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Robotics as Part of a 21ˢᵗ Century School Curriculum

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Abstract

It is generally accepted that knowledge alone is not enough to embrace the challenges of the 21st Century. A set of skills and dispositions, known as the 21st Century Skills, should be acquired to successfully face and solve complex problems in life and in the workplace. At CURRO we continually investigate new educational tools that can assist learners in developing these skills. The current paper hypothesises that Educational Robotics is an excellent tool to achieve exactly that, if implemented effectively. It is important to note that, in the current educational paradigm, Robotics is mostly taught extramurally to support the teaching of Physical Science and/or Information Technology to a select few. By doing this, the opportunity is neglected to develop the desired 21st Century skills in all learners. The major challenge is to integrate Robotics in the formal school curriculum at an early stage as implemented by the CURRO school educational programme. By doing this, all our learners are exposed to the benefits of Robotics. This programme is a tool with which learners are introduced to the very important skill of coding; we trust cognitive awareness will be cultivated and the skills needed to face future challenges will be developed.

Keywords: Educational Robotics, 21st Century Skills

Introduction

The Assessment and Teaching of 21st Century Skills (T21CS) document (Griffen & Care, 2012) states that today's curricula do not prepare students for living and working in an information-age society. The result is that first time workers often enter the workplace without the required 21st Century Skills categorised as follows:

- ways of thinking – creativity, critical thinking, metacognition
- ways of working – collaboration, communication
- tools for working – information literacy, information and communication technology
- living in the world – citizenship, life and career, personal and social responsibility.

It is therefore important that today's curricula not only cover reading, writing, mathematics and science, but also develop these skills to prepare learners for life and employment in the future. For the purpose of this article the focus will be on the ways of thinking and working and the use of technology in developing and teaching them.

The Framework for 21st Century Learning, confirms that learners need and deserve learning opportunities to prepare them for the challenges of work, life, and citizenship in the 21st Century. According to Professor Guy Claxton (Claxton, 2002), the father of Building Learning Power™ (BLP), we need to educate not only for exams, but for lifelong learning in order to keep on developing the necessary skills, dispositions and abilities to succeed in everyday life and challenging working environments. "It is about creating a climate or a culture in the classroom - and in the school more widely - that systematically cultivates habits and attitudes that enable young people to face difficulty and uncertainty calmly, confidently and creatively." (Claxton, 2012). According to Jean Piaget (1952) intelligence is "knowing what to do when you don't know what to do" (Piaget, 1952) and Lauren Resnick defines it simply as "the sum total of your habits of mind" and habits can grow and change. In other words, intelligence CAN grow and change! (Resnick, 1999)

The notion is that that Robotics is an exciting multi-disciplinary area that will dominate the 21st Century (Burbaitė, *et al*., 2013). In CURRO schools Educational Robotics is part of the formal curriculum from Grade 2 to Grade 6. It can be defined as a set of educational activities through which specific areas of knowledge are supported and strengthened and through which specific skills can be developed by designing, creating, assembling and programming robots. Scientists at Carnegie Mellon's Robotics Academy, a leading player in the Robotics field, state that when one teaches Robotics it is an opportunity for teaching Science, Technology, Engineering and Mathematics (the STEM subjects) in contexts that engage students as it is easy to grasp (2014). They believe that Educational Robotics may be the answer for developing the above mentioned skills and for preparing young people to face the challenges of this

century. Robotics will develop the necessary competencies in learners required in the new economy, an aspect that is often neglected in current school curricula. (Carnegie Melon, 2014)

The objective of this article was to see how and if Educational Robotics is used as a tool for teaching 21st Century Skills. In section "Background" a background is given of what was found in the literature. The specific 21st Century Skills is discussed in section "21st Century Survival Skills" while the current state of affairs in education is discussed in section "Education in the Present World." Robotics as a teaching tool in the 21st Century and the idea that coding can be seen as part of the new literacy is explored in sections "Educational Robotics as a Tool" and "Coding – a New Language."

The section "What is Needed," addresses some of the needs to ensure effective 21st Century teaching and learning. Current and future pedagogy, what the new workplace requires and demands and the challenges regarding the teaching of Robotics as part of a formal school curriculum, are discussed in sections "Pedagogy", "The New Workplace" and "Demands and Challenges."

In "Conclusions," the road ahead is deliberated.

The literature search was performed using Google Scholar and EBSCOhost databases searching for *Educational Robotics, 21C Skills and Critical Thinking.* This study focused on English articles published between 2010 and 2015.

Background

Prospects of the 21st Century are completely different to anything known before and technology has become a major influence in our everyday life. Therefore, technology should become part of any modern education system - not only to be used passively, but also as a tool to engage and create with!

21st Century Survival Skills

In the book, The Global Achievement Gap, Tony Wagner (Wagner, 2008a) states that there are seven survival skills that people will need. They are:

- critical thinking and problem solving
- collaboration and leadership
- agility and adaptability
- initiative and entrepreneurialism
- effective oral and written communication
- accessing and analising information
- curiosity and imagination.

"We need to use academic content to teach these seven survival skills every day, at every grade level and in every class" (Wagner, 2008b).

Education in the Present World

Pepper, the first humanoid robot capable of understanding human emotions and designed to live with humans, has been developed and introduced to the world on 5 May 2015 by Softbank Mobile in Japan. Educators are challenged to prepare learners for this rapidly changing world we live in and to meet challenges in the technological world after the fourth industrial revolution also known as robotization.

Although we are surrounded by technology, very few people appreciate and/or comprehend the technical side of how it operates. Not many school curricula teach learners to question or think about technology with the result that they become consumers of technology rather than engaging with it and using it as tools to create with (Eguchi, 2014). There is a need for modern technology to be introduced into our classrooms to excite our learners about the STEM subjects and to develop a variety of thinking and social skills (Saygin *et al.,* 2012).

> *"In so far as every science depends on data for both theory and application; laboratory or field data collection experience is an absolute necessity. Adding up numbers from a textbook example is not the same as recording those numbers or qualitative observations based on one's effort. When students "own" their data, the experience becomes a personal event, rather than a contrived exercise."* (George & Bragg, 1996)

The Organization for Economic Cooperation and Development (OECD) reported "technology everywhere, except at school" (OECD, 2008). More and more countries are realising the importance of ensuring that school leavers are computer literate. In September 2014 the UK Information and Communications Technology (ICT) curriculum was replaced with a new "coding" curriculum introduced at age five. The UK Department of Education realized that the skills mastered when learning to code will be valuable in life even if the technologies used to teach it may become out-dated. (Gove, 2012)

According to *Debating Europe,* 90% of European jobs require ICT skills, and yet there will be 900 000 unfilled ICT positions in the EU by 2020 (Anon, 2015). Less than 15% of European students have access in school to high-level ICT teaching (Collins *et al*, 2014). That is why the Europe Code Week was launched for the first time in 2013 by Neelie Kroes' Young Advisors with the support from DG Connect at the European Commission.

During Code Week 2014 all around Europe, more than 150 000 people, young and old created apps, websites, games and many other fabulous things by learning to code. In 2015 Code Week Africa was launched involving more than 80 000 children in 17 countries at 100's of workshops (Africa Code Week, 2015).

Educational Robotics as a Tool

A growing number of people believe that the best learning happens when learners are actively engaged in designing and creating things (Resnick & Silverman, 2005). Robotics is an excellent way of achieving exactly that and is generally seen as one of the most effective and child friendly tools for teaching coding in a funfilled way in an attractive learning environment (Turner, 2009) (Eguchi, 2010). It is a mixture of theory and practice and supports Papert's Constructionism Theory which takes Piaget's Constructivism Theory one step further. It states that learning is "building knowledge structures" which happens most effectively "where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe." In other words, learning happens best by making (Papert & Harel, 1991).

Robotics also has the potential to develop the above mentioned survival skills - skills that are deemed to be essential in the 21st Century (Benitti, 2012). The idea is not only to allow learners to build from instructions, but to allow them to design and programme their own models and to explore the ideas underlying their constructions (Resnick & Silverman, 2005). In Robotics learners should spend most of their time doing rather than listening as it gives them ownership of concepts in a way they don't get from traditional teaching (Gifford, 2014). It should be hands- and minds-on.

Most commonly, Educational Robotics is used to aid in teaching science or information technology, (Veselovska & Mayerova, 2014) but rarely to supplement the arts or languages or purely to develop 21st Century skills (Khanlari, 2013). Robotics improves problem solving skills, critical thinking, creativity, decision making, team-work, self-confidence, all of which are included in Tony Wagner's skills set according to (Khanlari, 2013.). According to Saygin et al, it promotes active reasoning and enhances student's interest and motivation to address complex or abstract problems (Saygin, *et al.,* 2012). In summary, Robotics has a positive impact on the development of 21st Century skills (Mubin, *et al*, 2013), (Alimisis , 2013).

Coding - a New Language?

Coding, programming and computer science will be the language of the 21st Century. "In a world that's increasingly run on technology, computer science is a liberal art that every student should be exposed to, regardless of their path in life," remarks Hadi Partovi co-founder and CEO of Code.org (Tyre, 2013).

"In terms of cognitive advantages, learning a system of signs, symbols and rules used to communicate - that is language study - improves thinking by challenging the brain to recognize, negotiate the meaning and master different language patterns. Students who speak English and Mandarin are better multitaskers because they're used to switching between language structures. Coding does the same thing, involving understanding and working within structures" (Adam & Mowers, 2013).

What is needed

In order to determine the needs for the future, it is important to critically look at the current pedagogy and curricula as well as at what is needed in the 21st Century workplace. The challenges and demands of teaching Educational Robotics as part of a formal school curriculum also need to be considered.

Pedagogy

In the traditional mode of teaching, knowledge is transferred one directionally from a teacher to the learners. Most learners taught in this way do not have the ability to apply the acquired knowledge in different situations, to effectively communicate and/or apply it creatively. It is therefore imperative that new strategies and ways of teaching to develop these skills should be adopted. Learning 21st Century skills requires 21st Century teaching (Saavedra & Opfer, 2012).

The New Workplace

20th Century padagogy needs to be adapted if we want to prepare learners for the workplace of this century. As the need for workers with computer science skills is exploding, the number of young people mastering those skills is actually reducing. According to Code.org the need for positions in computer programming grows at twice the U.S. national average (Code.org, 2015). Despite the need less than 2.4 percent of college students graduate with a degree in computer science. (Adam & Mowers, 2013)

Educational Robotics may be one way of getting more young learners interested in a qualification in coding. Robots should not only be seen as mere tools, but rather as tools to engage learners, having the potential to develop skills and new ways of thinking and learning (Burbaitė, *et al.*, 2013). Robotics is more than building robots - it is about combining motors and sensors, programming and solving real world problems and developing essential skills in the process (Gifford, 2014).

Demands and Challenges

These skills are however more demanding to teach and implementing a Robotics programme in a school poses a number of obstacles and challenges.

- One of the biggest of these is finding and training the appropriate teachers as Robotics has to be taught differently from most other subjects. Problems rarely only have one correct solution and it involves failing and trying again and again. Teachers as well as learners should embrace the process rather than only finding the right solution. Many teachers are intimidated by this new approach as they have rarely been trained to teach Robotics during their formal education. Without

motivated and well trained expertise it is a major challenge to successfully add Robotics to the curriculum (Gifford, 2014).

- Another need is the availability of well developed formal curricula as most institutions consider Robotics co-curricular and not as part of the formal school curriculum (Mubin, *et al*, 2013).
- As most Robotics programmes in schools are presented as co-curricular activities (Benitti, 2012) little data is available regarding the effects of Robotics on learners as part of a formal school curriculum. This implies that most learners are excluded from the opportunity to learn and master coding. Furthermore, Educational Robotics is normally used to teach science or IT related subjects.
- Teaching Robotics is time consuming and time tables have to be adapted to provide ample time for this activity.
- It also requires teachers to manage the costly sets and to keep the many small pieces together.
- Lack of a proper venue where the laptops, sets and and other resources can be permanently set up and stored, causes frustration with teachers and learners as it is too time consuming setting up a class before each lesson.
- Lastly there is a general perception that Robotics is difficult and that girls do not really enjoy it at as much as boys (Alimisis, 2013). These misconceptions needs to be addressed, minimised and/or erradicated.

The 21st Century skills are not only difficult to teach - it is even harder to assess as they are transcending across all subjects. It is however believed that individuals, organisations and nations that succeed in the 21st Century are likely to be those, in which this full range of skills has been developed in an integrated way (Orpwood, *et al.,* 2012). Therefore, despite the above mentioned obstacles, Educational Robotics may be one of the most effective and rewarding ways to supplement curricula and to introduce 21st Century teaching to develop skills, promote iterative learning and to understand and engage with technology in the process. Notwithstanding the challenges of implementing Educational Robotics as part of a school curriculum, the excitement and fun filled learning should be most rewarding for all involved.

Conclusions

The literature review revealed that educational Robotics is most commonly used to support the teaching of Physical Science and/or IT in schools. Very little evidence could be found of the possible positive effects of such a programme on the mentioned 21st Century skills.

In order to address this need for evidence, a longitudinal study will be conducted in selected CURRO schools. The development of these skills will be monitored in learners (11 -13 years old) before, during and after completing the Intermediate Phase CURRO enriched programme including Robotics. The

results of this study will be recorded, analysed and documented as a contribution to quantitative data on the development of 21st Century Skills in CURRO learners.

References

Adam, A. & Mowers, H., 2013. *Edutopia.* [Online] Available at: http://www.edutopia. org/blog/coding-new-foreign-language-requirement-helen-mowers. [Accessed 26 August 2015].

Alimisis, D., 2013. Open Question and new Challenges. *Themes in Science & Technology Education,* 6(1), pp. 63 - 71.

Anon., 2015. *Debating Europe.* [Online] Available at: http://www.debatingeurope.eu/ 2015/01/22/should-computer-science-be-taught-in-elementary-schools-in-euro pe/#.WKbYWzt97IV. [Accessed 10 March 2015].

Benitti, F., 2012. Exploringthe educational potential of robotics in schools:A systematic review. *Computers & Education,* Volume 58, pp. 978 - 988.

Burbaitė, R., Damaševičius, R. & Štuikys, V., 2013. Using robots as learning objects for teaching computer science. *X world conference on computers in education,* July.pp. 101-110.

Cape Town Science Centre, 2015. *CTSC Cape Town Science Centre.* [Online] Available at: http://ctsc.org.za/africa-code-week-2015-results-and-your-feedback/. [Accessed 14 October 2015].

Carnegie Melon, 2014. *Carnegie Melon Robotics Academy.* [Online] Available at: http://education.rec.ri.cmu.edu/educators/community/[Accessed 18 11 2015].

Claxton, G., 2012. *Building learning Power.* [Online] Available at: http://www. buildinglearningpower.co.uk/what_it_is.html.[Accessed 2015].

Code.org, 2015. *Promote Computer Science,* Seattle: s.n.

Collins , S., Mann , E., Kohnstamm , M. & Vesterbacka, P., 2014. *PRNewswire.* [Online] Available at: http://www.prnewswire.com/. Retrieved from http://www. prnewswire.com/news-releases/open-letter-to-eu-ministers-for-education-279101 521.html.[Accessed 4 February 2016].

Eguchi, A., 2010. *What is Educational Robotics? Theories behind it and practical implementation.* Chesapeake, Association for the Advancement of Computing in Education (AACE), pp. 4006 - 4014.

Eguchi, A., 2014. *Robotics as a learning Tool for educational Transformation.* Padova (Italy), s.n., pp. 27 - 34.

George, M. D. & Bragg, S., 1996. *SHAPING THE FUTURE New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology.* s.l.:DIANE Publishing.

Gifford, P., 2014. STEM's newest darling: Robotics. *The Boston Globe Magazine*, 2 October.

Gove, M., 2012. Digital Literacy Campaign. *The Guardian*, 11 January.

Griffen, P. & Care, E., 2012. *Assessment and Teaching of 21st-century Skills,* Melbourne: Springer.

Khanlari, A., 2013. Effects of Robotics on 21st Century Skills. *European Scientific Journal,* 9(27), pp. 26 - 36.

Mubin, O. et al., 2013. A Review of the Applicability of Robotics in Education. *Technology for Education and Learning,* Volume 1.

OECD, 2008. *New Millennium Learners: a project in in progress optimising learning: implications learning sciences research Education at a Glance 2014,* Paris: OECD Publishing.

Orpwood, G., Schmidt, B. & Jun, H., 2012. *Competing in the 21st Century Skills Race,* Ottowa: Canadian Council of Chief Executives.

Papert, S. & Harel, I., 1991. Situating Constructionism. In: *Constructionism.* s.l.:Ablex Publishing Corporation.

Piaget, J., 1952. The sixth stage: the invention of new means through mental combinations: The facts; Invention and representation. Conclusions. "Sensorimotor" or "practical" intelligence and the theories of intelligence: Associationist empiricism; Vitalistic intellect. In: *In The Origins of Intelligence in Children.* New York: International Universities Press.

Resnick, L. B., 1999. Making America Smarter. *Education Week,* 16 June.pp. 38 - 40.

Resnick, M. & Silverman, B., 2005. *Some Reflections on Designing Construction Kits for Kids.* Boulder, Association for Computing Machinery, pp. 117-122.

Saavedra, A. & Opfer, V., 2012. Learning 21st-century skills require 21st-century teaching. *Phi Delta Kappan,* 94(2), pp. 8 - 13.

Saygin, C., Yuen, T., Wan, H. & Akopian, D., 2012. *Design, Development and Implementation of Educational Robotics Activities for K-12 Students.* Pasadena, David Akopian - Publications.

Turner, P., 2009. *Why use Robots in Education. Educational Technology Solutions.* [Online] Available at: http://www.tribotix.com/EducationInfo/WhyRobotics.htm [Accessed 22 January 2015].

Tyre, P., 2013. *Smithsonian.com.* [Online] Available at: http://www.smithsonianmag.com/innovation/is-coding-the-new-second-language-81708064/ [Accessed 19 February 2015].

Veselovska, M. & Mayerova, K., 2014. Pilot Study: Educational Robotics at Lower Secondary School. In: J. Abascal, S. Barbosa, M. Fetter & T. P. Gross, eds. *Human-Computer Interaction – INTERACT 2015.* Vienna: Springer.

Wagner, T., 2008a. *The Global Achievement Gap.* 1 ed. New York: Basic Books.

Wagner, T., 2008b. Rigor redefined. *Educational Leadership,* 66(2), pp. 20-24.