IB extended Essays

Introduction

Over the last decades, rapid advancements in technology have allowed us humans to reach new heights: from the first car, to the first airplane built by the Wright brothers in 1903, to the Moon landing just 66 years later. Mankind has always had a spirit for innovation, exploration, creation and, recently, automation. The idea of self-sufficient, self-aware, sentient machines and computers has always fascinated us; the idea of artificial intelligence has been around since the ancient Greeks: they had imagined an automaton named Talos, who was tasked with protecting Europa (residing on the island of Crete) from attackers and invaders. The mathematical and technological concepts of artificial intelligence were not explained until Alan Turing developed the theory of computation, (Sipser, 2013) according to which a machine, by using different combinations of simple symbols (in this case 0 and 1, power and no power, on or off) could conceive any possible act of mathematical deduction (in other words, make decisions based on the input it receives).

The idea that computers and machines can simulate processes of formal reasoning and decision making was theorized in the Church-Turing thesis, developed by mathematicians Alonzo Church and Alan Turing, based on the lambda calculus mathematical function designed by Alonzo Church. The specific field of AI research was born at a Dartmouth College workshop, in 1956. The pioneers and creators of this field were Allen Newell (Carnegie Mellon University, CMU), Herbert Simon (Carnegie Mellon University, CMU), John McCarthy (Massachusetts Institute of Technology, MIT), Marvin Minsky (Massachusetts Institute of Technology, MIT) and Arthur Samuel (International Business Machines, IBM). Along with their students, they created programs that could play checkers (draughts) that could reportedly beat average human players by 1959, programs that could solve algebraic problems, that could prove logical theorems, and some that could even speak English. This prompted the Department of Defense of

the United States to fund AI research laboratories both domestically and around the world, including at MIT (Heather Knight, 2006) . They underestimated the difficulty of developing efficient and effective AI programs/machines, and funds were cut in 1974. In the early 1990s, using AI for data mining, logistics, diagnostics (medical expert systems) created ties with other

4areas of research such as economics, statistics and mathematics which boosted AI back up to one of the top fields of research.

In the following years, artificial intelligence became real, though it was applied in a limited amount of fields; for instance, the chess-playing computer Deep Blue, developed by IBM in the late 1980s/early 1990s, beat the reigning world champion Garry Kasparov on the 11th of May 1997. It did this through a method known as brute forcing: evaluating every possible combination of moves based on the current position of the pieces on the board before actually making the move. It won by exploiting a mistake made by Kasparov in an opening move. This was a turning point in the field of AI and computing. Advancements in computing power, the reduction in infrastructure costs and material costs, the development of machine learning and deep learning, as well as that of artificial neural networks made AI research and application extremely common and valuable; in 2011, Apple released the iPhone 4S, and with it came Siri: perhaps the most famous AI assistant eve; it holds about 48% of the total market share in the field of AI assistants (Kinsella, 2018). Siri uses advanced machine learning algorithms and capabilities to adapt over time to its owner's preferences and habits. Smart home devices based on AI are also becoming quite common, with over 136 million units owned worldwide and a household penetration rate of 9.5% predicted to rise to 22.1% by 2023 (Smart Home, 2019). Google Home and Amazon Echo are two examples of these. They utilize voice recognition algorithms based on speech patterns and accents in order to fulfill the queries input by the user(s). They, much like Siri, adapt over time: active hours, passive hours, common requests, names, speech cadences and other data is mined and used to adapt the algorithm. Nowadays, AI has made its way into the physical world: some robots equipped with AI software can be programmed to execute functions and complete tasks and can also learn from their experience. The application of robotics in the real world is becoming almost ubiquitous:

automated factories operated almost entirely by robots; autonomous/semi-autonomous drones sent in dangerous areas to rescue people or retrieve sensitive information, or simply used in everyday life to take bird's eye view photos and videos of the environment. It is hard to deny the

5fact that we are becoming increasingly attached to technology with every new advancement we make (Human Dependency on Technology, n.d.). This begs the question of the inclusion of such technology in education: there are schools of thought that believe that increasing the presence of technology in education could increase our dependency, while others believe that, given the current trends, it is better to learn and adapt to the new world rather than remaining set in one's ways. The latter is the more popular of the two; the study of robotics and AI is being integrated into schools all around the globe and at various levels of education ranging from primary school all the way to Master's Degree courses and Doctorates.

Technology in education

The use of technology in education has become the norm in the last decade: most schools teach courses such as computer science and ICT/ICT related subjects; most schools have computer labs, and most schools make use of the Internet to communicate with parents, students and other schools. However, the rapid advances in technology that have taken place in the same decade are changing the playing field more than some may expect. Several countries and unions of countries have put in place/are putting in place programs that encourage the use of technology and the teaching of technological skills: in January 2018, the European Union adopted a Digital Education Action Plan that includes 11 initiatives that support the use of technology and the development of digital competence in education. The plan has three main priorities:Making better use of digital technology for teaching and learning, which aims to improve upon the accessibility and availability of technology in schools and other educational facilities by enhancing access to the Internet (focusing on areas with poor access) and providing a framework that will be used to issue "digitally certified qualifications and validating digitally acquired skills";Developing digital competences and skills, which aims to develop a Europe wide network for online learning, using virtual campuses, cultural exchanges and blended mobility; Improving education through better data analysis and foresight, which will use AI based

learning analytics pilots in education and improve the learning experience over time. One of the

5

6fields of technological education/digital skills that is being promoted with considerable urgency is the study of Artificial Intelligence, robotics, and the relationship between the two.

In many modern schools, teaching robotics at various levels has become very common in the last 5 years (Eguchi, 2013). From basic Lego Mindstorm robots that can pick up items and change direction when they see a specific color, to more complex machines capable of learning basic activities by themselves using machine learning, AI based classroom resources are slowly becoming the “present” of education rather than the future. The “AI revolution” is truly global: robotics is a field taught in countries all over the world by various schools and institutions; the I.T.I.S (Istituto Tecnico Industriale Statale) establishments in Italy, to secondary and primary schools in the United Kingdom, through international schools in China (TECHNOLOGY & INNOVATION, n.d.) and now Africa (Sandra, 2018). It is believed that the study of robot-building and programming can spawn very practical skills in students such as logical thinking, analytical skills, problem solving and solution-building.

The most evident advantage of teaching robotics in schools is that students are more likely to develop interests in STEM classes and develop an interest in technology and science, which are becoming extremely valuable in today’s society. TheScuola di Robotica(Laboratori e corsi per studenti, n.d.) initiative present in Italy offers robotics courses in schools, as well as independent workshops in order to learn the basics of coding, programming and following flows of logic and reasoning. They state that by integrating robotics in an interdisciplinary curriculum, students will build knowledge related to science, math and computer science that will be crucial when it comes to understanding reasoning skills used in other fields such as linguistics and philosophy, among others. The study of robotics is being used to teach students about programming and coding, skills that are becoming more and more valuable as the job market shifts more and more towards high-tech and tertiary sector jobs. Many educational robot packages have a programming interface with which students can modify the robot’s actions (e.g. the Mindstorms EV3 software, made to be used with Lego EV3 Mindstorms robots), which plays a part in teaching students about flows of logic and thinking skills. Teaching coding using robots

7is more gratifying for students, since their actions have consequences on a physical object in the real world, rather than a virtual program on a computer screen. This, as mentioned previously, not only helps students learn the skills directly related to programming, but also problem solving skills, algorithmic thinking and logical thinking (Barak & Zadok, 2007). As students progress through their studies of robotics and programming, they can decide to use text based coding rather than GUIs to program their robots, which will further develop programing skills. The EV3 software allows the use of RobotC, based on the C programming language. This is possible with some tweaking and a firmware installation on the robot's control unit.

Students will also develop the ability to make accurate predictions based on code they have written, processes they have designed, or simulations they have created and run. This will make it so that students will develop different ways of thinking and will acquire higher level cognitive abilities that will be invaluable in their careers in the future. In primary and lower secondary schools, robotics can be used to teach children the importance of collaboration and teamwork, as well as communication skills. TheSant'Anna School of Advanced Studieslocated in Pisa offers higher level robotics courses for students pursuing Master's degrees and Doctorates. These courses go into depth about the implications of robotics and AI on the real world: economic implications, social and ethical implications as well as laws, regulations and policies related to the development of the field. Universities and colleges around the world are offering more and more courses on artificial intelligence and advanced robotics: countries such as the United Kingdom, Macedonia, the United States and Italy are beginning to encourage engineering and computer science students to take courses that involve the study of artificial intelligence.

Effect of robotics on students worldwide

In order to see the level to which teaching robotics affects students and the areas in which this leads to improvement, I sent out a survey to Design and Technology and robotics teachers from different geographical locations so as to get an idea of how economic development, technological development and culture affect the way in which robotics is taught and the opinion

8of the public on this subject. My interviewees are Mr. Clement Low the pedagogy director at Nullspace Robotics (an institution that provides technology education. They provide programming and robotics classes to various schools within Singapore and internationally, as well as theirCentre for Robotics Learning.), and Mr. Carlos Leon, a Design and Technology and robotics teacher from Colombia, currently teaching internationally at Ecole Ruban Vert. The questions I asked were related to their approach in teaching robotics, the advantages of learning programming and robotics, and the way their respective communities perceive the increased emphasis on technology and programming in education. The answers I received were thought-provoking and not necessarily what one may expect. I inquired about the approach they took in the teaching of robotics: using abstract models and applying them to the real world was the answer in both cases, which is to be expected considering that programming is a mostly abstract concept that affects the real world. The way teaching robotics and systemic thinking affected their students was mentioned: the consensus was that systemic thinking skills allow students to make complex relations between physical mechanisms and algorithms, and also allows them to more easily use their pre-existing knowledge to arrive at conclusions. They also commented on changes in the way their students approached problems, mentioning that changes were not radical or entirely obvious, but were significant enough to make a change. The fact that robotics is an optional class in many cases makes it so that students with an incline for science choose to take it, but if the class is designed properly and made more appealing to other students, they will benefit from improved skills in mathematics, research and interestingly language (likely due to the analysis of programming languages, which would make it easier to understand the way their own language works). The perception of robotics by their respective communities was also mentioned in their answers; students see robotics as a sort of game, their parents see it as “futureproofing”, and many teachers see it as more work unrelated to the curriculum. Since STEM subject require a different approach to learning (practice, repetition and good logical basics), and this approach is sometimes limited by teaching curriculums. This means that students cannot fully benefit from their STEM courses, and that robotics could be invaluable in helping them learn and grow. The way the general public (not necessarily the local communities) perceived the teaching of robotics has changed: it is no longer just an option to develop research

9skills and technical skills, it is now more popular as a learning model (systemic thinking, algorithmic thinking, approaching problems in a more logical way). The increasing popularity of robotics made it so that international competitions became more common, further driving the popularity into an upward spiral. Competitions such as the FIRST Global Challenge are proof of this (THE 2017 FIRST GLOBAL CHALLENGE, 2017).

In short, robotics seems to be proving extremely valuable in boosting performance in school, both in STEM subjects like math and sciences and non-STEM subjects such as languages and history. Other countries have started implementing robotics courses that provide students with skills necessary to compete at an international level. One such country is Kyrgyzstan; in collaboration with the Aga Khan School and Aga Khan Lycée, a program called Junior First League robotics was put in place in late 2017/early 2018. The JFL is a 9-week program that aims to teach students about STEM subjects and various world issues such as recycling and waste management in a fun and engaging way. The program was a success, and thus became a regular after-school activity in both establishments. According to their website, over 20 students from each school are benefitting from this initiative (FEATURE: Robotics Programme sparks innovative learning in Central Asia, 2018). Several volunteers from Canada went to Kyrgyzstan and Tajikistan to provide training in various subjects/courses. One of these teachers, Sobia Makhani, was asked to train teachers in Kyrgyzstan. She trained teachers from government schools, as well as teachers from AKES schools (Aga Khan Education Services). The training session lasted 11 days and involved 30 teachers. She participated in the JFL program and provided training to students as well, with a more practical course for 32 students. The regional head of education for AKES, Aziz Batada, claims that“teachers and students who participated in last summer’s robotics and upgrading programs have commented on their wonderful learning experiences, with many teachers developing new approaches to their own teaching practice. Students were motivated to further develop their English language proficiency and Math problem-solving competencies, resulting in increased self-efficacy when applying to English speaking Universities in the region, including the University of Central Asia and Aga Khan University.”(LEGO Robotics, English Upgrading and Math Numeracy programmes delivered in

10Tajikistan, 2018). Kyrgyzstan was present at the FIRST Global Challenge international robotics competition in 2017 and 2018, and obtained good results for a country that only recently started developing robotics programs and was competing internationally for the first time, placing 87th in the 2017 Global Challenge (THE 2017 FIRST GLOBAL CHALLENGE, 2017), and 158th in 2018, narrowly losing out to Team Australia (THE 2018 FIRST GLOBAL CHALLENGE, 2018). This goes to show the impact that robotics can have in mostly rural countries such as Kyrgyzstan and Tajikistan. Admittedly, the sample size is relatively small, but the impact that this program has had was too positive to be dismissed entirely.

Effects of robotics on students with disabilities

The use of robots in education is not just limited to programming and developing logical thinking in students; robotics can also be used to promote inclusivity in classrooms and help students with disabilities and/or learning deficiencies. Some schools have implemented programs involving robots for children with autism. In 2013, researchers from the University of Birmingham, in collaboration with researchers from the University of Valencia and ACER (Autism Center for Education and Research), developed “a suite of intelligent behaviors” (Robots in the classroom for children with autism., 2013) for the Nao robot developed by SoftBank robotics (formerly known as Aldebaran robotics), a French robotics firm whose aim is to develop robots that can be used in as many fields as possible; for instance: research, education and healthcare, as well as private use in households. The aim of the project is to help children with autism to recognize emotions and improve social skills and emotional intelligence. Nao and other robots like it are used in more than 10,000 schools worldwide to help children with autism (Williams, 2018) . They are used to develop social intelligence and reduce anxiety in a classroom setting, which is something that children who fall under the spectrum offer suffer from. Robots are used for this purpose because, unlike humans, they do not change facial expression or show emotions indirectly through body language and tone of voice, which makes them the ideal candidate for working with children with reduced social and emotional abilities. Children with autism greatly benefit from consistent and unchanging environments, and robots such as Nao offer just that. Reports indicate that children who regularly interact with Nao achieved an

11increase of 30% in social interactions and improved verbal communication when a robot was present (Falconer, 2013). The same report found that this increase was mirrored in interactions between the children and their parents and teachers. Ben Waterworth, a teacher at Topcliffe School in the UK says that“The ASD [autism spectrum disorders] children benefit a lot from using Nao. You see a different side of them when they are working with him. You see them comfortable with Nao, responding to him and I just think these are features you just would not see with a human. They would be more shy with that person, they would be more withheld or withdrawn, whereas with Nao they are more outgoing."(Falconer, 2013). This shows the value of robots in the classroom; students who fall into the autism spectrum benefit massively from their use in their education. Robots are also used to teach students with autism about STEM concepts such as motion and algebra in a more interactive way, which is highly beneficial to children with autism. For instance, Bee-Bots (robots specifically designed to teach problem solving and directionality to children) are used in teaching problem solving in math: the robot lands on a problem, and the student has to solve it. If the solution is correct, the robot moves onto the next problem. This makes it easier to grasp abstract concepts like basic algebra and mathematical problems. In the realm of physics, a robot known as Sphero is made to run through a maze while adding weight modules to improve friction. This helps the students get a better understanding of concepts such as motion and direction by providing a physical object that can be interacted with rather than having a virtual object move on a screen, or simply a written problem (Williams, 2018).

Conclusion

To conclude, I believe that robots and robotics should be a tool used in every classroom in every school. The teaching of robotics and programming helps students develop important skills such as critical thinking, logic, problem solving and creativity while providing a physical object that can be manipulated in the real world rather than an abstract computer program. The modern job market requires increasingly high levels of IT proficiency due to the evolution of technology, and thus children who study robotics will be more prepared for the future and life outside school. Their use in classrooms as a learning tool has proven invaluable when it comes to

increasing inclusion; children with autism benefit greatly from the consistency and predictability

11

12of robotic behavior, which can bridge the gap between children with autism and those without, and may finally eliminate the stigma against the spectrum