

Robotics as a Learning Tool for Educational Transformation

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Abstract. Educational robotics is a transformational tool for learning, computational thinking, coding, and engineering, all increasingly being viewed as critical ingredients of STEM learning in K-12 education. Although robotics in education for school age children has been in existence since the late 1900s and is becoming more popular among young students, it is not well integrated as a technological learning tool in regular school settings. The paper aims to convey the importance of integrating educational robotics as a technological learning tool into regular curriculum for K-12 students and explain how it helps students prepare for the future.

Keywords—*Educational Robotics; STEM education; Computational Thinking; Engineering Thinking; Coding*

1. Introduction

The world is changing at a rapid pace. Technological advancements have accelerated, enhanced by the interconnectedness brought on by the power of the Internet and social media and resulting ‘flattening’ of the world [1]. New technological tools are introduced in our life more rapidly than ever before. New iProducts are introduced into the market almost every six months. Creative project crowdfunding platforms, such as Kickstarter (<http://www.kickstarter.com>) and Indiegogo (<https://www.indiegogo.com/>), are contributing to the accelerated birth of innovative technological tools by providing essential funding.

News headlines featuring various robotic innovations are a strong indication of how much popular attention robotics technology has garnered in recent years. When watching the Jetsons television program in the 1960s and 1980s, very few people believed that a humanoid robot, like Rosie, could become a reality in their lifetime. On June 5, 2014, Softbank Mobile, a Japanese company, in collaboration with Aldebaran Robotics, a French company, unveiled *Pepper*, the world’s first personal humanoid robot able to assist humans by reading and responding to human emotions¹. Pepper is scheduled to be on sale for less than US\$2,000 in February 2015. Prior to the introduction of Pepper, Amazon introduced its drone delivery system and Google announced its acquisition of eight robotics companies in 2013, including Boston Dynamics, a Boston-based robotics company that produces robotics creations supported by the Department of Defense, and Schaft Inc., a Japanese robot venture start-up company, and the DARPA Robotics Challenge trial was held in December 2013, followed by its final in December 2014. Aldebaran Robotics’ NAO, an autonomous and programmable humanoid robot, has been used in various educational settings including RoboCup Soccer league for the development of algorithms for humanoid soccer and for the research of children with Autism.

¹http://www.softbank.jp/en/corp/group/sbm/news/press/2014/20140605_01/
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5th International Conference Robotics in Education

1.1 Recent Movements in Education

Technology is ubiquitous and integrated into every aspect of our lives. Our students are digital natives who have grown up using smartphones or iProducts. Home computers have been in existence since before they were born. A second grade student shared that he thought ‘B.C.’ means “before computer”! Although their lives are filled with technology, our students rarely stop to think about how their devices actually work. They rarely realize that technological tools could be fixed when they stopped working. Instead, they simply ask for new one, as if those technologies are disposables. We have failed to teach students to question or think about technology, which has the danger of creating passive users of those tools.

Popular interest in robotics has increased at an astonishing rate in the last several years [2]. Robotics technology has been implemented in a variety of fields including medicine, elderly care, rehabilitation, education, home appliances, search and rescue, car industry and more. The world and its economies are changing at such a speed that it is impossible to predict what it will look like even at the end of next week [3]. Although the world is rapidly changing, public education has maintained almost the same system since its introduction to the world [3]. Though educational reform efforts have been made around the world, the trouble lies in the fact that the majority of schools are trying to prepare students for the future by continuing what was done in the past [3].

There have been several educational movements in recent years that encourage educational innovation, such as the introduction of K-12 coding (coding education for primary and secondary students). During the Computer Science Education Week in December 2013, an initiative to bring coding into classrooms around the world called the Hour of Code was launched. During the week of December 9th to 15th, Code.org reported 15 million students from 170 countries participated in an hour of coding. One in five U.S. students participated and more girls participated in computer science in US schools than in all of the past 70 years [4]. The Hour of Code has created a large movement encouraging integration of coding in primary and secondary education. In the United Kingdom, a new curriculum framework published in 2013 emphasizes coding and engineering design [5]. It reported,

We aspire to an outcome where every primary school pupil has the opportunity to explore the creative side of Computing through activities such as writing computer programs (using a pupil-friendly programming environment such as Scratch). At secondary school every pupil should have the opportunity to work with microcontrollers and simple robotics, build web-based systems, and similar activities. We recognise that not all pupils will wish to seize these opportunities, but they should be able to do so if they do wish to. [6, p.4]

Integrating computational thinking in primary and secondary education

curriculum is another movement that encourages K-12 coding. Computational thinking is a problem-solving method that uses techniques typically practiced by computer scientists. Computational thinking is “increasingly being viewed as an important ingredient of STEM learning in primary and secondary education. STEM is clearly center stage for policymakers, curriculum designers as well as researchers” [8, p.1]. Since modern economies are profoundly influenced by technology-related industries, acquiring computational thinking is crucial for the success of the next generation of students. Engineering education is an important focus in education because of the recent emphasis on STEM education. “Engineering in K-12 Education: Understanding the Status and Improving the Prospects” (published in 2009) emphasizes the importance of integrating engineering education into primary and secondary education curriculum [9]. The report suggests that engineering education enhances students’ learning in STEM subjects, as well as their awareness and willingness to pursue careers in the field of engineering. Integrating engineering into curriculum will increase the technological literacy of students. The maker movement has helped encourage innovative change and creativity in schools. ‘Making’ integrates elements of K-12 coding, computational thinking, engineering and STEM education. Maker Faire, an annual event for *makers*, launched in 2006 by Make Magazine, has spread around the world, inspiring school age makers to participate. The White House recently announced plans to host their own Maker Faire² in the near future. Maker Education Initiative (<http://www.makered.org/>) is a non-profit organization formed “to create more opportunities for young people to develop confidence, creativity, and spark an interest in science, technology, engineering, math, the arts, and learning as a whole through making” [7 , para 1].

Robotics in education is one of the best technological and educational tools to integrate all of the movements previously described. Using robotics introduces students to emerging and innovative technological creations, as well as encouraging their participation in the act of making, which, in turn, nurtures them to become active creators rather than consumers of technological products in the future.

2. Robotics in Education for Transdisciplinary Curriculum

Introduced to the field of education as the next big thing, STEM education is commonly understood as an educational approach that integrates Science, Technology, Engineering and Mathematics, which was [24]. STEM education aims to expand the number of students pursuing advanced degrees and careers in STEM fields, increase the size of the STEM-capable workforce, and promote STEM

² <http://www.whitehouse.gov/blog/2014/02/03/announcing-first-white-house-maker-faire>

literacy for all students [25]. Increasing the size of the STEM workforce requires a transdisciplinary approach to integrating STEM knowledge and skills. As students integrate STEM academic concepts (not just one of four subjects in isolation) and real-world lessons, they will then learn to apply STEM knowledge in a context that links school, community, work, and the global enterprise [Tsupros, N., Kohler, R., & Hallinen, J. cited in 24]. Educational robotics is an effective learning tool for project-based learning where STEM, coding, computer thinking and engineering skills are all integrated in one project. Robotics provides opportunities for students to explore how technology works in real life, *all with one tool* through the act of making.

Learning with educational robotics provides students with opportunities for them to stop, question, and think deeply about technology. When designing, constructing, programming and documenting autonomous robots, students not only learn how technology works, but they also apply the skills and content knowledge learned in school in a meaningful and exciting way. Educational robotics is rich with opportunities to integrate not only STEM but also many other disciplines, including literacy, social studies, dance, music and art, while giving students the opportunity to find new ways to work together to foster collaboration skills, express themselves using the technological tool, problem-solve, and think critically and innovatively. Educational robotics is a learning tool that enhances student experience through *hands-on mind-on* learning. Most importantly, educational robotics provides a fun and exciting learning environment because of its hands-on nature and the integration of technology. The engaging learning environment motivates students to learn whatever skills and knowledge needed for them to accomplish their goals in order to complete the projects of their interest.

The following section provides three examples of the transdisciplinary integration of STEM, coding, computational thinking and engineering skill learning as students work to learn how technology works through robotics projects.

2.1 WaterBotics (<http://waterbotics.org/>)

WaterBotics is a NSF funded underwater robotic curriculum for middle and high school students developed by the Stevens Center for Innovation in Engineering & Science Education at Stevens Institute of Technology. The WaterBotics program provides hands-on experiences for participating students to learn engineering design and STEM concepts, while using information technology tools to increase awareness and interest in engineering and IT careers. The WaterBotics curriculum asks small groups of students to work collaboratively to design, construct, test, and redesign their underwater robots. The program uses LEGO Mindstorms NXT kits and other components for the construction of the underwater robots. Students use Mindstorms software to program a remote controller using NXT to control the robots to maneuver in the water. The WaterBotics curriculum covers various standards including the National Science

Education standards, International Technology and Engineering Association (ITEEA) Technological Literacy Standards, and the International Society for Technology in Education (ISTE) National Educational Technology Standards (for more information: <http://waterbotics.org/curriculum/standards/>). The curriculum also emphasizes the engineering design process (1. design task; 2. Brainstorm; 3. Design; 4. build; 5. test; 6. redesign; and 7. share), an important element of engineering thinking process. From the author's experience when participating in the teacher training workshop provided by the project, the WaterBotics program has the potential to enhance students' learning of computational thinking skills defined by ISTE and CSTA [26], including confidence in dealing with complexity, persistence when working with difficult problems, ability to deal with open ended problems, and ability to communicate and work with others to achieve a common goal or solution. Students also learn up-to-date underwater robotics technology by watching various videos and visiting research facilities.

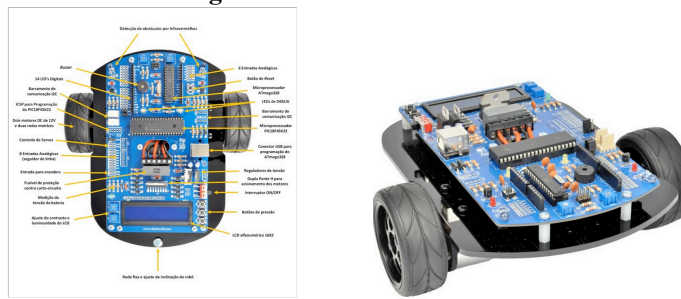
The WaterBotics program reported that the program had positive impacts on student learning of science concepts and programming knowledge, based on the statewide program with more than 2,600 participating middle and high school students in New Jersey during the period of 2006 to 2009 [27, 28].

2.2 RoboParty (<http://www.roboparty.org/en/>)

RoboParty is a robotic camp organized at Universidade do Minho in Guimarães Portugal, by Professor A. Fernando Ribeiro, his students and staff from the institution's Industrial Electronics department. During the three-day camp held on campus, school age children learn electronics, mechanical engineering and programming, while participating in various cultural and sports activities. The students register in teams of three with one teacher or mentor working side by side with the students. Each team receives one Bot'n Roll One A, an Arduino based robotics kit per team. The kit comes with one Arduino based controller board with all the necessary connection ports printed on the board (Fig. 1). They solder all of the components, sensors and motors provided in the box to complete the circuit. Through the hands-on experience of building with trial and error, since one soldering mistake will cause the robot to have trouble turning or moving, the students learn electronics and mechanical design. Once the robot is built (Fig. 2), the students learn C-based programming using Arduino IDE. There are three different challenges that the students may attempt to solve: Pursuing competition (a line following race), Obstacle competition (maze with walls), and Dance competition (free robotics dance to music). While developing algorithms and code for each challenge, students learn to program. On the last day, the teams compete in each challenge and showcase their robotic creations and algorithms. According to the preliminary study conducted in 2011, participating students gave very positive feedback and showed an increased interest in engineering [29]. In addition, students indicated that they had positive learning experiences while

working as a team, communicating their process and product, managing disagreements and engaging in productive decision-making.

Fig. 1. & 2. Bot'n Roll Robot



2.2 RoboCupJunior (robocupjunior.org)

RoboCupJunior (RCJ) is an educational robotics initiative that promotes STEM learning, coding, computational thinking and engineering skills with hands-on, project-based and goal-oriented learning through an educational robotics competition. RCJ is open to all children up to 19 years of age. RCJ has three challenges or leagues designed to attract and motivate students to pursue robotics – soccer, rescue and dance. Since the challenges of each league remain relatively unchanged from year to year, student learning is scaffolded. Students continuously develop and sophisticate their solutions as they grow and expand their skills and knowledge over time. RCJ is committed to the *education* of young robotics scientists rather than a pure focus on competition. All three Junior leagues emphasize both the cooperative and collaborative nature of engineering design, programming and building in a team setting [12]. Each year there are more than 30 countries participating in RCJ initiatives. The annual RoboCupJunior World Championship attracts more than 250 teams from participating countries. In a study conducted with the US teams participating in the RoboCupJunior World Championship 2013, participating students reported very positive feedback on their learning of STEM, computational thinking and engineering skills as well as learning of soft skills including communication, collaboration, presentation skills, learning to be patient, and not giving up [30].

3. Conclusion

The three examples provided are just a few of many successful robotics programs and projects that utilize the transdisciplinary integration of STEM,

coding, computational thinking and engineering skill learning. Robotics in education effectively engages students in the learning of STEM concepts, coding, computational thinking and engineering skills, all necessary knowledge and skills for students to become successful members of the workforce in the future. Educational robotics is an all-in-one technological learning tool that promotes the future success of our students and should be integrated more and more into school curriculum.

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