Foreword

In the early 1920's a young Czech playwright, Karel Čapek, was at work on a play. Up to that point, he had minor success as a journalist and a political critic, and this was his first foray into writing for the theater. It was a play based in the future, a piece of science-fiction long before science-fiction had become an established genre. In this somewhat dystopian play, Karel described a day at a factory populated by artificial people, created from synthetic organic matter, who took care of most of the work typically done by humans. Since these beings were crucial to the story he was trying to write, he needed to find an appropriate name to describe them. He struggled to devise a name for these workers, initially considering calling them *labori,* from the Latin *labor,* for work. Not satisfied with that neologism, he turned to his brother and frequent collaborator, Josef Čapek, for inspiration. Josef suggested the word *roboti* (which also meant labor or hard work in the Slavic languages). Karel liked the suggestion, thus, the word *roboti* ended up in the title of his play: RUR or *Rossumovi Univerzální Roboti*. The play premiered at the prestigious Prague National Theater on January 25, 1921 to positive reviews, and was soon translated into multiple languages and performed across the world. It premiered in New York City in October 1922, where none other than Spencer Tracy (the soon to be Hollywood superstar) played a word-less robot. Karel went on to write more plays, stories, and other politically engaged works in favor of free expression and in opposition to fascism and communism. He was nominated seven times for the Nobel Prize in Literature, though he never won the award. He died at home of pneumonia in 1938 just before he was about to be captured by the Gestapo for his anti-fascist views. His brother, the person who actually coined the word *roboti*, was not as lucky, and died in a concentration camp.

We must recognize that despite his literary fame when alive, Karel Čapek's work is barely remembered today. And the one thing he is remembered for is coming up with the word *robot.* Though there had been earlier descriptions of human-like automatons, and Čapek's creations are more akin to what we would now call androids, the word, robot, has stuck—particularly once it entered the English language in translation as *Rossum's Universal Robots.*

Robots soon become a mainstay of science fiction, whether in books or in cinema, for humanoid machines that can do various tasks for humans. But robots are no longer just fiction. Though they may not (for the most part) look humanoid, programmable mechanical devices that perform tasks without the aid of human interaction are omnipresent in our world today. From the Roomba vacuums zooming around our homes, to the machines that automatically harvest corn; from robotic hands that help surgeons conduct intricate surgeries, to the dancing robots created by Boston Dynamics—robots are already an important part of our present, and even more so, of our future.

The science and technology of robotics design, manufacturing and application has grown by leaps and bounds over the past decades. This revolution has been fueled by developments both in software (particularly machine learning and Artificial Intelligence) as well as better understanding of the mechanics of movement and object manipulation. In that sense, robotics is almost a perfect encapsulation and convergence of ideas in the STEM (science, technology engineering, and mathematics) disciplines.

As we look to the future it becomes increasingly important that we understand the role of the STEM disciplines in defining and determining our future. And robots, by extension, will be an important part of this. Thus, since education is inherently about preparing our next generations for the future, we must consider ways to help youth in our schools and universities become more knowledgeable about what these technologies mean for us.

That said, one of the challenges of such technologies is their opacity—by which we mean that they are often "black boxes," with their inner workings hidden from us. By contrast, the inner workings of most industrial age tools (such as mechanical machines and clocks) were visible to the naked eye. The opacity of newer digital technologies often makes them appear impervious to human intervention and meaning making.

Therefore, it is unsurprising that most depictions of robots and their influence on our lives, even starting with Čapek, have been dystopian. Science fiction has often picked up on fears about the potential wrong directions or dystopias brought about by unknowingly diving into technological phenomena with our eyes wide shut. We rarely have any understanding of the inner workings of complex digital artifacts, or any sense of how things are constructed and come together. The result of this lack of understanding is often a sense that technological phenomena are often happening *to* us. There is a lack of awareness, from a critical perspective, about how such technological tools are engineered to shape our lives or behaviors, both for better and worse. People are often left feeling that they simply must trust in the tools to work properly and to shape society in our best interests, rather than feeling like they have an actual stake in the game. At both individual and societal levels people need a better understanding of STEM, developed through the use, construction and manipulation of hands-on technological knowledge—such as robotics—to make the opaque workings more transparent.

There are social, ethical, and pedagogical imperatives to equipping our next generation of citizens to be more informed and thoughtful about how these technologies work. To understand how these tools function, we must appreciate and recognize that they are human made creations that can be re-made, re-imagined, and re-designed to better serve broader humanistic goals. By developing STEM through robotics, students have the opportunity to explore the makings and workings of tools that are shaping our world, and which will certainly shape our future. Whether or not they go into the field of robotics, learners need opportunities to both build STEM knowledge through engaging modalities like robotics, and to develop that sense of critical awareness of the inner workings of technologies.

A strong societal drive for STEM advancement and learning goes back to the start of the 'space race' that developed between nations back in the 1950s and 1960s. But since that time, the need for STEM development has grown and proliferated internationally. Nations often judge themselves in education by comparing STEM scores on tests like PISA. There is also much discussion and concern over the forecasted lack of STEM workers to meet the demand of the future. However, many of discussions around STEM would do better to acknowledge the importance of engaging students in applications that are not only driven by workforce needs—but by STEM learning that actively connects to their desire to construct, to inquire, and to delve into exciting and constructive modes of thinking, making, and learning.

That is where this book's work on robotics learning through STEM can be so powerful. It delves more deeply into work that is both practical and scholarly, driven by theories such as TPACK, yet also grounded in classroom practice—both showing what creative and powerful robotics STEM learning can look like, and rigorously investigating its outcomes. Too often when we see instances of robotics learning in classrooms, it is either in one-off examples of studies published in a single article or chapter, or in specific practical examples of an interesting lesson. This book offers a more comprehensive exploration of the topic in a more in-depth, long-term, and thorough approach. The authors take us through their multi-year journey from its inception through the development over time. They ground their investigations in foundational theoretical frameworks, such as design-based research, technological pedagogical content knowledge (TPACK), and the 5E instructional model. This both situates their work within educational research and extends it as well through the design of examples, lessons, and cases to present a picture of this long-term STEM learning robotics project. The concrete, detailed learning elements in many chapters have practical resonance for educators as well as the investigation of research outcomes. This book, in that sense, occupies a unique place in its presentation of STEM robotics learning. It offers much to both educational practitioners and researchers alike to help in developing teachers and learners who can engage and inquire within STEM in hands-on, understanding-driven ways.

This work is essential, if for no other reason than to prevent the dystopian vision of Karel Čapek (and many others) from becoming reality. It is a deeply humanistic effort and the authors of this book should be applauded for taking on this challenge through a multi-year, multi-faceted, and pedagogically impactful research program.

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