time and speed to be examined and discussed through the construction, programming and design of motion of the robots (Karim, 2015). The motivation of the students, their attitude towards learning and their engagement was claimed to be significantly improved (Robinson, 2005). Moreover, content knowledge of the students was greatly strengthened through activities that focussed on concepts like friction, forces, weight, and the diameter of the wheels and were associated with the fundamental laws of Newton by utilising robotic constructions (Karim, 2015). Other examples in the same direction refer to a solar car, a rubber catapult and wind turbine which contributed in teaching the basic forms of energy and energy conversion techniques. Studies that were developed for the analysis of activities related to Physics which required a theoretical and practical understanding of their implementation showed that students improved both in their written ability to explain science and in the interpretation of graphs relating to speed, time, acceleration and deceleration using robots (Karim, 2015).

Hence it is concluded that the use of robotic constructions has a lot to offer as it can positively contribute to the increase of student's motivation, their engagement in learning, their creativity and their positive attitude towards education and its subjects through problem-solving situations. Thus, the importance of using robots as tools for both the introduction to the robotics field as well as teaching concepts of programming and STEM approach is indisputable.

Challenges in the Use of ER

Despite their growing acceptance, robotics activities are generally not found in regular K–12 classrooms. One of the explanations might be that there is inadequate experimental evidence to validate the impact of robotics activities on curricular goals. Most of the literature on the robotics application in education is subjective and illustrative in quality (Ford *et al*., 2006; Lau *et al*., 1999). Some exploratory studies have stated positive views of the educational advantage of robotics activities among teachers and students (Petre & Price, 2004; Robinson, 2005). This is inspiring, but the assessable evidence is needed to satisfy educators of the positive influence of robotics activities on curricular goals. A majority of researchers relied on non-experimental methods, implemented a different approach to validating their studies. However this shows that experimental methods are sorely lacking; quantitative analysis is needed, as pointed by Benitti (2012).

Conclusion

As robot technologies evolve, the use of robots has achieved popularity to assist teaching and learning. Over the past few years, researchers have presented substantial evidence that the robot is an excellent teaching support for mathematics and science. Moreover, educational robots are helpful to students in developing collaboration and problem-solving abilities. This paper highlighted the potential for using robots as an instructional tool for teaching, by analysing the characteristics of robots. To conclude, the roles of educational robots can be described regarding two categories: learning materials, and teaching companions. We also understand that there will be new robot educational functions in the future, for example, utilising robots as communication mediators to support group learning etc. By interacting with the robot, the children can respond with high motivational levels. The robot can also exhibit gestures and body movements so it could be the partner with the teacher to tell stories. Robots can create an interactive and engaging learning experience. Instructors will have more time to guide weaker students when the robot is the primary focus of attention. The major factors regarding whether the robot is likely to be useful in teaching, involve usability and the availability of relevant learning activities and content. Compared to other instructional tools for teaching, robots have the advantages of being able to demonstrate highly mobile behaviours. However, by current technologies, there are many challenges and limitations to the expanded use of instructional robots that involve lack of adequate teacher training, complicated techniques, and the inability of robots to adequately portray emotions.

Research in Educational Robotics in recent years is a growing field which has revealed the great potential that robotics has to offer in science, technology, engineering and mathematics (STEM) education at all levels from kindergarten to university. Although robotics has not still found the place it deserves in school curricula, a growing number of robotic actions and events take place in formal and informal education involving educators, researchers and students. At the same time, the market offers a growing number of robots and platforms proposed for the educational purposes, and this trend may continue over the coming decades. However, the benefits in learning are not guaranteed for learners by just mere introduction of robots in the classroom; technology alone cannot affect minds; robots are just another tool and not the end point for improving learning. The role of the curriculum and the alignment of robotics technology with relevant theories of learning (constructivism and constructionism) are the crucial factor that determines the learning results.

References

Akey, T.M.: School Context, Student Attitudes and Behavior, and Academic Achievement: An Exploratory Analysis. MDRC (2006)

Alimisis, D. (ed.): Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods, School of Pedagogical and Technological Education (2009)

Alimisis, D., Arlegui, J., Fava, N., Frangou, S., Ionita, S., Menegatti, E., Monfalcon, S., Moro, M., Papanikolaou, K., Pina, A.: Introducing robotics to teachers and schools: experiences from the TERECop project, Constructionism 2010, Paris, France, 16–20 August 2010

Alimisis, D., Moro, M., Arlegui, J., Pina, A., Frangou, S., & Papanikolaou, K.

(2007, August). Robotics & constructivism in education: The TERECoP project. In *EuroLogo* (Vol. 40, pp. 19-24).

Alimisis, D.: Robotics in education & education in robotics: shifting focus from technology to pedagogy. In: Proceedings of the 3rd International Conference on Robotics in Education, pp. 7–14 (2012)

Anagnostakis, S., Michaelides, P.G.: Laboratory of educational robotics' - an undergraduate course for primary education teacher – students. In: 3rd International Conference on Handson Science, Braga, Portugal, pp. 329–335 (2006)

Arlegui, J., Menegatti, E., Moro, M., Pina, A.: Robotics, Computer Science curricula and Interdisciplinary activities. In: Workshop Proceedings of SIMPAR International Conference on Simulation, Modeling and Programming for Autonomous Robots, Venice, Italy, pp. 10–21 (2008)

Barak, M., Zadok, Y.: Robotics projects and learning concepts in science, technology and problem solving. Int. J. Technol. Des. Educ. **19**(3), 289–307 (2009)

Barker, B.S., Ansorge, J.: Robotics as means to increase achievement scores in an informal learning environment. J. Res. Technol. Educ. **39**(3), 229–243 (2007)

Barker, S.B., Nugent, G., Grandgenett, N., Adamchuk, I.V.: Robots in K-12 Education: A New Technology for Learning. Information Science Reference. IGI Global, United States of America (2012)

Baumgartner, E., & Reiser, B. J. (1998). *Strategies for supporting student inquiry in design tasks.* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education*, *58*(3), 978-988.

Beran, T. N., Ramirez-Serrano, A., Kuzyk, R., Fior, M., & Nugent, S. (2011). Understanding how children understand robots: Perceived animism in child–robot interaction. *International Journal of Human-Computer Studies*, *69*(7), 539-550.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Bruckman, A., & Resnick, M. (1996). The MediaMOO project: Constructionism and professional community. In Y. B. Kafai & M. Resnick (Eds.), *Constructionism in practice: Designing, thinking, and learning in a digital world* (pp. 207–221). Mahwah, NJ: Lawrence Erlbaum Associates.

Cielniak, G., Bellotto, N., Duckett, T.: Integrating mobile robotics and vision with undergraduate computer science. IEEE Trans. Educ. **56**(1), 48–53 (2013)

Cuban, L. (2001). Oversold and underused: Reforming schools through technology, 1980-2000.

Doulgeri, Z.: Robotics: Kinematics, dynamics and control of articulated arms. Kritiki, Athens (2007).

Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* (pp. 170–198). Bloomington, IN: Association for Educational Communications and Technology.

Eguchi, A.: Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education, Padova, Italy, 18 July 2014, pp. 27–34 (2014)

Feldman, R.S.: Developmental Psychology, Development Across the Life Span, vol. 1. Gutenberg, Athens (2009)

Frangou, S., Papanikolaou, K., Aravecchia, L., Montel, L., Ionita, S., Arlegui, J., Monfalcon, S.: Representative examples of implementing educational robotics in school based on the constructivist approach. In: SIMPAR Workshop on Teaching with Robotics: Didactic Approaches and Experiences, Venice, Italy (2008)

Highfield, K. (2010). Robotic Toys as a Catalyst for Mathematical Problem Solving. *Australian Primary Mathematics Classroom*, *15*(2), 22-27.

Johnson, J.: Children, robotics, and education. Artif. Life Robot. **7**, 6–21 (2003)

Kafai, Y. B. (1996). Learning design by making games: Children's development of design strategies in the creation of a complex computational artifact. In Y. B. Kafai & M. Resnick (Eds.), *Constructionism in practice: Designing, thinking, and learning in a digital world* (pp. 71–96). Mahwah, NJ: Lawrence Erlbaum Associates.

Kahn Jr, P. H., Kanda, T., Ishiguro, H., Freier, N. G., Severson, R. L., Gill, B. T., ... & Shen, S. (2012). "Robovie, you'll have to go into the closet now": Children's social and moral relationships with a humanoid robot. *Developmental psychology*, *48*(2), 303.

Karatrantou, A., Panagiotakopoulos, T.C.: Algorithm, pseudo-code and Lego Mindstorms programming. In: Proceedings of International Conference on Simulation and Programming for Autonomous Robots/Teaching with Robotics: Didactic Approaches and Experiences, Venice, Italy, pp. 70–79 (2008)

Karatrantou, A., Panagiotakopoulos, T.C.: Educational robotics and teaching introductory programming within an interdisciplinary framework. In: Jimoyiannis, A. (ed.) Research on e-Learning and ICT in Education. Springer, New York (2011)

Karim, M., Lemaignan, S., Mondada, F.: A review: can robots reshape K-12 STEM education? In: Proceedings of the 2015 IEEE International Workshop on Advanced Robotics and its Social impacts (2015)

Kiriakidi, F., Taraperas, C., Karatrantou, A., Panagiotakopoulos, T.C.: Educational robotics in support of teamwork activities in primary education. In: 6th National Congress of Computer Science (2012)

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., *et al.* (2003). Problem-based learning meets case-based reasoning in the middleschool science classroom: Putting Learning by Design into practice. *Journal of the Learning Sciences, 12*(4), 495–548.

Kozima, H., & Nakagawa, C. (2007, August). A robot in a playroom with preschool children: Longitudinal field practice. In *RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication* (pp. 1058-1059). IEEE.

Mikropoulos, T.A., Bellou, I.: Educational robotics as mindtools. Themes Sci. Technol. Educ. **6**(1), 5–14 (2013)

Mills-Tettey, G.A., Dias, M.B., Browning, B., Amanquah, N.: Teaching technical creativity through Robotics: A case study in Ghana. In: International Conference on AI Workshop on AI in ICT for Development (2007)

Mitnik, R., Nussbaum, M., Soto, A.: An autonomous educational mobile robot mediator. Auton. Robots **25**(4), 367–382 (2008)

Mubin, O., Stevens, J.C., Shahid, S., Mahmud, A., Dong, J.: A review of the applicability of robots in education. Technol. Educ. Learn. (2013).

Nourbakhsh, I.R., Crowley, K., Bhave, A., Hamner, E., Hsiu, T., Perez-Bergquist, A.,Wilkinson, K.: The robotic autonomy mobile robotics course: robot design, curriculum design and educational assessment. Auton. Robots **18**(1), 103–127 (2005)

Nuget, G., Barker, B., Grandgenett, N., Adamchuk, V.: The use of digital manipulatives in K-12: robotics, GPS/GIS and programming. In: Atman, C. (ed.) Proceedings of the 39th IEEE International Conference on Frontiers in Education Conference, pp. 302–307. IEEE Press, Piscataway (2009)

Owens, G., Granader, Y., Humphrey, A., Baron-Cohen, S.: LEGO therapy and the social use of language programme: an evaluation of two social skills interventions for children with high functioning autism and asperger syndrome. J. Autism Dev. Disorders **38**(10), 1944–1957 (2008)

Panagiotakopoulos, T.C.: Applying a conceptual mini game for supporting simple mathematical calculation skills: students' perceptions and considerations. World J. Educ. **1**,3–14 (2011)

Papadanelis, G., Karatrantou, A., Panagiotakopoulos, T.C.: Utilization of lego mindstorms NXT for teaching programming: the concept of the variable. In: Proceedings of the 6th Panhellenic Conference "Didactics of Computer Science" (2012)

Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), *Constructionism*. Retrieved 6, 2016, from http://www.papert.org/articles/SituatingConstructionism.html

Papert, S. (1993). *Mindstorms: Children, computers, and powerful ideas* (2nd ed.). New York, NY: Basic Books.

Papert, S.: The Children's Machine. Basic Books, New York (1993)

Piaget, J. (1971). The theory of stages in cognitive development.

Piaget, J.: The Principles of Genetic Epistemology. Basic Books, New York (1972)

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching and Teacher Education, 42*(2), 185–217.

Resnick, M. (1998). Technologies for lifelong kindergarten. *Educational technology research and development*, *46*(4), 43-55.

Resnick, M. (2003). Playful learning and creative societies. *Education Update*, *8*(6), 1-2.

Robinson, M.: Robotics-driven activities: Can they improve middle school science learning? Bull. Sci. Technol. Soc. **25**(1), 73–84 (2005)

Rogers, C., Portsmore, M.: Bringing engineering to elementary school. J. STEM Educ. Innovations Res. **5**(3/4), 17 (2004)

Shimada, M., Kanda, T., & Koizumi, S. (2012, October). How Can a Social Robot Facilitate Children's Collaboration?. In *International Conference on Social Robotics* (pp. 98-107). Springer Berlin Heidelberg.

Spiro, R. J., Coulson, R. L., Feltovich, P. J., & Anderson, D. K. (1988). Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains. In Sugimoto, M. (2011). A mobile mixed-reality environment for children's storytelling using a handheld projector and a robot. *IEEE Transactions on Learning Technologies*, *4*(3), 249-260.

Sullivan, F.R.: Robotics and science literacy: thinking skills, science process skills and systems understanding. J. Res. Sci. Teach. **45**(3), 373–394 (2008)

Wei, C. W., Hung, I. C., Lee, L., & Chen, N. S. (2011). A joyful classroom learning system with robot learning companion for children to learn mathematics multiplication. *TOJET: The Turkish Online Journal of Educational Technology*, *10*(2).

Yerion, K.A., Rinehart, J.A.: Guidelines for collaborative learning in computer science. ACM SIGCSE Bull. **27**(4), 29–34 (1995)