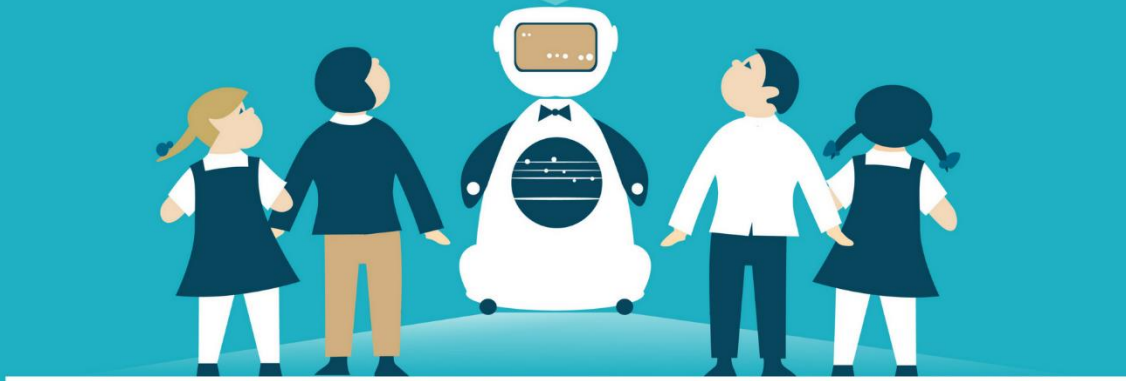


Why Teach Robotics?

Exploring the potential applications of robotics in a classroom setting



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Over the last several years, interest in Educational Robotics has flourished as teachers and schools embrace the potential of robotics to provide hands-on and engaging ways to teach design, engineering and technologyⁱ. Also seen as a way to introduce and incentivize students to pursue careers in Science, Technology, Engineering and Math (STEM) fieldsⁱⁱ, the use of Educational Robotics is now more affordable and robust, thanks to all of the increased attention and investments given to the medium. The resulting technological advances greatly contribute to the accessibility of this toolⁱⁱⁱ. In fact, robotics are now considered by some to play a similar role in the classroom as computers once did, beginning with the early 90's and the introduction of the use of CD-ROM's and Microsoft PowerPoint in classrooms^{iv}.

With Educational Robotics' growing presence comes important questions. What are the best uses of this new and exciting tool? How can we establish best practices? How do we conceptualize the purpose of Educational Robotics in the classroom? These questions may be more complicated than they seem at first glance. And answering them may first produce more questions than when we began. For example, do students use educational robotics as a medium to display their ideas and thinking, or do students create ideas and thinking by interacting with the medium? Are Educational Robotics a way for students to show their competency, or are they an infrastructure upon which students build new competencies^v? Perhaps considering an aspect of computer use in the classroom can help to shed more light on the topic.

A medium can have a different scope based on its application. Painting can be seen as a medium, one that can be used to paint a fence or the Sistine Chapel. The versatility of computers as a medium has, arguably, even greater enormity; a computer can be used in the classroom with a very limited scope, either as a calculator or as a word processor, yet also seen and embraced as a powerful means of communication all its own. As Mark Guzdial has pointed out, computers can be understood as a modern form of Gutenberg's printing press^{vi}, and as a way to think about other domains. As such, technologies like computer modeling and algorithms have had a significant impact on our understanding of the fields of math and science^{vii}.

What then, is the scope of Educational Robotics? Educational Robotics can be used as pre-built objects that perform very specific tasks, while some Educational Robotics systems allow students to become active participants in designing their learning – as well as creators of computational artifacts, instead of passive users of devices that others have made for them^{viii}. This presents a unique set of opportunities for teachers. Educational Robotics thus becomes a medium providing students the opportunity to exercise their voice and choice in learning and engage them not only in problem solving, but also in problem finding, problem construction, problem analysis, and the planning and monitoring of problem-solving efforts. Educational Robotics then, becomes something much bigger - a medium to prepare students for the complexity of the challenges awaiting them as they prepare for jobs that currently do not exist^{ix}, and also a way to incorporate other valuable dexterities (e.g. communication and collaboration) belonging to the broader spectrum 21st century skills.

The efforts by schools to implement the medium of Educational Robotics seem to have produced as many manifestations as different motivations driving the initiatives. Some schools use this tool as an integrated part of a stand-alone computer science or STEM course, while other schools

use this modern solution to supplement traditional subjects. Still other schools use them as after-school activities that then capitalize on the motivational effects of “gamifying” and competitions to raise student participation and engagement. In the same manner that schools learned not to restrict computers’ use to expensive calculators, the use of Educational Robotics should not be limited by perceived constraints.

Worth exploring in detail are the following uses for Educational Robotics:

- To understand our world
- To teach integrated STEM education in novel ways
- To teach Computational Thinking
- To become comfortable with iteration and learn from failure
- To be exposed to and learn about the jobs of the future

To Understand Our World

Science is the explanation of the natural world. Students that are scientifically literate are able to understand both the concepts and practices of science. Therefore, teaching students science offers them an opportunity to understand the world they inhabit. This is why high school curricula all over the country includes subjects like Astronomy, Biology and Chemistry. But what of Robotics? Clearly, robots are prevalent in our everyday lives, and that prevalence is increasing^x. Improvements in the technology associated with robots, has led to exponential growth of computation power and data storage^{xi}. This has resulted in robots capable of learning and making decisions informed by the experiences of other robots. Robots are no longer machines that perform simple functions. Additionally, the rising demand for robots and robot technology cuts across industries. Yes, factories are homes for many robots, but robots are also now more common in educational and entertainment settings. It is quite possible that in the near future robots are assisting many members of the elderly population live independently in their homes, thus creating a new field of “co-robots.”^{xii}

Schools, rightfully, teach about planets and stars that exist light years away...but not about the technology that many interact with on a daily basis. This is a challenge, but also an opportunity. Education drives science and innovation. The study of Biology continues to lead to better treatments and the eradication of sicknesses and disease^{xiii}. If Robotics became a core academic subject in our schools, it could potentially have a similar impact.

To Teach Integrated STEM Education in Novel Ways

Educational researchers suggest that teachers often struggle to make connections across STEM disciplines^{xiv}. This presents a challenge to schools as the Next Generation Science Standards feature cross-cutting concepts spanning different scientific domains. Therefore, students will have difficulty transferring concepts oftentimes taught in isolation to the integrated context they will see on assessment exams. Another unintended consequence of teaching scientific concepts in isolation, is its tendency to create a learning environment where students become disengaged. The authentic examples they see of science in their daily lives has deep integration across STEM

disciplines as opposed to singularity. The goal of STEM education is to help students organize information within and across disciplines, to be able to identify and reason with deep, structural similarities and patterns within this information; the culmination ideally resulting in the ability to apply this organization of knowledge to complex situations and problems in everyday life^{xv}.

Educational Robotics can help address these challenges by functioning as a facilitator for teachers and schools as they look to organize STEM instruction. Since the scope of Educational Robotics moves far beyond a toy that can be given simple instructions, classrooms that utilize Educational Robotics can offer students robust engineering and programming challenges.

One example from an intermediate robotics curriculum^{xvi} asks students to create a scale model working prototype of an automated parking garage. The engineering challenge of the activity demands that the prototype must be structurally sound and contain at least four parking spaces. From a programming standpoint, the system must be able to identify how many cars and available parking spaces are currently in the garage, the location of each car, and use a color-coded system to access and deliver the car back to the owner. Successful solutions will require the use of at least two sensors (or input devices). Throughout the activity, students will have to investigate and troubleshoot both hardware and software solutions, building knowledge across physical sciences, engineering and computer science, while organizing this knowledge in order to create the functional prototype of an automated parking garage system. Building an automated parking garage prompts students to create and then troubleshoot a solution that has both hardware and software components. Additionally, because of the use of sensors, students have to be able to analyze and interpret data. The organization of all of these components together, in order to then create application that addresses a real-life scenario speaks directly to the goals of an integrated STEM education.

To Teach Computational Thinking

During the past 10 years, Computational Thinking has grown in popularity and inclusion within K-12 classrooms^{xvii}. Computational Thinking is included as part of the Next Generation Science Standards and as an essential part real-world math and science. Computational Thinking is widely considered to be an integral part of any STEM classroom^{xviii}.

A primary motivation for introducing computational thinking practices into science and mathematics classrooms is the rapidly changing nature of these disciplines as they are practiced in the professional world.”

(BAILEY & BORWEIN 2011; FOSTER 2006; HENDERSON et al. 2007)

“In the last 20 years, nearly every field related to science and mathematics has seen the growth of a computational counterpart.”

(WEINTROP et al. 2017)

The increase of the popularity of Computational Thinking as a concept, both in and out of schools, has led to schools attempting to find effective tools to integrate and teach computational thinking to their students. A corresponding goal has been to broaden participation in the classes - particularly computer science - that delve heavily into computational thinking; addressing the gender gap in this subject area has also been a consistent goal. Currently, girls account for approximately half of all AP test-takers, but account for only 25% of those taking AP computer science classes^{xix}.

Educational Robotics can be an effective tool to teach computational thinking while also helping to broaden participation goals.^{xx xxi} Recent advances in Educational Robotics have lowered costs and increased ease of use, making them more accessible to students and progressively turned to as a reliable way to learn abstract STEM concepts. As such, the connection between computer science and robotics is clear; students have the ability to program their robots to perform complex tasks, both in the classroom and on competition fields. While the performance of complex tasks may be the end, the means involve decomposing these tasks into smaller parts and then iteratively building them together to create a solution. In classrooms, the scaffolding of that process is vitally important, and once again, Educational Robotics can be effective in facilitating both the decomposition and scaffolding of complex tasks. As a result, robots can be an effective tool to teach computational thinking, as the initial evidence shows.^{xxii xxiii} The effective teaching of computational thinking also results in the ability to apply computational thinking in different domains. The ability to effectively teach generalizable computational thinking skills, while simultaneously offering ways to help diversify the students that enter these fields, makes Educational Robotics a significant contributor to the integration of computational thinking into schools and the Computer Science for All movement.

To Become Comfortable With Iteration and Learn From Failure

Engineering design and the scientific method are related phenomenon, but contain important distinctions. In science, there is an emphasis placed on finding general rules that describe the actions of our world and universe, whereas engineering involves finding solutions to a particular problem that satisfies all of the constraints contained within that problem^{xxiv}. Some have summarized this distinction with the saying “scientists investigate but engineers create”^{xxv}. When considering the creative process, we must recognize its often significant dependence upon iteration.

Multiple iterations are crucial to engineering ideas and activities that are designed to achieve certain objectives, whether meeting/exceeding customer expectations or participating in a competitive challenge. The required multiple iterations inherent to Educational Robotics activities have been recognized as capable of maintaining student interest and sustained engagement.^{xxvi} Also, the composition of the robotics kits themselves, with many different pieces that can be quickly assembled and then disassembled, fosters an attitude of iteration. Because multiple iterations often address the important life lesson of “try, try again,” students benefit immensely from learning that “failures” can be embraced as all part of the process. Another broadly applicable lesson borne of a more abstract look at the ancillary benefits of the tool is Educational Robotics’ tendency to present multiple solutions to even the simplest challenges. What could broaden a student’s horizons more than realizing there are indeed multiple solutions to the same problem? We’ve seen this produce interesting benefits: an increased likelihood in students requesting feedback from teachers and a higher likelihood of students understanding what they are learning as important.^{xxvii} The benefits only compound from there - teachers engaging students in this way can lead to higher student self-efficacy, the key element leading to that greater willingness to learn from failure.^{xxviii}

To Be Exposed To and Learn About the Jobs of the Future

Change, our only constant, is no stranger to the nature of work. In 1900, approximately 40% of the American workforce worked on farms. Today that number is only 2%.^{xxix} If that seems too long ago, too far-removed, consider that as recently as 50 years ago, the average worker did not need to read or write during their workday.^{xxx} The tides of today can be epitomized in a widely-read and discussed 2013 study by The University of Oxford Department of Engineering Science, which estimates that 47% of current jobs are at risk of being lost to automation.^{xxxi}

An important distinction of the current concerns, as opposed to the normal churn of job destruction and job creation of yesterday, is “job polarization.” The term applies to the hollowing out of employment opportunities, meaning, there is high-demand for high skill and low skill jobs, but opportunities for middle-skilled and middle-wage jobs have declined.^{xxxii} This significant problem can be traced to the automation of routine work, and the answers involve acknowledging the inevitability of automation by working creatively towards augmentation. The businesses riding these wave successfully are those responding with flexibility and fluidity, learning to work with technology rather than running from or rebelling against its daunting presence and impact.^{xxxiii} As educators, it is vital we too respond creatively, searching for innovative solutions to the uncertainty of the future. It is up to primary and secondary education systems to acknowledge the realities on the horizon, and teaching relevant and valuable skills, which in the current case, may mean things computers are simply not good at. These include creativity, interpersonal skills, and problem solving, all skills that can be cultivated by a refined use of Educational Robotics.^{xxxiv}

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