Education 4.0 and 21st Century Skills: A Case Study with Robotics Activities in Classroom

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Abstract. *One of the most researched topics in Education 4.0 is the use of robotics in education. In this paper, we performed a case study related to skills developed for Education 4.0 through robotics activities, without involving competition. Students followed the process suggested by LEGO Education Maker and answered a self-assessment questionnaire about their developed skills and participated in a focus group. The teacher also reported her perceptions about the developed skills. We performed a qualitative analysis and the results indicated that robotics activities helped students to develop some skills, but it is still necessary to propose new approaches that will support students more in robotics activities.*

1. Introduction

Due to the increasing complexity of products and processes, today's employees have to be qualified for more than just repetitive operations. The development of skills to autonomously deal with failures or new tasks is getting more significant [Schuh et al. 2015]. Therefore, it is vital for the youth to keep pace with changes in order to be competitive. The youth needs to have the skills to respond to the recent social changes. This is a new challenge to redefine the education, the so-called Education 4.0 [Puncreobutr 2016].

The code 4.0 has been used to mark the disruptive change, which takes place in the manufacturing industry through the application of Information and Communication Technology (ICT), creating the term Industry 4.0. Since then, the code 4.0 has been applied to many other fields, which are equally affected by the rapid changes in the world [Wallner and Wagner 2016], such as Work 4.0, Healthcare 4.0 and Education 4.0. Education 4.0 has the purpose of developing people for being ready to be creative and innovative [Puncreobutr 2016].

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The evolution of skills for the successful implementation of Education 4.0 is of significant contemporary interest to both researchers and practitioners. One of the most researched topics in Education 4.0 is the use of robotics in education. Experts highly encourage the use of robotics in classrooms to convey the most important 21st century skills to children [Eguchi 2014].

According to Eguchi (2014), educational robotics creates a great environment for students to bring together and develop solutions for real-world problems. In this context, one of the aspects to be considered is that some identified studies involve robotics activities structured as competitions. Although competitions are motivating for many students, others consider them frustrating [Rusk et al. 2008].

This paper aims to fill the aforementioned gaps by providing a case study related to 21st century skills developed for Education 4.0 through robotics activities, without involving competition. This study does not involve competition because we desire to stimulate and develop the children's skills with other learning styles. We focus on five main skills: creativity and innovation; critical thinking, problem solving and decision making; learning to learn and metacognition; communication; and collaboration. We chose these skills because they are the most studied skills in the related works.

The next section defines the main terms and concepts of Education 4.0. Section III discusses 21st Century Skills. In Section IV, we describe the goal, planning and execution of the case study. In Section V we present our qualitative results. Finally, we summarize our conclusions and provide a future work in Section VI.

2. Background

Skills of 21st century consist of leadership, collaboration, creative, digital literacy, effective communication, emotional intelligence, entrepreneurship, global citizen, problem-solving and teamwork, the life skills or the innovative skills to live in the era of Education 4.0. In addition, it is necessary to include the skills of building an intelligent nation with critical thinking, creativity and innovation, cross-cultural understanding, information and media literacy, career and learning skills [Puncreobutr 2016]. The following will present works that define and apply the main skills of the 21st century.

The KSAVE Model [Binkley 2012] structures the analysis of 21st century skills frameworks. The authors created an overall conceptual diagram. This diagram defines ten skills: (i) Creativity and innovation; (ii) Critical thinking, problem solving, decision making; (iii) Learning to learn and metacognition; (iv) Communication; (v) Collaboration; (vi) Information literacy; (vii) ICT literacy; (viii) Citizenship; (ix) Life and career; and (x) Personal and social responsibility.

Cross et al. (2016) proposed a framework for defining and recognizing student's talents in the areas of Computational Thinking (CT) and Engineering Design (ED). The CT definition includes three categories of skills: (i) problem-solving, (ii) abstraction, and (iii) algorithmic thinking. The ED definition includes six categories of skills: (i) defining the problem, (ii) intentional design, (iii) innovating, (iv) refining and testing, (v) prototyping, and (vi) communicating design.

World Economic Forum (2016) projected that, from 2020, there will be a shift in employee skill requirements, and the top ten skills, according to their order of

importance would be as follows: (i) complex problem solving, (ii) critical thinking, (iii) creativity, (iv) people management, (v) coordinating with others, (vi) emotional intelligence, (vii) judgment and decision making, (viii) service orientation, (ix) negotiation, and (x) cognitive flexibility.

Benitti and Spolaôr (2017) performed a literature review on state-of-the-art robotics applications to support STEM teaching. They identified that the most usual skills found in the reviewed papers are related to teamwork and problem solving. In addition, some selected publications report experiences on mathematical skills, communication, brainstorming, presentation, creative thinking, critical thinking, strategy making and leadership. Some initiatives are competitions, e.g., the First Lego League, aiming to develop skills by means of programing and assembly of robots based on Lego.

3. Case Study

Our study focuses on the evaluation of skills in the context of Education 4.0, providing qualitative insights gathered in a Brazilian school through robotics activities without involving competition. Our findings contribute to shed light on the needs for skills linked to Education 4.0, setting the stage for future research on the topic and providing companies and education stakeholders with first indications to detect skill gaps and initiate competence development.

The goal of case study is to analyze the development of five 21st century skills in robotics activities with high school students. To analyze the students' performance in robotics activities, we investigated the following 21st century skills: (a) creativity and innovation, (b) problem solving, (c) communication, (d) collaboration, and (e) learning to learn. We chose these skills because they represent the most studied skills in the related works identified in the literature. Creativity is often described as a thinking skill or at least as an important aspect of thinking that can and should be fostered. Innovation, on the other hand, is more closely related to economics, in which the goal is to improve, advance, and implement new products and ideas. Problem solving involves identifying gaps in knowledge and asking significant questions that clarify various points of view and lead to better solutions Communication, in the context of this case study, can be defined as an awareness of various types of verbal interaction (conversations, debate etc) and the main features of different styles and registers in spoken languages. Collaboration involves interacting effectively with others, i.e., knowing when it is appropriate to listen and when to speak. Finally, Learning to learn is described as the knowledge and understanding of one’s preferred learning methods, the strengths and weaknesses of one’s skills and qualifications [Binkley 2012].

3.1. Planning of the Case Study

To analyze the developed skills, we divided the case study in two parts: execution of the robotics activity, and evaluation of the developed skills. In the first part, we defined the process that the students should follow in the robotics activity. The process chosen was the LEGO® Education Maker Process. This process contains the following stages: (a) define the problem, (b) brainstorming, (c) define the design criteria, (d) go make, (e) review and revise the solution, and (f) communicate the solution.

Problem definition is the activity where the students define a real problem to solve or find a new design opportunity from the start. We prepared inspirational images for the problem to help students thinking about the design of their solutions. Brainstorming is an active part of making. In this stage, the students explore their thoughts through sketches and notes. This allows students to work alone before sharing their ideas. After this, the students share their ideas with their groups. Definition of the design criteria comprises discussions and an agreement about the best solution to build. It is important for the pupils to set clear design criteria. Once the solution to the problem has been made, the students return to these criteria, forming then the basis for testing how well their solution works. Go make involves making both the design and programming of one of their ideas using the LEGO® MINDSTORMS® Education EV3 Core Set. The students may also need to brainstorm ideas when trying to figure out ways to improve their idea or when achieving a poor test result and having to change a feature of their design. Reviewing the solution helps students to develop their critical thinking and communication skills. Group review and feedback help both students giving and receiving the feedback to improve their work. Communicating the solution involves presenting their work in front of the class. The students should present the design of the robot, as well as its operation.

In the second part of the case study, we defined the evaluation process that the students and the teacher must provide about the developed skills. We divided this part of the case study in three stages.

In the first stage, each student should use a self-assessment form to evaluate their developed skills. The intention of this form is to help students reflect on what skills they developed well and what they could develop better. Students assess themselves according to the ‘Four Bricks Scale’ in which the biggest brick represents the highest rating and the smallest brick represents the lowest rating. The students should circle the brick that shows how well they developed each skill. To better evaluate each skill, we defined statements based on the work of Bikley et al. (2012). The statements and the ‘Four Bricks Scale’ can be seen in Table 1.

In the second stage, we applied Focus Group (FG) to enhance the understanding of the students’ perceptions about the robotics activities in classroom. FG is a qualitative technique used to collect data through organized group interviews to discuss a certain object, such as a technology [Grigoreanu et al. 2009]. The FG should have a moderator that must encourage the participation of all who are involved in the discussion. França et al. (2015) presents a role-play strategy that promotes the adoption of the roles of “lovers” and “haters” to the subject of discussion, in which lovers must argue in favor of the object and haters must argue against. In this strategy, one can adopt the FG board to support the discussion. We created the FG board based on the skills selected in this case study. Figure 1 shows the FG board used in this study, which we divided into ten statements: (i) It supports creativity and innovation because…; (ii) It supports problem solving because...; (iii) It supports communication because...; (iv) It supports collaboration because...; (v) It supports learning to learn because...; (vi) It does not support creativity and innovation because…; (vii) It does not support problem solving because...; (viii) It does not support communication because...; (ix) It does not support collaboration because...; (x) It does not support learning to learn because. In this case study, lovers should argue in favor of statements i, ii, iii, iv and v regarding the

developed skill in the robotics activities in classroom. Haters should argue in favor of the statements vi, vii, viii, ix and x. The participants should highlight their perceptions with post-its supporting each argument in the FG board.

In the third stage, we applied a questionnaire to understand the teacher's perceptions about the robotics activities in classroom. We created the questions based on the statements presented in Table 1 for each skill. For example, regarding the Creativity and Innovation skill, we asked: "Did the students think creatively and innovatively? In other words, did they create new and valuable ideas?". The other questions follow the same logic.

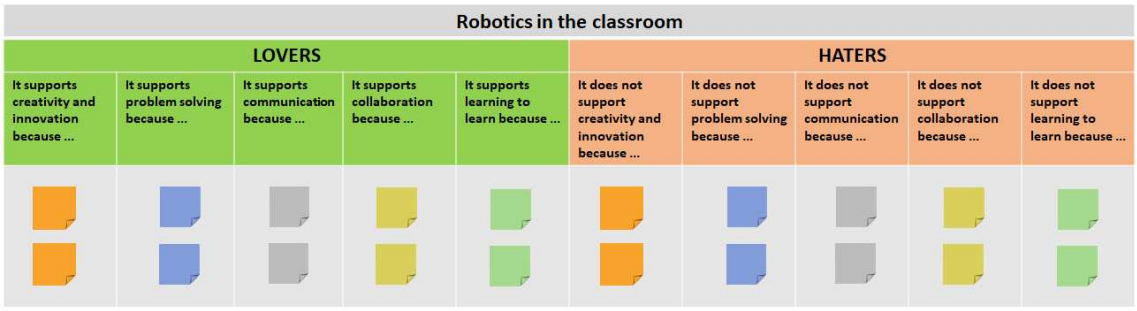

Figure 1. Focus Group Board.

3.2. Execution of the Case Study

We carried out this case study with thirty-four high school students from a school in Brazil. It is noteworthy that the students who participated in this case study already had introductory robotics classes and had already done other robotics activities, both designing and programming the robot.

In the first part of the case study, we established work groups. The teacher helped in the division of the groups, given that she knew the students who had more knowledge in building and designing robots. Thus, she balanced the groups with similar level of knowledge about robotics. We divided the students in five groups (A, B, C, D e E). Group A had six students and group B, C, D and E had seven students. Each group received a document containing the context of the problem to be solved and a LEGO® MINDSTORMS® Education EV3 Core Set. The context document addressed the issue about the holes in the streets, which are one of the major problems in today's cities. These holes can cause damage to cars, such as cut tires and broken wheels, and can cause tragic accidents. One of the challenges of the city hall is to detect which streets are bumpy and close these holes. In addition, workers do this work manually. Therefore, the groups should create/simulate ways to detect holes in the streets using a robot. When the robot detects these holes, it should stop, simulating their closure.

The students looked at the context document and images, then they decided upon a problem to solve or a new design opportunity, spending three minutes for this activity. Next, the students worked independently, spending three to five minutes to generate as many ideas as they can to solve the problem. After this, the students shared their ideas with their group, spending five minutes for this activity. Once all the ideas were shared, each group selected the best idea(s) to make. After, the students defined two to three design criteria that the design must meet, spending five minutes in this activity. Next,

the students made one of their group's ideas using the LEGO® MINDSTORMS® Education EV3 Core Set. The groups spent 30 minutes to build the robot and 40 minutes to program it. Then, the students tested and evaluated their robots against the design criteria that they defined before they started making their solutions, spending five minutes in this activity. Finally, each group presented their solution to the class, spending five minutes. Overall, students spent about 2 hours to complete the activities.

In the second part of the case study, each student used the Self-Assessment Form to evaluate their developed skills. We present the results of this evaluation in Subsection IV.C. After this, we divided the students into two groups (with seventeen students each) to facilitate the discussion in the Focus Group (FG). One group assumed the role of lovers and the other group assumed the role of haters for the developed skills in the robotics activities in classroom. During the FG, one of the authors of this paper performed the role of moderator. Throughout the study, a video camera recorded the students' discussion. At the end of the study, the teacher provided feedback through a questionnaire on how the robotics activity developed the skills in her students. The results of the FG and the teacher's feedback are presented in Section V.

3.3. Quantitative Results

Table 1 presents the results of the students' self-assessment about their developed skills. Four students considered that they had a low development in the skills described in the sentences "I used my skills to help my colleagues achieve our goal" and "I learned to be independent in my activities". Moreover, several students (3 students marked the smallest brick and 14 students marked the second smallest brick) considered that few of their ideas were put into practice. On the other hand, 91.8% of the students believe that they had a high performance in respecting the different ideas of the colleagues.

Table 1. Results of Students' Self-Assessment Regarding the Developed Skills

Skill	Statements				
Criativity and Innovation	I had new and valuable ideas	3	5	13	13
	I communicated my ideas to my colleagues	0	7	16	11
	I put my ideas into practice for use	3	14	13	4
Problem Solving	I thought in solutions to the problem	1	7	15	11
	I interacted with my colleagues to achieve better results in difficult parts of the problem	2	6	8	18
Communication	I communicated clearly with my colleagues	1	5	13	15
	I understood what my colleagues were telling me	2	3	11	18
Collaboration	I listened to my colleagues with care and patience	0	5	7	22
	I respected the different ideas of my colleagues	0	1	6	27
	I organized the teamwork to reach our goal	2	4	12	16
	I used my skills to help my colleagues achieve our goal	4	11	12	7
Learning to Learn	I was able to take the time to learn	1	5	18	10
	I learned to be independent in my activities	4	11	12	7
	I learned to have discipline in my activities	2	3	22	7
	I learned not to give up easily	2	2	14	16
	I focused on the activities	4	5	10	15

4. Qualitative Results

We carried out an analysis of the qualitative data that we obtained. The comments that the students gave in the post-its on the Focus Group provided data on their developed skills during the use of robotics in classroom. Moreover, the teacher's feedback provided more insights about the use of robotics in classroom.

4.1. Students' Perceptions

This subsection presents the analysis of the students' perceptions regarding the developed skills through the use of robotics in classroom. In relation to the Creativity and Innovation skills, students believe that Robotics: stimulates creativity; supports the creation of new artifacts or objects; uses tools to stimulate creativity; and has innovative techniques (see quotation Q01 and Q02 below).

"*It innovates the world, because some people create things that other people do not even imagine*" (Q01)

"*Because it brings innovative techniques capable of performing tasks that were not possible*". (Q02)

Regarding Problem Solving skill, students asserted that Robotics: brings a certain dynamic way of working; stimulates logical reasoning; supports problem resolution more quickly (see quotation Q03, Q04, and Q05 below).

"*Robotics brings a certain dynamic way of working to make resolutions easier*". (Q03)

"*Because it works with (...) reasoning thus stimulating the line of thought*". (Q04)

"*[Robotics] solves the problem faster*". (Q05)

Regarding Communication skills, students consider that Robotics supports students to talk to each other to solve a problem; and reduce the difficulty of accessing something or someone (see quotation Q06 and Q07). However, some students detected some communication failures, such as: some people are not able to communicate; and some people do not know how to share things (see quotation Q08 and Q09 below).

"*[The] students talk to each other to solve such problems*". (Q06)

"*Because the difficulty of access to something or someone decreases*". (Q07)

"*Communication is necessary yes, but people are not able [to talk]*". (Q08)

"*Because they (...) do not know to share things*". (Q09)

In relation to Collaboration skills, students believe that Robotics: stimulates the formation of ideas together; one learns to divide tasks; and is more agile and easy to interact with (see quotation Q10, Q11 and Q12). However, some students noted some difficulties during the team's collaboration, such as: sometimes people work alone; and sometimes just the will of the team leader is done; (see quotation Q13 and Q14 below).

"*Supports given that through group work stimulate the ideas together*". (Q10)

"*Because we work as a group, we learn to divide the tasks*". (Q11)

"*Supports communication because it is more agile and easier to interact with*". (Q12)

"*They work alone. They are selfish, they do not communicate*". (Q13)

"*Only the will of the leader is done*". (Q14)

Regarding Learn to Learn skill, students believe that Robotics: allows expanding knowledge through the exchange of ideas; and people have fun learning (Q15 and Q16). However, some students noted some learning difficulties, such as: broad themes need more study; it needs dedication and study to learn (see quotation Q17 and Q18).

"*Robotics allows us to expand our knowledge through exchanges of ideas*". (Q15)

"*With this we learn by playing and have fun learning*". (Q16)

"*Broad themes need further study*". (Q17)

"*Robotics needs dedication and studies to work properly*". (Q18)

4.2. Teacher's Perceptions

This subsection presents the analysis of the teacher's perception regarding the developed skills through the use of robotics in classroom. Regarding Creativity and Innovation skills, the teacher stated that Robotics: supported students to think creatively and innovatively; and supported the students to develop creative ideas that impact in several areas (see quotation Q19 and Q20 below).

"*The students had the challenge of setting up the structures because they were limited in material resources, and yet they still cared to build differentiated designs, in addition to what was requested*". (Q19)

"*The experiences that they had during the assembly and the implementation of the Robot addresses the multidisciplinary between the areas*". (Q20)

Regarding Problem Solving skill, the teacher believes that Robotics: supported students to interact with each other to produce better results in complex parts of the activities; and supported the students to understand that everyone can propose solutions to the problem (see quotation Q21 and Q22 below).

"*Students with more experiences in robotics inserted in different groups, interacted with each other to share in order to complete the mission, and in turn, the students who learned from them also shared their brief experiences with those who interacted little*". (Q21)

"*They [the students] were able to experience building solutions for everyday needs and found that anyone can propose solutions and innovate*". (Q22)

Regarding communication skills, the teacher noted that Robotics: supported the ability to communicate; and supported the ability to formulate their arguments convincingly in favor of robotics (see quotation Q23 and Q24 below).

"*[Robotics supported communication] effectively during sharing experiences*". (Q23)

"*In the short experience [the students] defended the use of robotics on important issues and the oppositions also defended well raising the point of view of the importance of human efforts in robotics*". (Q24)

Regarding Collaboration skills, the teacher noted that Robotics: supported the students to speak clearly their ideas to their colleagues; Partially helped students listen carefully and patiently to their colleagues; and helped students leverage the strengths of other peers to achieve a common goal (see quotation Q25, Q26, and Q27 below).

"*[Students] tried to be accurate to complement their ideas information*". (Q25)

"*Although [the students] were not encouraged to compete, the euphoric environment nevertheless gave them a sense of urgency*". (Q26)

"*[Students] assigned the most difficult tasks to those who had more experience*". (Q27)

Regarding Learn to Learn skill, the teacher noted that Robotics generated students' autonomy and perseverance in learning. In addition, the teacher said that Robotics allowed students to have the ability to concentrate for extended periods of activity (see quotation Q28 and Q29 below).

"*Autonomy and perseverance (...)*". (Q28)

"*[The students] were focused on finishing, because it involved a lot of practice, stimulated them more*". (Q29)

5. Conclusion and Future Work

This paper presented a case study about developed skills in a robotics activity with high school students of a Brazilian school. Both the students and the teacher of the discipline provided feedback on the developed skills in the robotics activity.

Through the qualitative analysis, it was possible to realize that the students developed well the skills of Creativity and Innovation and Problem Solving. The students also provided positive feedback regarding these skills, such as: the use of tools to help stimulate creativity; and the stimulation of logical reasoning. In fact, Robotics seeks to stimulate the creation of new ideas to solve day-to-day problems. In addition, it seeks to stimulate students to think outside the box and seek the structuring of thinking according to the norms of logic to arrive at the solution of a problem.

In relation to Communication, students felt that Robotics supported them to communicate for the same purpose. However, some students identified that there are people who even with Robotics have difficulties communicating. Therefore, new methodological approaches that stimulate students' communication in robotics activities should be proposed, in order to help more timid and introspective people.

Regarding Collaboration, students believe that Robotics facilitates interaction among people. However, one of the students noticed that on many occasions, only the will of the team leader prevailed in front of the others. It is worth mentioning here that we did not establish team leaders in the case study. What may have happened in this case is that students who had more experience with Robotics may have taken the lead, taking responsibility for making decisions. Thus, one idea would be in new studies to seek to use a rotational leadership approach, so that all students can make decisions.

In relation to Learn to Learn, some students realized that they obtained learning in several areas through the robotics activity, in addition to learning having fun. However, some students noted that it is necessary to dedicate and study to learn robotics. As robotics activity is multidisciplinary, students need to develop concepts from several areas, such as mathematics, computing, among others. In fact, studying several concepts takes time and depends very much on the student's dedication to learn.

Finally, the teacher of the discipline also provided her feedback on the performed robotics activity and considered that robotics does, indeed, aid in creativity and problem solving. In addition, for her, robotics activity partially helped students to

listen carefully and patiently to their colleagues and to plan and manage the work. It is still necessary to propose new methodological approaches that will support students more in planning the process they will adopt in robotics activities. In addition, greater awareness is needed about having patience to listen and consider the opinions of colleagues. Ideally, in this case, it is encouraged to not discard any of the students' ideas. In future work, we intend not to ask the students to choose one of the ideas for the team to work. They will be able to combine all ideas into one. Perhaps this is a way for students to feel that their ideas are considered relevant and put into practice.

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