ENGINEERING EDUCATION FOR K-12 STUDENTS: STORYTELLING AND CURRICULUM FRAMEWORK FOSTERING ACTIVE LEARNING

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Abstract
The educational urgency to improve and establish STEM education may be driven by environmental, social and economic impacts of the twenty-first century demands, which is included nowadays in educational policies and inside the schools. The field of STEM education and educational technology has been part of an important innovation process in schools around the world, and the process of integrating science, technology, engineering, and mathematics in the learning process can be complex, considering schools environment, teacher education and resources.

The E (engineering) in STEM is an emblematic and promising subject and it is calling attention from k12 schools, educators and policy makers in education. The use of robotics to enhance engineering education has been part of students learning environment in schools for many years.

This paper proposes a framework to address a curriculum design approach that drives engineering education using robotics, highlighting the constructionist perspective. Pedagogy and its dimensions such as methodology, teaching and learning related to educational robotics and engineering education are presented within theoretical and educational foundations. Beyond the use of robotics, deepens the discussion of curriculum design and engineering education during robotics activities, and how storytelling as a methodological approach can facilitate learning engineering concepts.

Keywords: Curriculum design; Engineering education; Active learning and methodology.

1 INTRODUCTION
STEM approach has been considered an important part of student learning in primary and secondary education around the world. Many countries have recently launched national and regional curriculum standards for engineering education, fostering active learning by different pedagogical approaches. One of those is the use of robotics to teach engineering.

As a technological resource used by educators, robotics is one of the most upgraded and integrated into school’s activities around the world. From STEM projects through political pedagogical standards, formal education is allowing computational thinking and constructionist approach to emerged in teaching and learning process using robotics and its technology. Many countries, including Brazil, have been benefited by a growing number of educational robotics technology such as LEGO Mindstorms, fischertechnick, Kibo, K’Nex, GoGo board and others.

Robotics projects in k-12 education in many schools represent as an isolated practice in different development projects, because these projects have been identified as a specific subject in the curriculum, which means it has been using in professional education in high school or College. Robotics have been seen by educators and the population as a sophisticated toy, in which people that love robotics find themselves in championships and conferences around the world.

The research in robotics has been reaching the university context – engineering and mechanics – and industries. The interest for the subject is growing, and we can see the investments from the government in educational technology. Even with all the investments, only a few k12 schools in Brazil integrate educational technology subjects (such as robotics) in curriculum. Projects that are more significant are limited in professional education and College.

Despite all that, It’s not unusual to find educators interested in exploring robotics, STEM curriculum and constructionist concepts in their practice. Influenced by researchers and projects using robotics in schools, by cinema and media, or by simply amused by technology, teachers and students mobilize themselves to create and conduct their projects. Making the design, build, program and analyse the results of robotics become a motivated activity in learning process and STEM curriculum, helping cognitive process, as well as provides creative activities.
2 METHODOLOGY

Beginning in 2003, the school acquired initially knex and LEGO Mindstorms (RCX) educational sets to start its afterschool program. The goal was to develop a program to give students an opportunity to learn and engage in engineering and robotics activities.

The activities were based on engineering and robotics concepts and were developed considering students from 6th grade to high school (11 to 17 years old). Once a week for three hours, students interested in those activities participated in this program offered only after school and they could design artifacts with either knex or mindstorms.

Usually, the projects were presented by the teacher, with challenges prepared based on science concepts and mathematical problems. One aspect of this approach was that only students with a personal interest in robotics and engineering looked for to participate, which represented less than 5% of total students at the school.

Although a small percentage of the students participated at the beginning, it was significant to create a motivational atmosphere and to initiate a discussion about robotics integration into curriculum activities.

During the afterschool program phase, students started to talk more about different possibilities with this technology in the classroom, asking teachers and the administration about using robotics sets to learn different types of subjects such as science, math and even humanities.

After only two years of afterschool programs, the administration decided to add another step into educational robotics and constructionism perspective allowing science and math teachers to integrate educational robotics in science fairs projects.

The 2005 science fair integrated robotics with 9th grade and high school students. Teachers decided to use robotics with a group of 35 students, divided into small groups of 5 and let them with the choice of their own projects. Therefore, students worked for two months in their projects, designing, building and programming devices to present at the science fair.

Thereby, educational robotics classroom activities started to be planed based on computing, robotics and subjects content. At the same time, teachers prepared a storytelling approach with 1st to 5th grade to integrate educational robotics.

![Figure 1. Storytelling, from left to right – (Story with a challenge; an engineering design and Keywords to study during the project).](image)

After reading a story, which contains a challenge, students always in groups of three or four start to plan the solution, picking up an engineering design prototype to build. Actually, students begin the activity a week before, investigating the problem and keywords teachers give them in order to maximize the time between every project.

The engineering design process is an important part of engineering education in K-12 schools, as show below:
An example of this storytelling approach is the activity called “submarine” with students in 5th grade in 2017. After students had read the story with two characters talking about submarines, they did research about it; then, students designed their prototypes and built the submarine based on engineering design process and programmed it to do what the students planned. At the end, students showed their projects to the class and shared ideas and choices, registering the most important parts of the physical construction and how the mechanism created worked. A quote from the students about the most important parts of the submarine created and how it works:

“The motor, engineering basis, gears and propellers. The motor makes the propellers spin and the submarine moves”. Student (2017)

Every project/activity has keywords related to four dimensions: technology; science; vocabulary and engineering to guide the teaching and learning process. For example, in the submarine activity these are the keywords:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Science</th>
<th>Vocabulary</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relation between structures and motors</td>
<td>Experiment and relation to motors, design and engineering</td>
<td>Motors, structures, design, machines;</td>
<td>Description and explanation of construction;</td>
</tr>
<tr>
<td>Assembling components</td>
<td>Simple machines;</td>
<td></td>
<td>Test and evaluation;</td>
</tr>
<tr>
<td>Evaluation;</td>
<td>Scientific investigation;</td>
<td></td>
<td>Engineering design;</td>
</tr>
</tbody>
</table>

Figure 3. Submarine activity (novel, design’s prototype and the submarine model built – 5th grade).
3 RESULTS

We consider the perspective of robotics in the curriculum in a broader way and its integration into the curriculum permeates both the curricular framework itself and afterschool projects. However, we prioritize the integration of robotics in the curriculum, as the afterschool projects have specific characteristics, allowing greater flexibility in the development of the projects.

Relevant element of this aspect lies in the fact that schools, in general, do not have the “clear” direction about what to teach related to robotics, for instance, they usually have difficult to choose related any robotics content and thus take different paths in relation to the choice of didactic materials and contents for this component.

Indeed, this is fundamental when we discuss about integrating robotics into the curriculum. Differently from subjects such as mathematics, science, geography, historically constituted as the school core curriculum with structured contents for each school year(educational policies), which contribute to a diversity of didactic-pedagogical contents.

For instance, we can think of schools that are planning curriculum of robotics based on the concepts of technology linked directly with the materials of this resource, such as learning programming and the use of sensors and motors. In this case, schools demonstrate difficulties in aggregating contents from different subjects that constitute the school core curriculum.

Another example are schools that privilege content linked to subjects such as science, mathematics, physics, which limits the concepts of technology learning.

Therefore, to think of robotics integration in the curriculum is indispensable to considerate the perspective of three axes: science, technology and subjects, according to the model we propose below:

![Figure 4. Educational Robotics curriculum model.](image)

These aspects provide guidance to the design of robotics curriculum in formal education environment and their integration in a meaningful way, having as reference the construction of knowledge and the autonomy of students in the teaching-learning process.

In science, elements such as investigation process, research, hypothesis, scientific method, among others are central. This axis contributes to a curriculum guided by the immersion of the student in a process of investigation of the studied phenomena, in research and tests of hypotheses.

About technology, we need to consider the knowledge of functioning parts such as sensors, motors, electronics, programming language, the field of computation itself, computational thinking, and advances in technology (as a technological artifact).
Finally, **subjects**, which contemplate the school core curriculum (Physics, Language, History, Sciences, and Mathematics), those referring to robotics, engineering, artificial intelligence, creativity, as well as soft skills such as teamwork, collaborative learning, among others.

The organization of these three axes is what we call the “DNA” of interdisciplinarity. In this sense, it refers to the whole process of knowledge production, constituting itself not as the simple inter-relation between knowledge, but the concrete constitution of all knowledge produced in the activity or project.

Interdisciplinarity is the production of meaning in the whole process, and not only the "mixing" of areas of knowledge around a theme/project, in other words, it enlarges the interconnections and produces knowledge that did not exist before, involving aspects of philosophy, anthropology and sociology. (Fazenda, 2010)

Therefore, we propose this model for educational robotics curriculum design, in which for every project or activity the three axes must be present as a core curriculum, with interdisciplinarity as a DNA considering a link to the three axes and balancing the importance of content knowledge related to the teaching and learning process.

4 CONCLUSIONS

Considering this context, robotics curriculum can contribute to an emancipatory teaching-learning process for both student and teacher. These aspects usually encounter challenges in order to actually materialize during day-to-day of school education, given the relation time/space, available resources, teacher training, among others.

Integrating robotics is fundamental, because it goes beyond a technological resource that allows the active participation of students in constructing knowledge. It has the potential to contribute to the development of projects that aim the emancipation of students in learning complex concepts and skills development of the 21st century.

In addition, it contributes not only to the construction of a multi-referenced curriculum, which considers both the historically constituted core contents and the particular contexts of each school for the development of pedagogical projects, but also for the strengthening of a culture of technology use in education that has as fundamentals the autonomy and emancipation of students in the teaching-learning process.

It is not, therefore, simply to add robotics in the curriculum framework because it is interesting, to "conquer" new students, nor to use this technological resource at a few times during the school year.

Creativity in the context of integrating robotics in the curriculum stands out as another fundamental element. Integration projects of such technology that contemplate activities that do not allow students to create in all steps described are limited to only superficially incorporate robotics.

Thus, during the stages of a robotic activity, students need to exert creativity, for example, they cannot receive ready-made assembly model and instead they need to build the device based on the challenge proposed at the beginning of the activity. They need to create the device’s programming and not receive it ready to just test it.

In this sense, creativity must permeate the learner’s action during all stages of a robotic activity, in order to maximize the reach of this technological resource in the teaching-learning process and, therefore, ensure the integration of robotics in the curriculum significantly.

REFERENCES


