Creativity and Contextualization Activities in Educational Robotics to Improve Engineering and Computational Thinking

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Abstract. One of the objectives of the introduction of educational robotics in the schools is the need to adapt the curriculum of the technology to the today's requirements of the students and the development of the skills, competencies and disciplines involved of STEAM. In this paper cover related aspects of the computational thinking, the engineering thinking required to develop the context-oriented activities through technological platforms based on educational robotics. The contextualization of the activities worked with Scratch and LEGO Mindstorms are the basis of two study groups. Different methodologies of learning of the technological platforms are used in these groups.

The methodology developed during several sessions of the academic course is the main argument to introduce the Educational Robotics and the development of the STEAM in a traditional school of Barcelona.

Keywords: Educational robotics · STEAM · Engineering thinking · Computational thinking · Learning process · Creativity

1 Introduction

What today is understood by educational robotics involves several trends, tools, and methodologies to teach science and technology contents in the schools.

The educational institutions have introduced educational robots in their curriculum and their technical applications in the last 15 or 20 years, through all the different levels [1]. Consequently, the educational robotics has become an integrative discipline representative of novel teaching methodologies and that indicates technological progress. The use of robots in education goes beyond more research to develop a new technology; integration of robotics in education and research in the field of teaching STEM (Science, Technology, and Mathematics Engineering) or STEAM (Science, Technology, Engineering, Arts and Mathematics) to become a reality [2–4].

Furthermore, robotics as a subject itself is increasingly present in the curriculum organization, and there are many schools that introduce robotics as another subject as their curriculum. The reality, however, is that both trends are very intertwined in the

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daily school; which applies robotics as a subject in isolation and is only focused mainly on learning the construction, installation and programming of the robot. This will leak other teaching opportunities and take advantage of the potential of robotics as a learning method [5], both connected to the content linked to STEAM.

Although the current robotics technological reality offers many resources, educational robotics skills need some improvements to cover all stages of education, whether in Early Childhood Education [6] Primary or Secondary Education [7, 8] and is covering applications in different disciplines and learning activities.

The evaluation forms and learning resources based on the development of engineering and computational think are based on the constructionism, such as LOGO [9] have evolved in teaching structures of the coding based on multiple platforms such as programmable block Scratch [10] and LEGO Mindstorms [11]. These learning platforms are used in several schools to introduce the teaching of subjects such as coding, technical, science, and robotics.

Finally, the emergence of new teaching methodologies such as Problem Based Learning or Project Based Learning, both with a vision very close to Constructivism [12] promotes the integration of educational robotics and its entire environment learning in the curriculum.

The next study is focused on the analysis of how they apply these methodologies in learning robotics and STEAM, particularly emphasizing creativeness and context of the activities to improve the structures of thought the development of computational thinking and engineering. The computational thinking is beyond the simple fact of coding or the interaction with computers [13]. This thinking like engineering thinking is related to the ability of analysis, and problem-solving skills. These skills are the ones that students must acquire to be ready for the company today.

2 Framework

La Salle Bonanova School, a 125 years-old institution, is in the upper part of Barcelona. The teaching that is carried out can be considered traditional but in the route map of the school exists an intention to shift in the education system towards the use of innovative techniques to enhance learning. To do so, the School has committed to the integration STEAM of the educational robotics and Problem Based Learning and Project Based Learning as a catalyst of this methodological change to all education stages, from pre-school, primary, secondary and high schools covering a total of almost 2000 students.

Within the context of Spain and Catalonia in particular, the content about digital content has a customized design according to each center [14]. This subject is developed along the three years of secondary education with a distribution of 2 h per week throughout the year. The distribution of subjects and teaching units does not exist the subject of robotics explicitly, but knowledge related to technology, computer science, coding, and the use of information technologies in general.

The ratio of Spanish students is about 35 students per classroom, so turns to be challenging to focus on attention to diversity. Thus, the desire to introduce educational robotics as a teaching methodology transverse perfectly fits the trend of methodological change that is proposed from the Catalan government; where the capacities, skills and competencies are acquired from students becoming the center of teaching methodologies.

3 Learning Goals

There are several goals of the introduction of educational robotics in this school. These include promote a series of skills and abilities linked to the STEAM disciplines, solve the challenge of improve engineering thinking, the development of computational thinking, promote cooperative work and have technical knowledge of technology platforms. These objectives are linked to the development of the skills of the students throughout the secondary school program. Is for this reason that in this first year, the aim goal is to establish the bases so that the school crated its own methodology of work with educational robotics.

The main goals during 2015-2016 course, as the first year of implementation of educational robotics program are, to get the first knowledge of various educational IT platforms and enhance skills and abilities of students in technology and science. These two goals are quite different, for this reason and in order to differentiate them clearly, they have been separated in the development of assessments both in the analysis of the results.

The learning goals of the technological platform are focused on the knowledge of Scratch and LEGO Mindstorms. This knowledge, although that will be an initial level, will be large enough for the two platforms to be used in the upcoming courses and use them for learning other STEAM concepts and continue developing engineering and computational thinking.

Although that the learning goals are the same as all educational levels, the difficulty of the activities has been modulated depending on the requirement of the course.

The other main goal is the development of skills and competence in the curriculum of the secondary school. These competences are developed in an own framework [14]. In the case of this study, the authors have made an adaptation of other experiences, in other educational stage and environments that can be found in the literature [15, 16].

And finally, the two last goals of this study are to establish the need to include creativity and artistic aspects as an important factor in the learning process; and contextualize the activities approaches and improves learning technological concepts.

4 Methodology

As already mentioned, the subject of Technology in Secondary Education does not specify that teaching robotics is required. However, the curriculum does contain contents and knowledge related to this field. The curriculum organizes the Technology subject in 2 h of class per week during the academic year. The school and the authors of this paper are committed to introducing methodological, logistical and contents changes in this subject.

First performing a separation into two types of contents; the first one is dedicated to the teaching of technological processes of the industrial world, building and design process. These includes the official curriculum content and is properly distributed throughout the 1st, 2nd and 3rd year of secondary [14]. Although, they are not part of this study, they are imparting weekly to all students of one hour during the academic course. The second types of content are those who are directly related to the use of in Information and Communication Technologies (ICT), and Educational Robotics (ER). It is in this block where the proposal of this study to achieve the learning objectives mentioned.

In the second type of content is a division into two small groups. While one group is doing, sessions focused on knowledge of ER, the other group receives lessons of ICT. Arriving in the middle of the academic year two groups exchanged. Therefore, considering that this study was conducted simultaneously in the first, second and third year of secondary distribution of classes and students is shown in Tables 1 and 2.

Table 1. Types of contents and groups distribution

Section 1	Lessons based on technology curriculum - All students	
Section 2	Group 1 ER* - Group 2 ICT	Group 2 ER* - Group 1 ICT

Course begins — Half course — End of course

* The groups studied in this paper are the Group 1 ER and Group 2 ER, which from now on were defined as Group 1 and Group 2.

Table 2. Students distribution

	1st Secondary			2nd Secondary			3rd Secondary	
	Group1	Group2		Group1	Group2		Group1	Group2
1A	17	16	2A	16	18	3A	17	17
1B	17	16	2B	18	18	3B	17	17
1C	17	17	2C	17	17	3C	18	17
1D	17	17	2D	18	17	3D	18	17
1E	17	17	–	–	–	–	–	–
	85	83		69	70		70	68

The division of the class is done to facilitate the work in the robotics classroom. This situation helps us to organize better the material resources and the human resources for all students. So, this way we can work with small working groups, furthermore we can observe that in STEAM subjects and in ER, using creativity, motivation and contextualization the activities, help and encourages to problem solving [17]. This separation in smaller working groups is the reason why there is a small variation in the methodology between Group 1 and Group 2.

What this paper would like to show, beyond the consolidation of the educational robotics methodology as an excellent learning resource, is developed the context to use activities and the creativity to be a fundamental pillar in the teaching STEAM.

Of a total of 445 students, 224 students in the first group receive the classes of ER in the period from September to January; and the second group of 221 pupils performed it from February to June, both terms correspond 15 teaching weeks, and therefore there has been an organized in 15 sessions. Once this division between groups the classroom is organized in small groups of 3-4 students, to achieve the cooperative work and peer-to-peer relation.

4.1 Methodological Differences

The authors wanted to show that the desire of changing educational model that seeks to La Salle Bonanova has a fundamental reason: to improve skills and clever minds to ensure that students meet the current demand of society. That is why to verify this, we have followed two trends that are currently in operation in the school and have led to methodological differences for teaching robotics block corresponding to educative.

With the background of technological learning platforms, LEGO Mindstorms and Scratch generated work dynamics and different teaching methods. The main methodological differences between the groups are as follows:

- Group 1:
  - In this group, each session has been very structured and can be based on traditional teaching, where the teacher conveys his whole focused where students and what you learn and how you learn is much guidance.
  - At its introduction to Scratch, the knowledge platform has been scheduled always and with little freedom of research; programs have been conducted following tutorials and defined structures and objects.
  - The teaching of the Scratch features such as loops, variables, objects movement or conditional has been making small programs where all students were the same task. The final evaluation is done by creating a free video game.
  - At LEGO Mindstorms sessions, students have learned to use the platform in a very structured session. Explained each block separately, making small LEGO Mindstorms EV3 robot applications already assembled. Once the students have an overview of the platform, has been challenged to make geometric shapes.
- Group 2:
  - In this group has been a contextualization of the activities always and entered creativity, art, motivation and collaboration among peers as an engine of creation. Been teaching real applications in robotics and space has been left to the imagination of science fiction films screened and creating fantastic stories.
  - Prior to the Scratch sessions, each group has written three little stories and presented to the rest of the class. Among the three little stories, students choose the best one.
  - Teaching features like Scratch loops, variables, objects or conditional movement has been doing quite a lot of freedom with small programs, although there are some recommended. The final evaluation is done by creating a video game based on one of the stories submitted.
  - In the LEGO Mindstorms platform, there has been an understanding of the working environment but has previously contextualized learning that the

application of the movement of the robot to do geometric shapes known. These shapes are contextualized in the real world, looking for similarities in design, architecture or engineering objects in the immediate environment to the students.

Tables 3 and 4 shows how distributed teaching Scratch and LEGO, how many sessions are needed for each content conceived and what are the teams that are working.

One aspect to highlight is the difference in the learning of some technical aspects. The number of sessions used to show the features of Scratch or Lego Mindstorms are not the same. This is because learning to use the platform has been more agile and faster in the second group. In this case, the second group received instruction on the use of creativity, there have been a work of communication and motivation before using Scratch. Similarly, there has been a contextualization of contents before using LEGO Mindstorms. These two aspects lead to changes in the learning process between the two groups and together with the analysis of the corresponding assessment results, leading to a several considerations about this. These issues are set out in Sect. 6 corresponding to Results.

Table 3. Group 1. Sessions distribution

Session name	Sessions	Concepts developed
Learning Scratch	1, 2	Create user account Scratch. Know the framework, libraries, characters, objects, background and operation of the blocks. Observe programs already made
Learning Scratch	3	Observe programs already made and make the first programs following a tutorial
Program ‘Pong’	4	Apply motion control blocks to perform the program ‘Pong’ following a tutorial. Loops and Conditional apply. The ‘Pong’ game is based on tried bouncing a ball that does not fall on the ground, to prevent it controls bar
Program ‘A little story’	5, 6	Make a little story by blocks of dialogue, control of movement and change background and costumes
Video Game	7, 8, 9	Define the concept of variable. Make a free-form game
Learning LEGO Mindstorms	10, 11, 12	Perform basic robot assembly following the instructions manual. Get functioning of Brick. Get workplace software. Interacting with the engine control units and display
Program ‘Geometric shapes’	13, 14, 15	Do the challenges go online 1 m straight, make a square, rectangle, circle and number 8

Table 4. Group 2. Sessions distribution

Session name	Sessions	Concepts developed
Creativity and motivation	1, 2	Talk about what creativity. Viewing videos on art and creativity. Get students through dialogue, former pressure tastes or hobbies. Teaching applications, videos and films of robotics and technology in today's world
Creativity and communication	3, 4	Writing three little stories by following the structure of introduction, middle and end where several characters appear, go in several different scenarios and can have several different endings. Presentation of three little stories aloud to the whole class support with a brief presentation and class vote on which of the three little stories is the best
Learning Scratch	5	Create user account Scratch. Know the framework
Program 'Pong' or 'Cat-Mouse'	6	There is an exhibition of some programs. Explain 'Pong' and 'Cat-Mouse' games, and then allowed that freedom to choose one and try to do. The 'Pong' game is based on tried bouncing a ball that does not fall on the ground, to prevent it controls bar. The 'Cat-Mouse'game is based on creating two animals chasing each other, depending on whether the cat touch your mouse or mouse touches the cheese is added or subtracted points
Video Game	7, 8, 9	Based on the story chosen the game takes place where you can introduce small variations that have a structure of game
Define and contextualize geometric shapes	10	Definition straight line, square, rectangle, triangle, circle and see in real life applications
Learning LEGO Mindstorms	11, 12, 13	Perform basic robot assembly following the instructions manual. Get functioning of Brick. Get workplace software. Interacting with the engine control units and display
Program 'Geometric shapes'	14, 15	Do the challenges go online 1 m straight, make a square, rectangle, circle and number 8

5 Evaluation

The evaluation group has made measuring some issues throughout the sessions under the same parameters for both study groups; it is generated rubrics. It should be mentioned that the notes or evaluations obtained from the rubrics are due to assessment throughout the process, and therefore in the last session activity where you expect a better note. However, we must differentiate two types of evaluation:

5.1 Assessment of Competence

The first section corresponded to the type of analysis and evaluation aspects competencies and included in the learning objectives in five areas: Communication, Collaboration and Community Building, Context Creation, Creativity and Conduct or Behavior. These areas are based on a rubric applied to kindergarten competence [15] and that the authors of this paper have adapted to the environment and the context of this study.

For each of these five areas, there are some skills or abilities assessed. This assessment is carried out at each session. However, the authors consider that the evaluation takes more importance in the last sessions, where is the resolution of the activity or challenge. The process of learning the skills is cumulative, so at the last sessions the assessment takes more importance.

An observation of behavior and the development of the activity of each student are done during each session. This observation is marked in the rubrics that shows on Table 5 and follows the 1-5 grading of Likert scale.

Table 5. Competent aspect evaluated

C1 Communication	C1.1 Exchange of ideas among group members
	C1.2 Expression of ideas and debate them
	C1.3 Demand for teacher support and is beneficial for the project
C2 Collaboration and Community Building	C2.1 Help peer group
	C2.2 The individual contributions make the group advance
	C2.3 Different work roles/Tasks diversity
C3 Context Creation	C3.1 The activity follows a structure designed
	C3.2 Analysis of the errors in the process
	C3.3 Justification of the solution
	C3.4 Write the process of solution to the challenge
C4 Creativity	C4.1 Initiative to make further steps in programs
	C4.2 Use of various elements outside environment platform
	C4.3 Application of concepts from other disciplines
C5 Conduct	C5.1 Concentration activity
	C5.2 Following the rules of the classroom
	C5.3 Responsible use of the material
	C5.4 Behavior with classmates and teacher
	C5.5 Motivation towards activity

In general, in all items the score of 1 corresponds to a very low level of competence or ability. On the other hand, the score of 5 corresponds to a complete integration of the skills in the development of activities were justified and argued the process and the takes of decisions.

5.2 Assessment of Contents

The other section is used to evaluate the relevant concepts and contents related platforms Scratch and LEGO Mindstorms. In this case, each platform specific concepts have been evaluated. Is for this reason that has been separated into two different rubrics. The items evaluated in each of these rubrics are shown in Tables 6 and 7.

Table 6. Evaluated items on Scratch activity

Conditional structures	- Understand the concept of conditional structures
	- Use different types of conditional structures
Loops	- Understand the concept or loop iteration
	- Use loops within the structure of the game
Objects	- Use various objects
	- Import objects outside environment Scratch
	- The motion control is done several ways
	- The use of objects follow criteria established
Scenario/Dresses	- Use different scenarios
	- Make changes in objects dresses
Bloc Posts	- Use the blog post to give orders objects
Text	- Use language structures
	- Dialogues appear
Variables	- Use variables to make a counter +
	- Use variables to make a counter -
	- Conditions certain actions variables
Music/Sounds	- Use music blog
	- Use varied sounds
	- Use block sound conditioning in another action

Table 7. Evaluated items on LEGO activity

Blocks movement	- Apply different types of engine blocks movement
	- Understand the various parameters that make up the blocks
Conditional structures	- Understand the concept of conditional structures
	- Use different types of conditional structures
Loops	- Understand the concept or loop iteration
	- Use meaningful use of the geometric shapes in the loop
Geometric shapes	- Apply different solutions depending on the geometric shapes
	- Understand the characteristics of shapes, and this is reflected in the solution of the program
Process	- There is a preliminary approach in solving geometric shapes
	- Express reasons solving each geometric shapes

The evaluation of these aspects is made through the delivery of activities and resolution of the challenges. For Scratch the evaluation is based on the video game, and in the case of LEGO Mindstorms evaluation is based on the resolution of the challenge of the geometric shapes. For each of the items is a graduation from 0 to 10, where 0 corresponds to no knowledge of the concept or item, and it is not used significantly in the resolution of the challenge; 10 corresponds to a high level of understanding of the concept and used perfectly within the platform.

6 Results

Following the structure of rubrics for assessment, the results are presented in two groups. The first group corresponds to the mean and standard deviation of the five competency areas, as shown in Table 8. The other group corresponds to the results of the evaluation of Scratch and LEGO platforms, which has also been made the mean and the standard deviation of all items and the results are grouped by levels and groups as shown in Table 9.

Table 8. Mean and Standard Deviation of competent areas for each course and group

		C1		C2		C3		C4		C5	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1	1st	2.68	0.50	2.48	0.64	2.25	0.77	1.66	0.65	3.73	0.86
	2nd	2.67	0.46	2.56	0.57	2.27	0.72	1.68	0.57	3.75	0.68
	3rd	2.84	0.42	2.54	0.58	2.45	0.61	1.95	0.56	3.79	0.69
Group2	1st	3.29	0.69	2.96	0.74	2.64	0.80	2.57	0.80	3.95	0.77
	2nd	3.06	0.66	3.01	0.67	2.66	0.66	2.61	0.80	4.04	0.54
	3rd	3.14	0.66	3.00	0.68	2.71	0.62	2.74	0.75	4.07	0.50

Table 9. Mean and Standard Deviation of Scratch and LEGO task for each course and group

		Scratch		LEGO	
		Mean	SD	Mean	SD
Group 1	1st	5.31	1.04	5.17	0.93
	2nd	5.44	1.08	5.11	0.91
	3rd	5.89	1.48	6.26	1.24
Group 2	1st	6.00	1.02	6.53	1.08
	2nd	5.92	1.19	6.22	1.09
	3rd	6.79	1.32	6.99	1.05

The results obtained in the competent areas have several readings. It studies began with the same knowledge to all groups and levels, and that the work is based on the same activity. That is why we should wait for the results obtained significant upper-mind better than other courses. However, in most of the skills, the mean is not significantly higher up there, and in some cases, the 3rd course does not get the best results.

On the other hand, if we compare the results between the two groups studied, observed in almost all skills are assessed improvement in group 2 compared to group 1. These differences in the average range between 0.22 and 0.61 in competences C1, C3 and C5. This is more relevant on skill C2. Collaboration and Community Building, and C4. Creativity, where differences in the average were 0.45 to 0.93.

The results of the evaluation of Scratch and LEGO platforms follow different trends and results of skills evaluation. Because these platforms have worked more technical and theoretical concepts, the results reflect the idea of getting some higher scores in the higher grades. The observed difference is not much when compared with the 1st to 2nd Secondary, but instead, highlights the increase in ratings to 3rd

7 Conclusions

The analysis of the results based on the difference method is one of the objectives described in this paper. The overall trend in the world of education is to enhance the skills and capabilities over to put emphasis on the theoretical aspects of the technology. We can see how the Group 2 obtained better results in the areas of competence and knowledge of technology platforms in comparison to Group 1. This validates the new approach proposed by the authors.

Another lecture that can be extracted from this study is how to direct lessons and activities. Beyond based on competence issues, the activities to be developed in the second group have been contextualized in situations close to students. Creativity and freedom to continue the learning process of students in the second group has encouraged creativity and learning more participatory. This has led to perform a task where solutions have been more creative and varied. Programs have been longer and more complex, therefore developed better computational thinking and engineering thinking. The goal of improving the technical knowledge of some of the technological platforms in the educational robotics also has been fulfilled. While both groups are treated so satisfaction these concepts, is in the second group where there is a significant improvement in the average and therefore an increase knowledge technical platform

One aspect observed by the authors that have not been mentioned in the process of obtaining the results is that the total duration of the course has not been homogeneous for both groups. Initially, the program was the course of 15 sessions, since the first group need to complete all 15 sessions learning, and in some cases, the low score is caused by not being able to complete the learning sessions. In contrast, the second group, usually need 14 sessions to complete the process and activities. We consider this very important when one of the most important aspects of the development of school curricula is the duration of the course and the needs to improve the learning process. To improve the analysis of results in future experiences, the authors study to use videos and other metrics, such as surveys or interviews to students. With these tools, we could get other data that the current use of rubrics cannot be analyzable.

The development of skills and abilities of the subjects STEAM should help these students to develop in the world of science and technology. Therefore, the main learning goal of this paper was to establish methodological bases in this school, to promote and improve learning skills and knowledge of some technological platform has been fulfilled. Future challenges for in coming years are focused into two aspects. The first relates to improving the design of activities. Especially standardize the environment in which contextualizes and promote a more active creative aspect. Another aspect to consider is the use of the technical concepts of programming. and thus, improve the use of platforms used in educational robotics, whether Scratch, LEGO Mindstorms or others.

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