Robotics integration to create an authentic learning environment in engineering education

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***Abstract*—Authentic education, which connects the lessons with students' real-lives and their prior knowledge, has the potential to create meaningful learning environments in which students see the lessons as meaningful, useful, and relevant. However, in undergraduate engineering programs, subject matter are usually irrelevant to students' real-lives. Such disconnections might demotivate students, resulting in a lack of qualifications for entering 21st century job market. I, as a robotics instructor, witnessed that robotics has the potential to create motivating authentic learning environments for students who are studying in the field of electrical and computer engineering. This study aims at inspiring other educators to integrate robotics into their teaching activities in order to contextualize the typically decontextualized subject matters in undergraduate electrical and computer engineering programs.**

I. Introduction

Twenty-first education systems not only should create environments in which students connect ideas to each other, but also should simulate real world situations and provide an opportunity for students to experience problem solving, social skills, and attitudes useful in real world situations. Authentic education is a type of education in which "materials and activities are framed around 'real life' contexts in which they would be used. The underlying assumption of this approach is that material is meaningful to students and therefore, more motivating and deeply processed" [1]. The focus of authentic education is to employ interdisciplinary ways in order to solve real-world problems [2] and to help students in the process of learning, by creating an environment in which they "see the lesson as meaningful and relevant" [3].

In engineering programs, undergraduate courses do not usually provide students with an opportunity to solve meaningful real-life engineering problems that are beneficial for their lives and societies. Students are usually conditioned to take some theoretical courses, do some assignments and projects, take exams, and then forget the subject matter they studied. Although undergraduate students are sometimes asked to do some projects and experiments, they are not usually involved in authentic experiments. Therefore, they do not usually get involved in meaningful motivating engineering projects that have the potential to help them develop their creativity, problem-solving, and innovation skills. When I was studying in the field of electrical engineering, I witnessed that many undergraduate students were struggling with learning coding and electronics. Also, many of the courses were perceived by my classmates as unnecessary and useless courses; many of us wondered about the need to take such unnecessary courses. Many of my friends, who are now engineers, still blame the education system for teaching them so-called *useless courses*. The main reason for this challenge is the fact that the subject matter was "divorced from real experience" [4], where students were not engaged in authentic learning experiences. In fact, what is usually lacking in undergraduate engineering programs is authentic tasks in which students feel the satisfaction of accomplishing something real. Authenticity, which includes clear applications of learning experiences in the real world [5], provides students with an opportunity to create and develop innovative solutions for real problems, share their findings with the world, and see their activities as something beneficial.

I also witnessed that many of my friends had difficulties for entering job market, although they graduated with excellent GPAs. On the other hand, some newly graduated students who could find a job lost their job after a few months. The main reason for the difficulty in finding a job and keeping the positions was a lack of required skills and qualifications. In fact, while there is a huge difference between learning about engineering principles and learning to be an engineer [6], students in undergraduate engineering programs are not usually trained to be a good engineer. This lack of qualifications is due to the fact that students are not usually well-trained to solve real-life problems encountered when working in industry. In undergraduate engineering programs, students are usually trained to have great short-term memories, rather than to exercise improving their critical thinking and problem solving skills through authentic education. Engaging students in authentic situations not only prepares them to solve 21st century problems, but also facilitates the development of 21st century skills [7], [8]. Therefore, students who did not experience authentic education may not be qualified to work in the 21st century job market. However, it has been argued that creating authentic education is not always easy to implement: some authentic activities are impossible to perform in the classroom and some other activities are too dangerous, difficult, or expensive [6].

As a person who was involved in designing educational robots and teaching robotics to students in different levels, I believe robotics is well-suited for creating an authentic learning environment for electrical and computer engineers, because it does not have content barriers and is not dangerous or expensive. Therefore, in order to address the lack of authenticity issue and to inspire other educators to create an authentic learning environment for students, this paper is focusing on robotics as a learning tool which has the potential to contextualize the typically decontextualized subject matter.

II. Robotics and Authentic Education

A review of literature demonstrates that robotics projects provide opportunities for students at different ages to apply and utilize learnt concepts, skills and strategies to solve real-world and personally meaningful problems [4], [9]- [12]. When working on robotics projects, students encounter “applied, real world challenge[s] such as an engineering problem to solve or a novel science investigation to perform” [13]. Robotics provides an opportunity for students to apply theoretical principles in meaningful real-life contexts, and reduces the ambiguity of the processes [14]. In fact, robotics contextualizes the abstractions that are taught in the classroom and helps students connect and apply learnt concepts [3], [15]. This connection creates an excellent platform which engages students in complex activities, allows them to learn the subject matter in a personalized and meaningful context, and motivates them to study and learn. Authentic robotics projects also provide an opportunity for students to think and act like scientists, engineers, and specialists [16]. Therefore, it confronts students with difficult challenges, engages them in experiments which require different ways of thinking, assigns them the role of decision-makers, encourages them to deeply analyze the problems -rather than simply act as learners-, and develop their problem solving skills. Authentic robotics also helps students promote their skills for living in the digital world, and has a great impact on developing 21st century skills, such as problem-solving, creativity, critical thinking, and collaborative skills [14], [17]- [21].

III. Theoretical Framework

This study is based on principles drawn from constructivism and constructionism theories.

A. *Constructivism theory*

Constructivism theory emphasizes that learning takes place as a result of mental construction by the learner [22]- [24]. Constructivism considers an active role for learners and emphasizes that the learner gains an understanding of the features and constructs his/her own conceptualizations, knowledge, and solutions to problems by exploring from the environment and interacting with objects and events through personal experiences [25], [26]. Constructivism states that learners’ conceptual changes take place as a result of immersing in real-world situations and interacting with people and things [27]. Robotics supports constructivism by providing an opportunity for students to connect experiences and curriculum, and generalize from their experiences [2].

B. *Constructionism theory*

Constructionism draws on constructivism and considers important roles for contexts, individual minds and their favorite representation, artifacts and learning through hands-on experience [27]- [29]. Papert emphasizes that designing and building a tangible and personally meaningful object, finding problems, and solving them is the most efficient way to learn powerful ideas. Papert describes constructionism as below [27]:

> Constructionism —the N word as opposed to the V word— shares contructivism’s view of learning as “building knowledge structures” through progressive internalization of actions… It then adds the idea that this happens especially felicitously in a context 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.

The goal of constructionism is to give “children good things to do so that they can learn by doing much better than they could before” [28]. Papert argued that using the Lego NXT in the classroom allows for a constructionist approach to benefit instruction and student learning. Furthermore, different studies stated that robotics supports Constructionism theory by developing meaningful learning and understanding through hands-on and cooperative activities [12], [30]- [32]. Lego Mindstorm, with its building materials (e.g. blocks, gears, pulleys, and axels), sensors (light, touch, and sound), and programming software supports a constructionism approach and provides a unique opportunity for students to experience hands-on projects and design and to construct their own robots [33].

A review of literature demonstrates that robotics supports constructivism and constructionism, provides meaningful hands-on learning experience, provides authentic learning environments and helps students to make connections between experiences and curriculum, improves students’ lifelong learning skills, and actively engages students with the curriculum [15].

IV. My Experience as a Robotics Instructor

My experience, as a robotics instructor who tried to integrate robotics into k-12 schools as well as higher education, confirms the existing literature surrounding the use of robotics for the purpose of creating authentic learning environments. I witnessed that robotics has the potential to create an environment which is connected to students prior knowledge and experiences (e.g. building soccer robots) and helps students truly retain learning in a meaningful way. This kind of authentic problems and projects, which are touched and felt by students, leads them to produce ideas and engages them in the process of knowledge building [34]. Based on my experience, robotics also provides an opportunity in which students feel what they learn is not useless knowledge; rather, it is applicable in the real world. For example, my students had opportunities to apply what they had learnt and built Mars explorer robots, rescue robots, and firefighter robots. In fact, robotics creates a “Lifeworthy Learning” environment in which students see the subject as something “that is likely to matter in the lives learners are likely to live” [35]. Based on my experience, these kinds of authentic experiences motivate students to study better, as they see themselves as productive knowledge builders. A lack of authenticity, on the other hand, will result in missing the core motivation of advancing knowledge and will lead to a failure of knowledge building process [36], [37].

I also witnessed that robotics simulates the messiness of real life and provides an opportunity for students to learn that solving real problems is not as smooth as they usually think and is not as simple as academic tasks; it is "usually very different from textbook problems and puzzles" and sometimes requires long periods of effort and critical problem solving [34]. As an example, while some students used to think electronics components with same *nominal specifications* would result similar outputs, during robotics projects they realized that electronics components may have different *actual specifications* that would affect their outputs and efficiency. In fact, students realized that *actual specifications* are not necessarily equal to *nominal specifications*, depending on the precision of the manufacturer and the technology that is used. For example, some students experienced that DC motors that were used in their robots were not actually identical, although they had same nominal specifications. As a result, one of the DC motors was faster than the other one and their robots were unable to move on a straight line. I encouraged them to think about a way to solve this problem and adjust motors' speeds. Some of the students suggested to write a program so that both motors would have the same speed; this was truly the right solution. Based on my experience, robotics creates an environment in which students can exercise problem solving and critical thinking. Whenever my students encountered unexpected problems or situations, I encouraged them to think to find a solution to resolve the problems by themselves, as they need to be prepared to face much more complex problems in the real engineering world. I witnessed that students were not initially confident to solve these kinds of unexpected problems by themselves, but during the semester they became much more confident about suggesting solutions for the problems.

Overall, my experiences prove that robotics makes connections between the subject matter and real-world, helps students learn subjects in a personalized and meaningful context, and leads students to believe the subject matter is relevant, meaningful, and useful. It also improves students' motivation, prepares them to encounter and solve 21st century challenges, and helps them improve their critical problem solving skills which is required for 21st century job market; therefore, students would have less barriers to enter the job market and keep their positions.

V. DISCUSSION AND CONCLUSION

My experience, along with the existing literature demonstrate that robotics, with its multidisciplinary nature, meets the criteria for creating authentic education environments, engages students in a transdisciplinary learning environment that helps educators to ensure that the learning experience is relevant to students' lives and prior experience. Such an environment connects theory and practice, and provides an opportunity for students to mimic real-life ways of thinking and doing. Authentic education goes beyond the content, and considers important roles for multiple disciplines, perspectives, ways of working, habits of mind, and communities [6]. Perkins suggested that a *Worth Learning* curriculum should have the following six trends which he calls six "*beyonds*" [35]:

- *Beyond the basic skills* –Worth Learning curricula should go beyond the basic skills and should create a learning environment that helps improve students' 21st century skills and dispositions, such as critical thinking and collaboration skills.
- *Beyond the traditional disciplines – Worth Learning* curricula should include renewed, hybrid, and less familiar disciplines, not just simply focus on traditional disciplines.
- *Beyond discrete disciplines* – Worth Learning curricula should not just focus on discrete disciplines; rather should include interdisciplinary topics and problems.
- *Beyond regional perspectives* – Worth Learning curricula should take into account the global perspective and problems.
- *Beyond mastering content* – A Worth Learning subject is not a subject without any application in the real word; rather, it should connect the content with life situations and issues.
- *Beyond prescribed content* – A Worth Learning curriculum is not a predefined curriculum, but should provide an opportunity for students to see they have more choices in their learning.

Robotics creates an environment which meets all the criteria that a Worth Learning curriculum should have. A review of literature demonstrates that robotics is an excellent tool for improving students' 21st century skills, including problem solving, critical thinking, collaboration and teamwork (e.g. [18], [20], [21], [38], [39]). It also has a hybrid interdisciplinary nature and engages students in solving problems in multiple disciplines, by integrating different fields such as electrical engineering, computer engineering, and mechanical engineering. Furthermore, robotics provides students with a variety of learning options and has the potential to be used to solve global problems and concerns (e.g. explorer robots and rescue robots). Therefore, robotics can be considered a worth learning subject and tool, and engineering students and their instructors should take advantages of its great potentials.

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