A Methodological Approach to the Learning of Robotics with EDUROSC-Kids

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Abstract

With advances in science and technology, several innovative researches have been developed trying to figure out the main problems related to children's learning. It is known that issues such as frustration and inattention, between others, affect student learning. In this fashion, robotics is an important resource that can be used towards helping to solve these issues, empowering our students in order to push their learning up. In this case, robotic tools are generally used considering two different paradigms: as the main focus and as a secondary focus. Actually, these paradigms define the way that Educational Robotics is implemented in schools. Most of the approaches have implemented it as the main focus, which is teaching Robotics. Nevertheless, there are quite a few works that implement robotics as a secondary focus, which is currently assisting the learning process in several disciplines. The main contribution of this work is a complete three steps methodology for Robotics in Education to guide projects in order to either use it alone or to teach robotics with others topics. Our experiments show the importance of devising a study plan and evaluation method because the process is iterative and could improve the final results. As a novelty, here we have joined and extended our previous works by proposing a new set of methods with guidelines and strategies for applying the educational robotics standard curriculum for kids, named EDUROSC-Kids. We propose several tools that have been developed to organize the learning topics of Robotics for children, including the desired outcomes during the learning process. As said our current approach is divided in three steps (or phases): setting up the environment, defining the project, and performing evaluation. The proposed curriculum organizes robotics contents into five disciplines: Robotics and Society, Mechanics, Electronics, Programming, and Control Theory. Also, it considers a set of topics for each discipline and defines the level of knowledge that is recommended to achieve each group of children based on Bloom's Nomenclature. The contribution on this paper is a crucial step towards linking the general learning process with Educational Robotics approaches. Our methodology is validated by presenting practical experiences with application of EDUROSC-kids and the proposed method with a rubric guidelines into groups of children.

Keywords Robotics learning · Educational robotics · Standard curriculum · Learning assessment · Schools and industry

1 Introduction

A current field of research involving Education and Technology is to figure out and solve the main problems related to the children's learning, such as frustration and inattention, between others. With recent advances in science and technology, several innovative studies have been done mainly in the light of technology-assisted learning methods [32] towards helping solving these problems. In this direction, Robotics is an important tool that has been applied in order to empower students and push their learning up, as already verified by several researchers [3, 5, 43, 47]. Actually, Education is considered one important application area of Robotics, where students and teachers apply and use robotics tools, so that a better understanding of both is necessary.

In the past few decades, the term robotics meant something to be used in the future, including technology and many artifacts that were usually seen in movies.

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Nevertheless, the area of Robotics has already influenced and contributed to Education since the end of the sixties and early seventies when Seymour Papert developed the idea of using Logo as a computer programming language for young children [9]. In fact, this idea has been spread and nowadays it is part of a field of knowledge named Educational Robotics, which is found worldwide in the curricula of several schools.

Since 1980, they were rehearsed several definitions of Educational Robotics. A good example is the work of Nikki [11] that defines it as a tool for the inclusion of robots in classrooms, in order to teaching Language, Science, and other traditional areas of the learning process. From these initial works, Robotics has taken an important role in Education that was driven to the industry (nowadays the 4.0 industry) that needs professionals with more knowledge in this area that could produce better results in the optimization of time and financial resources.

Other aspects of the actual human (learner/teacher) - robot interaction (HRI) and the method's impact on it such as the related architectures [8] arise with the use of Robotics in the classroom. This also includes robotic ethics and human well being, as described in IEEE standard 7007 and IEEE standard 7007 [33] and in IEEE standard 7010 [19], which is about the recommended practices for assessing the impact of autonomous and intelligent systems on human well-being. Besides some pretty new researches have been done with fruitful results to HRI, ethics, and human well-being, actually, these topics are beyond the scope of the present paper, which is otherwise built over our previous research results [34, 40]. From these previous works we noticed that it is important to standardize contents, skills, and evaluations for educational robotics [34]. In this way, it is possible to set up the concepts that are necessary to be learned in each age and/or level of expertise for developing robotics projects. Also, when talking about children, the standardization becomes crucial because it must be strictly correlated to the primary and secondary education curriculum of a country. E.g. the National Curriculum for Basic Education in Peru, and the Common National Curriculum Base - BNCC in Brazil. A way for evaluating the progress of children according to these local guidelines should also be developed [40].

Having a robotics curriculum and its evaluation in mind is only the first and fundamental step for having a wide application of robotics in the educational context. The next step is to link the robotics curriculum with the general curriculum (primary and secondary education curriculum). That link must include teaching methods and strategies for using robotics prototypes in the learning process and also how to use general knowledge (from STEAM and non-STEAM subjects) in robotics training [28]. Both ways of educational robotics application have its own peculiarities and also share challenges; so, strategies for application must by guided by an standardized and flexible process which includes the before mentioned link.

With this in mind, in this paper we join and extend our two preliminary works. The first work has introduced the EDUROSC-Kids curriculum for teaching children from 6 years to 18 years old, where competencies, skills and levels of knowledge were established [34]. The second work has introduced an evaluation rubric for measuring the progress of learning by using three criteria (design, building and programming, and soft skills) [40]. The main contribution of this work is to define a set of guidelines and strategies allied with the EDUROCSC-kids curriculum in the two aforementioned approaches for educational robotics, which is a crucial step in linking the general learning process with the approaches.

In this sense, this paper is organized as follows. In Section 2 the two approaches for implementing educational robotics are explained. Section 4 explains the EDUROCS-kids curriculum. In Section 5 we sketch out the guidelines and methodologies for applying EDUROSC-Kids. Section 6 shows experiences of using the guidelines proposed in this paper, in addition to the EDUROSC-kids curriculum and the evaluation rubric, which are introduced. Finally, in Section 8 the conclusions of this work are drawn with a last discussion on the results and main further contributions.

2 Educational Robotics and Its Approaches

There are several definitions of Educational Robotics that can be found in works in the related literature. Some of the papers, besides talking about educational robotics, are just about the simple use of robots for teaching any contents, that sometimes are few related to its use and could be done without using this powerful tool [10, 36, 45].

Nice examples of a definition for it are the ones proposed by Pedroso and Mafra [35], and by Silva [43]. The firsts claims that educational (or pedagogical) robotics refers to the use of a robotic system composed of hardware (physical component of the system in which purchased material, or scrap, or yet assembly kits are used) and the software (logical component of the system used to control the robot) in a pedagogical environment of interaction between teacher and student [35]. Nevertheless, according to Silva it is the process of teaching and learning mediated by the robot, which aims to build knowledge in several areas of knowledge, and that can be employed at different levels and stages of teaching [43].

Delgado [11] was one of the first to propose that educational robotics could be used as a tool to teach mathematics, science and other subjects. The TRTWR (Teaching Robotics, Teaching With Robotics) Workshop in

2012 served as a place for discussing the main role of robotics in education and for defining the research lines of it. Catlin and Robertson [9] differentiated between the terms *education robotic* and *robotic education*. The first can be used to define or teaching something with robots and the second defines the teaching about robots. Also, they say that if the objective is teaching robotics, then robots can be used to teach it and take advantages of *education robotic*. Finally, in the same line, Dimitriou [12] proposed a methodology to teach robotics with robots (Table 1).

In the present article, Educational Robotics is mainly understood as the process of introducing Robotics and its related topics inside the set of knowledge of a certain curricular content that is being acquired by a student. The introduction of Educational Robotics in the learning process can be done by following two paradigms (see Fig. 1): robotics as the main actor/protagonist/topic, or as the coadjuvant actor/topic.

Each work about educational robotics found in literature can be classified into one of the two paradigms above proposed. This means that it can be classified as a work either for teaching with robots or for teaching robotics. Thus, educational robotics can be defined as the insertion of robotics and all of its background into a specific curriculum. More than that, in this insertion, robotics can be the main focus or can be the secondary focus (as above said). In the following we depict cases where robotics is the protagonist and also where it is a coadjuvant discipline.

2.1 Robotics as the Main Focus

Intelligent robotics, internet of things (IoT), digital simulation, and programming of robots are popular terms in the population because these are pretty new, emerging technologies. Hence, in order to be capable of developing projects in all of the former subjects, it is necessary to have knowledge and skills in robotics. In this sense, many approaches proposed the development of skills in the main fields that are the basis for doing Robotics: Mechanics, Electronics and Computing.

Examples of the aforementioned approaches can be found in the work of Dimitriou [12], who proposes a program to teach the main concepts of robotics to high school students that are majoring in computer science. In the work of Plaza et al. [37] a course to teach robotics with

Table 1 Robotic Education × Education with Robotics

Robotics as the Main focus	Robotics as the Secondary focus
To learn Robotics	To learn other subjects
Use other subjects as tools	It is a tool to help to learn other subjects
Robotic Education [9]	*Education with Robotics* [9]

different platforms to children from 10 years and upper is proposed. Lastly, the work of Barreto et al. [6] presents a survey about published scientific literature that claims the use of robotics in schools between 2000 and 2009. That work includes 101 analyzed papers where 80% of them explore topics associated with robotics. So, all of them are considered to be robotic education approaches with robotics as the main focus.

2.2 Robotics as the Secondary Focus

A variety of approaches can be found nowadays using robots as tools in order to teach both STEAM and non-STEAM topics. Besides Science, Technology, Mathematics, Engineering and Arts, it also includes disciplines like Religion, Language, and History between others. The main goal of these approaches is to provide more efficient directions for learning in comparison when using traditional materials that are considered sometimes as boring by some group of children.

Examples of this paradigm include the work of Ponce et al. [38] who explains the use of different robotics platforms to teach topics as: sound propagation, the metric system, fractions, and some Physics contents. Authors of the work compared the results of teaching the mentioned topics by using robots and without them. The main conclusion is that the robot helps to teach but the teacher is a very important component of the learning process. A similar finding has been observed in other works as the ones of Barrios-Aranibar et al. [5] and Thomaz et al. [47]. Other examples in Robotics as second focus are: the work of Segovia and Souza [42] who used robotics as a motivational tool for Teaching English; and the work of Xefteris et al. [49] who used robotics and related technology for teaching geography and history.
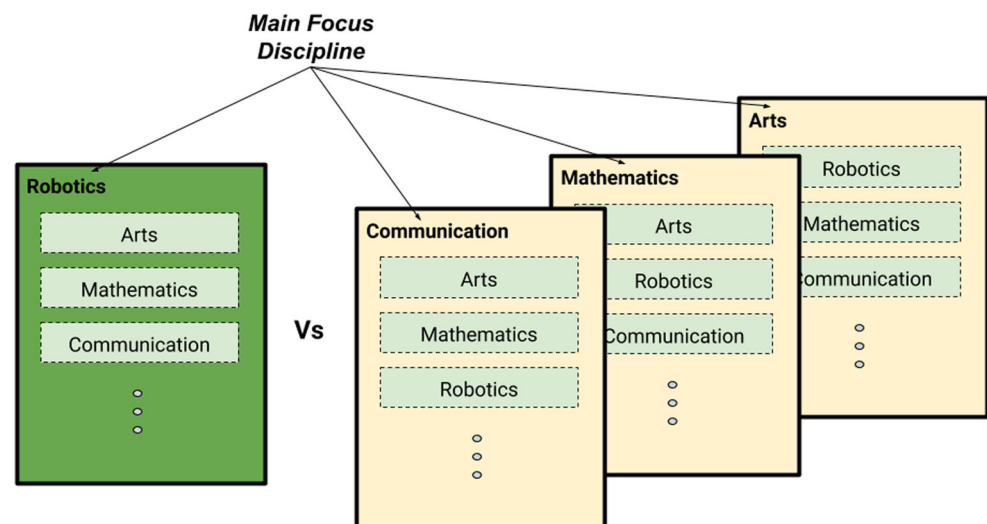
3 Related Works (State of the Art)

Many approaches have been developed in order to motivate children, teachers, schools, and industry to increase their technological literacy. Jung et al. [24] presented an study with more than 30 works explained a lot of benefits to use educational robotics to motivate the learning in children. They explained that all of these works identified two points. The first one is that robotics could connect other skills of different areas and the second point is related to the age of students, because young children could learn as much abilities as other children. As Jung mentioned, robotics is a tool in that many student could see and apply their knowledge in real situations. Misirli et al. [31] mentioned that students can take off the robotics as a tool to help their develop of skill and empower them and

Fig. 1 Paradigms for Application of Educational Robotics

their studies because they are active agent in this process and not only consumers of technology. Anwar et al. [2] presented an study in 139 approaches about the benefits of robotics in the process of learning. They mentioned that the robotics give opportunities to understand and explore solutions to real problems and many others authors demonstrated that students improve their knowledge. The students develop their skills in science, engineering and others science as arts. In these studies showed that many students that experimented their education with robots choose engineering majors and develop abilities to solve several problem with iterative design process.

Other experiences as the one of Kitano et al. [26] that explained the Robocup Junior Project, has as objective the teaching of engineering and the knowledge of robotics for schools, children and even their families. Other results are reported by Hobson [18] who describes the experience of working with students from different schools for developing a robot that is capable of helping the society and that enables team work and socialization. Also, Heuer [17] describes a project developing a robot for museums. That project included the development of soft skills in students.

The Edurosc-Kids is a proposal to organize the learning topics of robotics for children, however, describing how these topics could be teaching for children. Different projects to teach robotics to Children were proposed as Jojoa et al., Blancas et al. Jojoa et al. [23] proposed a methodology to teach mobile robotics for children. This methodology has four step to design solutions to mobile robots. The authors said that problem-solving habits are cultivated throughout their course. Blancas et al. [7] proposed a methodology called CREA with six sessions in order to teach programming for children. They worked with Arduino Platform and evaluate their method with Wilcoxon signed-rank test. They assessed a group of children and the conclusion was an improve the behavior of children around

the six sessions. However, children explored different topics around the robotics, the authors proposed CREA to teach programming. In this case, they use the robots to motivate them. Scaradozi et al. [41] explain an specific program to include Educational Robotics to School. The program include specific objectives for five cycles around the primary school. Many approaches were proposed to use Robotic to teach other concepts as mathematics, Computer Science and others. Friebrom et al. [15] presented an experience to concepts of Computer Science using robotic for children. Jung et al. [24] presented a summary of 41 articles to explain different ways to teach objectives, teach contents, and to teach methods of robotics education in connection to STEM education. Filipop et al. [14] proposed an experience to teach robotics in secondary school. All of them proposed an specific method to teach and describe their experience. However these approaches couldn't be apply in other experiments because their features weren't generalized in order to objective, hardware and users. This work proposes a methodology for teaching robotics where the users and teachers could propose an objective and planning their activities with this guide and choose their material, specific topic and project.

4 EDUROSC-KIDS Standard

The EDUROSC-kids [34] is more than just a proposal for a robotics curriculum. It aims to organize the learning topics of robotics for children, including the desired outcomes during the learning process, as will be described next. In relation to the curriculum itself, it organizes the robotics contents into five disciplines as shown in Fig. 2. The five disciplines are: Robotics and Society, Mechanics, Electronics, Programming, and Control Theory. Also, it considers a set of topics for each discipline and
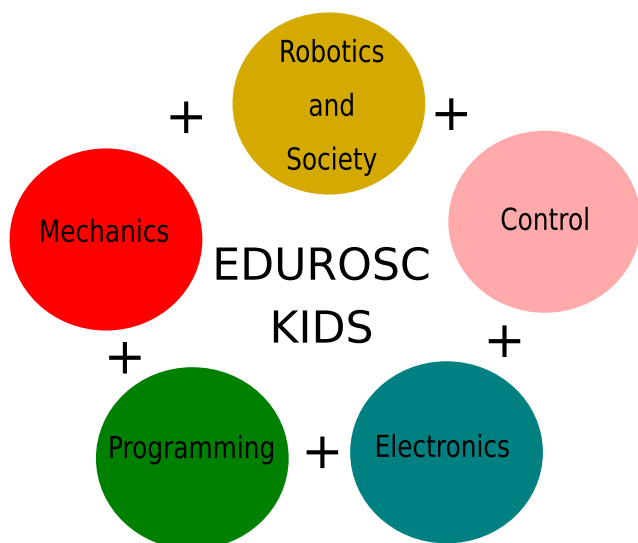
Fig. 2 EDUROSC-Kids: An Educational Robotics Standard Curriculum for Kids

defines the level of knowledge which is recommended to achieve the goals, for each group of children, based on Bloom's nomenclature. The groups are based on age of children grouping them like the K-12 education system does. These groups are G1 (Group One) for elementary school, G2 (Group Two) for middle school, and G3 (Group Three) for high school. These disciplines, their topics, and recommended level of knowledge are explained next.

4.1 Robotics and Society

All technology developed by engineers, practitioners, and in general by any person must help people and contribute to the development of society and the common good. Thinking on this affirmation (either implicitly or explicitly), several researchers used to propose robotics applications in almost every area of knowledge as: Health care [1], Tourism [21], and Agriculture [48], between others. This reality leads to the need of teaching the discipline of Robotics and Society in order to develop, in the students, the awareness about how robotics affect the society.

This discipline seeks to clear to students topics as ethics and general knowledge about the principles of robotics [16]. The contents that are defined for this discipline are described in Table 2. So, this discipline is basically organized in five thematic contents: History of Robotics, Automatons, Hardware for Educational Robotics, Robotics News, and Innovation and Research Projects in Robotics. The main goal is to provide to students a general view of the state of art of robotics and to clear how it is affecting our society nowadays. In order to do that, the first stage is to teach about the history of robotics, the origin of the term robot and also on how to construct the historical first

artifacts that resemble robots (named The Automatons). After that, it is important for them to notice the current technology for prototyping robots (e.g. the hardware that is possible to be used for doing Educational Robotics). And, finally, it is important to teach about commercial products in robotics and new developments that are delivered to be used by people, always leading the student to think about the future developments.

4.2 Mechanics

Mechanics is a field that is part of the basis of any robotics development. Actually, a robot can be seen as a versatile mechanical device. In this sense, in Educational Robotics, the mechanical parts of a robot turn into an important field of study in order to understand the principles of designing and the operation of the different mechanisms, which can be used in prototyping and developing robots.

The contents that have been defined for this discipline and the the level of learning established for each group is described in Table 3. It is organized in eight thematic contents: Project and Construction, Design and Modeling, Specific Educational Robotics kits, Mechanisms, Gears, Gear-crank, Pulleys, and Simple Machines. The main goal is to provide students with the basic knowledge of designing, modelling and construction of robots. After that, students must learn a specific tool, generally in the form of an educational robotics kit. The knowledge about the kit must include all the parts that can permit the students to construct prototypes. Also, if the kit includes a tool similar to a CAD system, it is important to be included in the topics. Finally, students must learn about simple mechanisms and machines, which can give to them the necessary knowledge to design and construct specific type of robots like wheeled, walking or flying ones; or else robots with specific purposes like manipulating objects, cleaning, harvesting, and so on.

4.3 Electronics

As important as the field of Mechanics, Electronics is one of the basic areas for the development of robots. Nowadays, electricity is the main power source of robots and also is the basis element to perceive, send and process signals from/to the different sensors and robotic actuators.

The content defined for this discipline is described in Table 4. It is organized in two thematic topics: Sensors, and Actuators. We notice that processing signals (at electronic level) is not included because the main knowledge related to this field that must be passed to children learning robotics is included in the Programming and Control Theory areas. So, in this discipline students should learn how signals are represented and how the sensors can capture data from the real world and transmit them to a processor in order

Table 2 Thematic fields of the discipline "Robotics and Society"

Thematic content: Robotics And Society		G1	G2	G3
		Bloom's Level		
1.- History of Robotics	1.1 Important events in history. Introduction to the term "robot".	1	2	3
	1.2 Important events in history. The three laws of robotics.			
	1.3 Important subjects in the development of robotics: Mechanics, Electronics, Programming, Control engineering.			
	1.4 The role of robots within society.			
	1.5 Time-line of Robotics.			
2.- Automatons	2.1 Definition of Automaton	2	3	4
	2.2 The evolution of automatons in history.			
	2.3 Representatives of the Automaton's history: Hero of Alexandria and Leonardo Da Vinci.			
3.- Hardware for Educational Robotics	3.1 Educational Robotics Kits: Features, advantages and disadvantages.	2	3	4
	3.2 Educational Robotics Kits Examples: Lego, FischerTechnik, Vex, etc.			
	3.3 Open Hardware: Definitions, features, advantages and disadvantages.			
	3.4 Processors: Definition, features, types, advantages, disadvantages.			
4.- Robotics news	4.1 Service robots and Automation.	1	3	5
	4.1.1 Definition of service robotics			
	4.1.2 Technology in service: Security, advantages and communication.			
	4.1.3 Main Components of Service Robots.			
	4.2 News about developed of robots	1	3	4
	4.2.1 Health support robots: nurse robots, prostheses robotic			
	4.2.2 Bio-inspired Robotics: Cooperative Behaviors			
5.- Innovation and research projects in robotics	5.1 Robotics projects in Google: Google Cars, Boston Dynamics and others.	1	3	5
	5.2 Honda research project: Asimo Robot.			
	5.3 Major researchers in robotics.			

to obtain information about the robot environment. Also, students must learn the basis of the different actuators and how they can transform electronic signals into movement or specific actions in the real world. All of this in a very accessible level to the student.

4.4 Programming

Computing is also one of (if not) the most important fields which form the basis of Robotics. Robot programming is the practical approach of Computing when teaching it in Robotics. It includes the process of designing, writing, testing and maintaining source code of computer programs, to be run embarked in robots. Since robots are electric-mechanical versatile devices controlled by a computer, they can also be considered as computer systems themselves and all the techniques of computer programming can be applied directly to robot programming.

The contents defined for this discipline are described in Table 5. It is organized in two thematic contents: Programming Aspects, and Programming Techniques. At first, it is important to teach to students the fundamentals of programming. This means to understand what is an algorithm and how to use flow control statements. After that, it is important to teach basic concepts like data types, variables, propositional logic, and the use of operators. Next, it is important to teach about vectors and matrices and how they are used to implement and use functions. Also, in robot programming (specially for children) there actually exist several tools, most of them based on the concept of block programming as Blocky (https://github.com/google/blockly) or Bipes (http://www.bipes.net.br/) or even textual programming (http://www.natalnet.br/weduc). In this sense, it is important to teach both kind of programming styles (block based and text based). Finally, if instructors consider important, students can learn about different programming paradigms.

After Learning the basis of programming, students should learn specific topics of computing like sorting algorithms, graphs, meta-heuristics, artificial intelligence, and so on, depending on the level. The advanced topics can be chosen by instructors depending on the application, the

Table 3 Thematic fields of the discipline "Mechanics"

Thematic content: Mechanics		G1	G2	G3
6. Project and construction	6.1. Robot taxonomy according to the environment on which it works.	3	4	5
	6.2. Mobile robots: definition, types of robots according to their locomotion.			
	6.3. Manipulator robots: definition, joints, links, degrees of freedom.			
	6.4. Design and symmetry: definition and importance, application in robotics	2	3	5
7. Design and modeling	7.1. Evolution of ideas through the use of 2D prototyping tools for design.	2	3	4
	7.2. Materials and structures	2	4	5
	7.3. Building materials: recycling, complementary materials.			
	7.4. Structure properties: Definition, types and properties.			
	7.5. Triangulated structures.			
8. Specific Educational Robotics Kit	8.1. Main Features.	2	3	4
	8.2. Recognition of Pieces.			
	8.3. Researches with the Kit.			
9. Mechanisms	9.1. Axles and Wheels.	2	4	5
	9.2. Wheels: definition, classification according to their application.			
	9.3. Axles: definition, operation coupled to a wheel.			
10. Gears	10.1. Definition	2	4	5
	10.2. Roles of operation.			
	10.3. Principles of movement transmission .			
	10.4. Rack and pinion: rack definition, pinion definition, motion transmission.			
	10.5. Machines that use gears.			
11.- gear-crank	11.1. Features of the mechanism: Gear definition, Crank definition	2	4	5
	11.2 Mechanism operation: transformation from circular to linear movement.			
12.- Pulleys	12.1. Definition, operation of the mechanism.	2	4	5
	12.2. Principles of motion transmission.			
	12.3. Double pulleys: advantages of use for the transport of loads.			
13.- Simple machines	13.1. Levers: Definition.	3	4	5
	13.2. First degree lever: Forces acting on a First degree lever. Application.			
	13.3. Second degree lever: Forces acting on a second grade lever. Application.			
	13.4. Third degree lever: Forces acting on a third grade lever. Application.			
	13.5. Lever arms.			
	13.6. Inclined plane: Definition.			
	13.7. Action forces of an object on an inclined plane.			
	13.8. Machines derived from the inclined plane: Wedge and screw.			
	13.9. Motorized machines: Mechanisms with motors.			
	13.10. Design and construction			

availability of tools that are suitable for children, and the background of students that can permit them to understand and use effectively those concepts.

4.5 Control

Since the Programming discipline only intends to teach the fundamentals of robot programming, it is necessary to teach the students on how to link programming with the electric-mechanical parts of the robot. This means that it is important to teach how to obtain, process, and fuse sensory data in order for the robot to figure out the status of its environment. Also, the obtained data should be transformed into useful information that can be mapped into decisions and control actions for the robot actuators in order to have the robot acting according to some specific situations and needs. Those necessities are based on the mission of the robot.

Table 4 Thematic fields of the discipline "Electronics"

Thematic content: Electronics			G1	G2	G3
14. Sensors	14.1. Perception	14.1.1 Definition of perception.	3	4	5
		14.1.2. Human perception: senses.			
		14.1.3. Robotic perception: sensors.			
	14.2. Sound based sensors	14.2.1 Sound property.	2	4	5
		14.2.2. Distance sensor, sensor property.			
		14.2.3. Sound sensor, sensor property.			
	14.3. Light based sensors	14.3.1 Light property.	2	4	5
		14.3.2. Light sensor, sensor property.			
		14.3.3. Color sensor, sensor property.			
15. Actuators	15.1. Movement and action	15.1.1 Definition of movement	2	4	5
		15.1.2. Action definition.			
		15.1.3. Replica of actions and movements of living beings.			
		15.1.4. Actuator: definition, when and how to use it.			
	15.2. Motors and servomotors	15.2.1 Definition of electric current.	2	4	5
		15.2.2. Definition of engine.			
		15.2.3. Torque Definition.			
		15.2.4. Types of engines.			
		15.2.5. Direction of rotation and speed.			
		15.2.6. Types of engines.			
	15.3. Display and Sounds	15.3.1 Visualization and information gathering.	2	4	5

Table 5 Thematic fields of the discipline "Programming"

Thematic content: Programming			G1	G2	G3
16. Programming aspects	16.1. Algorithms	16.1.1 Algorithm Definition	2	3	4
		16.1.2. History of the term algorithm.			
		16.1.3. Algorithm design: flowcharts, Pseudo-codes.			
	16.2. Flow control statements	16.2.1. Conditional sentences.	1	2	3
		16.2.2. Repetitive sentences.			
	16.3. Basic Aspects	16.3.1 Data types	1	2	3
		16.3.2. Variables			
		16.3.3. Propositional Logic			
		16.3.4. Operators			
	16.4. Advanced Aspects	16.4.1 Matrix	1	2	3
		16.4.2 Functions			
	16.5. Block Programming	16.5.1 Pseudo-code	2	3	4
		16.5.2 Introduction to robot programming platforms			
		16.5.3 Programming offline and online environments			
		16.5.4 Virtual environments			
	16.6. Textual Programming	16.6.1 From Pseudo-code to Textual Programming	1	2	3
		16.6.2 Compilation and Bug correction			
17. Programming Techniques	17.1. Advanced Algorithms	17.1.1 Graphs	1	3	4
		17.1.2 Finite state machine.			
		17.1.3 Meta-heuristics			

The contents defined for this discipline are described in Table 6. It is basically organized in three thematic contents: Navigation, Teleoperation, and Feedback Based Control. This means that at first the students should learn how to implement self localization of robots by allowing them to exploring and navigating into their world. Also it is important to teach them how the dynamic behavior of robots is modeled. After that, it is important to teach students concepts about teleoperated robots and how to implement them, because it will help students to understand how to think and develop control algorithms for the robots. Finally, it is important to teach to students the fundamentals of control theory like PID control and other basic control techniques.

5 A Methodology for Applying EDUROSC-Kids in School

When thinking about educational robotics, researchers and practitioners, support their approaches in the development of projects. In this sense, many approaches for developing robotics projects have been proposed. Most part of them are developed for teaching STEAM disciplines. For example, Kopcha et al. [27] propose a method to develop a curriculum on STEAM for Robotic Education. However, as depicted above, robotic education is a tool that can be used to learn many kinds of concepts, including STEAM and non-STEAM, as explained by Bennitti [6]. Finally, Robotics is a field that can be taught as the main focus by using other disciplines as secondary ones. Thus, it is important to have

methodological guidelines for teaching both paradigms of educational robotics, and for both kind of disciplines, STEAM and non-STEAM.

In this direction, we propose a process that includes methodological guidelines to apply a robotics curriculum for implementing Educational Robotics by way of developing projects. This approach is general and can be applied with any curriculum. However, in this paper the EDUROSC-Kids standard curriculum [34] is used. The use of projects in educational robotics is widely disseminated in the community and also the most relevant tournaments related to the field apply this strategy [25, 26, 29, 30, 44].

The approach is basically divided in three phases: (1) *Setting up the Environment*, where must be considered socio-economic, cultural, and educational variables and also the topics included in the educational robotics curriculum to be used (e.g. EDUROSC-Kids); (2) *Defining the Project*, where the project components are planned and developed; and (3) *Performing Evaluation*, where the success of the project and the learning outcomes are measured. Figure 3 shows the flow diagram of the activities to be executed in order to implement a robotic project for educational purposes. For each project to apply the robotics to teach different topics, this work suggests to use our methodology because it supports an study plan and it is independent of an specific hardware or software. In this sense, the teachers need to recognize the environment, know the students and recognize the objective to achieve. After that, the course needs an study plan as Edurosc-kids that could guide the topics. The evaluation is very important because this process is iterative and try to improve the experiences of students.

Table 6 Thematic fields of the discipline "Control"

Thematic content: Control	G1	G2	G3		
18. Navigation	18.1. Dynamic	18.1.1. Direction and speed of movement	1	2	3
		18.1.2. Mobile Dynamic			
	18.2. Location	18.2.1. Where am I?	2	3	4
		18.2.2. Direction			
		18.2.3. Displacement.			
	18.3. Exploration	18.3.1. How do I reach my goal,	2	3	4
		18.3.2. Avoid collisions.			
		18.3.2. Linear and angular speed.			
19. Teleoperation	19.1. Teleoperated robots	19.1.1. Definition of a teleoperated system.	2	3	4
		19.1.2. Definition of master and slave.			
		19.1.3. Interface Definition			
		19.1.4. Operator definition			
		19.1.5. Bluetooth technology			
20. Feedback based control	20.1. PID control	20.1.1. Proportional Control	1	2	3
		20.1.2. Proportional - derivative control			

Fig. 3 Process for developing projects with application of EDUROSC-Kids curriculum
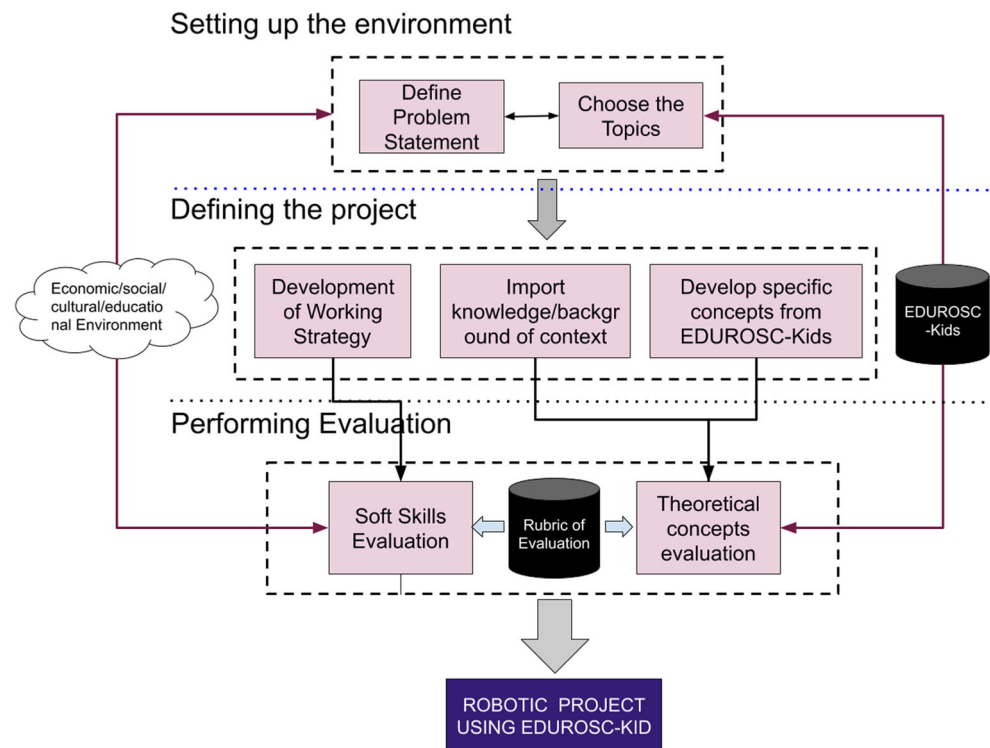
5.1 Setting up the Environment

It is known that if students understand the importance of gaining knowledge, they would be motivated to learn more and more. This assertion was made by Pea [39] when explaining math applications where the students have seen their world as a mathematical world. It is also valid for robotics, where the students can see the potential applications of robotics in every daily human activities.

Understanding the environment is an opportunity to learn and construct solutions for problems into it. These problems and its causes are an opportunity to find potential solutions [46]. For this reason, when a new robotic project is planned the objective is specified by the designer and the knowledge of the environment could help to achieve it. Also, the designer should decide if Educational Robotics is going to be implemented to learn some knowledge field with robots or to learn robotics by including the knowledge of other fields. That means that the designer should decide if robotics will be the main or the secondary focus. This is the first variable to set up when thinking about the environment itself. Also, the set of actions defined in the following must be performed at this initial stage.

5.1.1 Defining Problem Statement

In order to define the project, it is important to figure out a problem to be solved by it, as a project does not exist without a problem. In this sense, the following three questions (about the children's environment) need to be answered:

– How is the children's environment in terms of the cultural, social, economic and educational situation in their community?
– What are the main economic/social/cultural/educational drawbacks to solve in their environment?
– What are the prerequisites that children need to develop in the project, in terms of knowledge and resources?

Answers to the previous questions will help designers to think about what kind of project is the best for children. Also, designers must consider the project that will motivate most of the students, and also that the main objective is to develop basic concepts of science (and other disciplines), and soft skills using Robotics.

5.1.2 Choosing Topics

Considering the answers to the questions for defining the problem statement, it is necessary to define the topics that students must know about Robotics according to the variables that define their environment. As seen above, EDUROSC-Kids defines specific topics grouped into five disciplines (Fig. 2) and it suggests the level of learning that shall be reached on each topic. In this action, the designer must specify:

– How many sessions do they need in order to develop the desired levels of learning?
– What communication tools could he use to develop the teaching-learning process?
– What other tools could he used to stimulate the development of soft skills?

As seen, the main advantage of Educational Robotics is the inclusion of technology as a tool to develop knowledge and soft skills with a specific proposal. However, robotic projects must also help to increase the knowledge of theoretical concepts learned in the school and understanding the applications of them. Also, it is important that students understand the benefits of applying robotics in their environment.

5.2 Defining the Project

This is a second phase in the robotic project development with children. After the set up of the environment, the project is going to be planned and executed. We propose to achieve this phase in three steps, as depicted next.

5.2.1 Developing a Working Strategy

The educational robotics is a powerful tool to teach different contents such as engineering [6], computational thinking [4] and also other specific concepts. It can stimulate different skills as problem solving, creativity and collaboration [20]. In this step the designer should define:

– Teaching methodology, for example, the designer could choose project-based learning as showed by Karahoca [25] or some agile methodology, between others.
– Define the timing of sessions, which includes the number of sessions, as well the time to be spent in each session and the schedule of them.
– Working strategy of children considering is specific talents, previous knowledge, and preferences.

5.2.2 Importing Knowledge and Background of the Context

Children have a prior knowledge and need some knowledge about different topics, not only related to robotics, which can influence on the development of the project. This knowledge must be defined, and a strategy for using and improving it must be sketched. The selected topics must be categorized based on its relevance to the project and the level of knowledge needed from students.

5.2.3 Developing Specific Theoretical Concepts from Curriculum

In the phase of definition of the problem statement, it was chosen a set of topics to include in the project. However, it is important at this time to refine the selection based on the planning of the project. This can lead designers to include new topics or to eliminate some that are not so relevant considering the timing, the necessities of the project, and the previous knowledge of students.

5.3 Performing Evaluation

The use robotic projects is known to be a powerful tool to develop different skills in students. Actually, we have introduced a rubric for educational robotics on competition-based projects [40]. That rubric is well suited to be used in this approach because it is based on the use of robotics projects for developing knowledge and skills in students. However, an evaluation must be performed with it in the two main aspects described next.

5.3.1 Soft Skills evaluation

It corresponds to the third evaluation criterion of the rubric, on which the unifying and Team Aspects are evaluated. It includes four variables that are described as follows:

– Variable 1: Communication: In terms of effectiveness and consistency. It is considered if the student inquires questions, makes suggestions, answers questions correctly, and explains his answers.
– Variable 2: Team work: In terms of defining specific roles for each team member in the project and the support among members of the same team.
– Variable 3: Creativity-Ethics-Responsibility: In terms if uniqueness and imaginative design of the solution. Also, it is considered that robot and the students do not have unethical aspects by preventing damaging others.
– Variable 4: STEAM Topics Integration: In terms of linking the robotics project with the subject area the instructor wants to explore and see additional topics related to Science, Technology, Engineering, Arts and Mathematics. Also it is important to notice that this variable could be applied to non-STEAM topics.

5.3.2 Theoretical concepts evaluation

Corresponds to the first and second criteria of the rubric, which are related to Design and Design Process, and Building and Programming. Also this evaluation could consider other specific criteria for non-robotics topics to be evaluated. It is recommended that teachers design the specific criteria by mimicking what is proposed in the rubric. In the case of Design and Design Process, the following four variables are defined:

Table 7 Main thematic in Robotics Club UCSP since 2018

Year	Group according K-12					
	G1:6 - 9 years old		G2:10 - 13 years old		G3:14 - 18 years old	
	Theme	Quantity	Theme	Quantity	Theme	Quantity
2018	Smart Cities	45	Soccer robots	38	Manipulators robots	12
2019	Robots for Medical Assistance	48	Rescue Robots	48	Agroindustry Robots	16
2020	Farming Robots	38	Logistic and Automation Robots	38	Autonomous Parking	15

– Variable 1: Creation of Viable Solutions for the Challenge: In terms of proposition of multiple solutions and selection using relevant criterion of the best one.
– Variable 2: Simple and Complex Mechanisms and Systems: In terms of the number of simple and complex mechanisms used by students.
– Variable 3: Design Process and Documentation: In terms of having a structured process of design and development and also with the compilation of evidence.
– Variable 4: Use of Resources: In terms of correctly identifying the need for the resources used in the project.

And, in the case of Building and Programming, the next four variables are defined:

– Variable 1: Mechanical System: In terms of the quality of construction of the mechanical system designed.

Fig. 4 The Advertisement of Robotics Club - Summer 2020

Table 8 General Schedule of UCSP Robotics Club - Summer course 2020 - in G1 Group

SESSION 1: Introduction of motors, sensors; project with ultrasonic sensor
SESSION 2: Introduction to Agriculture; shovel tractor project
SESSION 3: Programming with challenges
SESSION 4: Final robot chassis, go back and forth with the ultrasonic sensor
SESSION 5: Plowing and Sifting
SESSION 6: Seed Dispenser
SESSION 7: Finish the robot with its three mechanisms
SESSION 8: Final Presentation

– Variable 2: Control System: In terms of the correct development of the control system of the prototype.

– Variable 3: Electrical and Electronic System: In terms of quality of connections and use of electrical and electronic components.

– Variable 4: Programming: In terms of the quality of the computer program developed for the prototype.

6 Experiments and Validation of EDUROSC-Kids

We performed several experiments in order to verify the applicability of the methodology proposed in this work. Basically, the Robotics Club of the San Pablo Catholic University at Arequipa (UCSP Robotics Club) is used as a test-bed for this, besides the EDUROSC-Kids has been adapted later to work with teachers in the Northeast of Brazil. Our Club attends children that want to learn robotics aging from 6 to 18 years old. Every year the club opens two cycles: Summer cycle and Annual cycle. The summer cycles are short courses (in January) and frequently it has 48 hours and 8 - 12 sessions. Table 7 shows the details to summer club since 2018 and specify special themes that we use to teach robotics.

In order to validate this approach, we explain two main cases:

– Case 1:Summer Club 2020: These case explain experiences with children with 6-18 years old. Our course of robotics had three groups according k-12. 38 children between 6-9 years old, 38 children between 10-13 years old and 15 children between 14-18 years old.

Table 9 Programming Discipline

16.1.1 Algorithm Definition
16.1.3.Algorithm design:flowcharts, Pseudo-codes.
16.2.1. Conditional sentences.
16.2.2. Repetitive sentences.
16.5.2 Introduction to robot programming platforms

– Case 2:Annual Club 2020: This case explain our experience with a virtual course because it occurred in September - November 2020.

In the following we depict the projects and also the virtualization of the club with the pandemics.

6.1 CASE 1:Summer Club Robotics

The club is divided according to k-12, into three groups: (1) G1 with children from 6 - 9 years old, (2) G2 with children 10-13 years old and (3) G3 with children 14 -18 years old. In a robotic project, the first step is to decide the role of educational robotics. It could be used as a tool to teach some concepts, or as a main focus in the project (that means for teaching robotics). The robotics projects proposed in the club have the robotics as main focus and they are planned with specific topics, according to the environment. Also, as an example, Figure 4 shows the advertisement of UCSP Robotics Club summer course for 2020.

The methodological approach introduced in this document has been used to plan the contents of each UCSP Robotics Club course. In order to better understand this, we explain below the step by step on how to plan the course according to the EDUROSC-KIDS directives.

The UCSP robotics club has many courses for children and educators. Here, we show the method for preparing the contents of a short course to children in G1 (6 - 9 years old) using EDUROSC-kids. The process has three phases, setting up the environment, defining the project, and performing evaluation (rubric), as described next.

6.1.1 Setting up the environment

The environment defines the Scope of the robotics project. In this sense, the planning needs to be organized in two steps:

A **Define Problem Statement**: It is all about the environment. So the following three questions (about the children's environment) are answered here:

Table 10 Specific Topics of the discipline "Robotics and Society" to Virtual Robotics Club Course 2020

Thematic content: Robotics And Society		Session	Kind of Evaluation	Time
1.-History of Robotics	1.1 Important events in history. Introduction to the term "robot".	1	Questionnaire	1h.
	1.3 Important subjects in the development of robotics: Mechanics, Electronics, Programming, Control engineering.	1	Questionnaire	1h
	1.4 The role of robots within society.	1	Questionnaire	1h
2.- Automatons	2.1 Definition of Automaton	2	Experiment	1h.

- Defining how is the children's environment: Children are 6 -9 years old. The social-economic position of the children is similar. 100% of them live in Arequipa-Peru. Arequipa is a city with 40% of its surface dedicated to agriculture. In Arequipa, a few technology is used in Agriculture.
- Defining what are the main (economic/social/cultural/educational) drawbacks to solve in their environment: Agriculture does not use technology. Land's owners employ people to sow and other activities. For this reason, the cost of production rises as well as the production is dependent of the workforce.
- Defining what are the prerequisites that the children needs to develop the project: In terms of knowledge and resources. The children know the products of the market and which of them are produced in Arequipa. About other concepts, they can read and understand different texts.

B **Choose the Topics**: According to the environment, the final project aims the design of a robot to help in the agriculture. This robot could help to sow. Many kinds of technologies are collected for showing different technologies. The topics of EDUROSC-KIDS are chosen to develop a prototype to solve the challenge. For that, the following questions are answered:
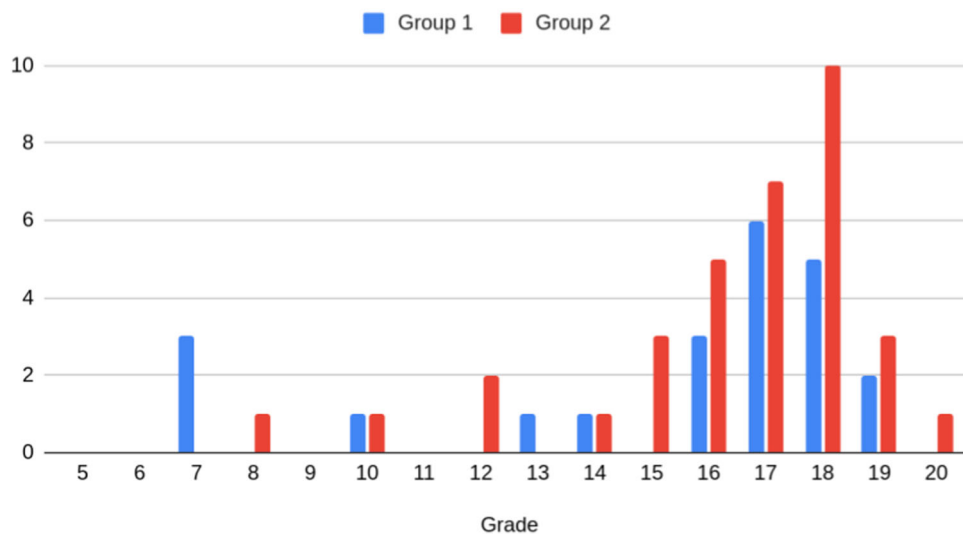
- How many sessions do they need in order to develop the desired levels of learning? This is a short course and is defined by 8 sessions. As well,
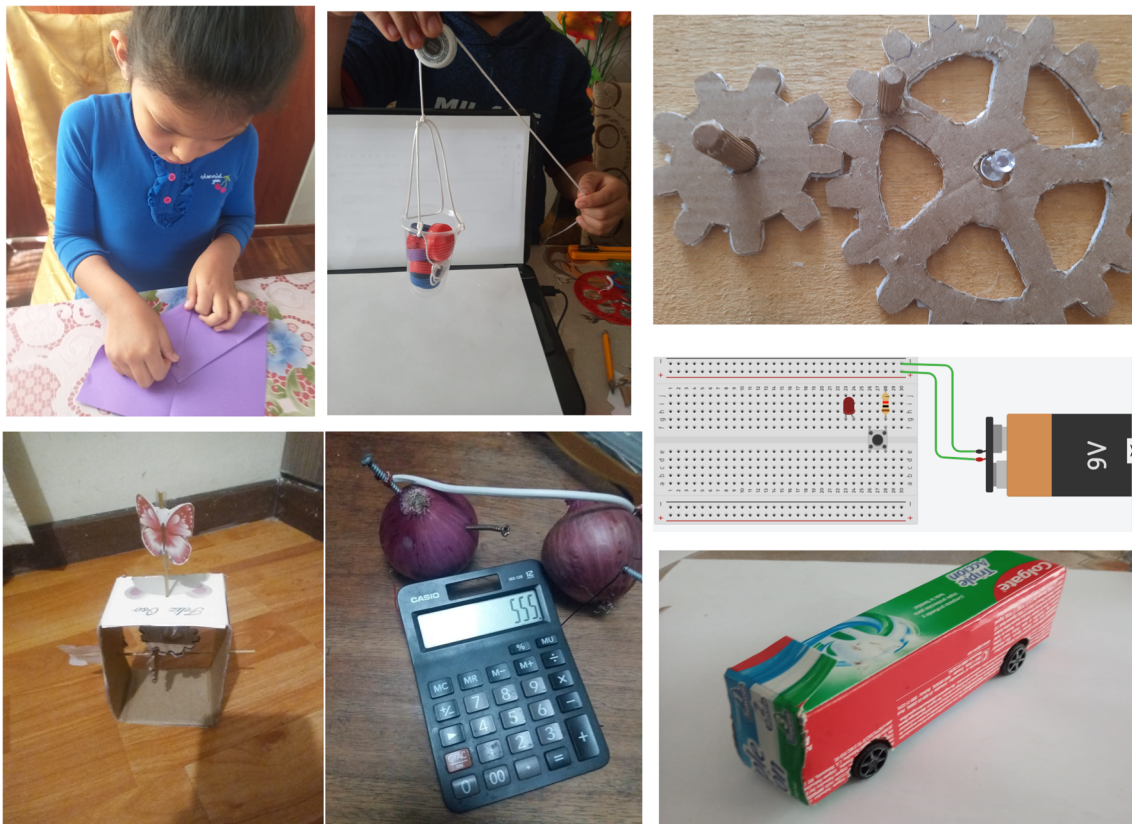
Fig. 5 Experiments of Children in the Virtual Course

Fig. 6 Grade after the evaluation of Topics Robotics and Society of EDUROSC-KIDS in two different groups of children

the children have 18 traditional classroom-based education and they need 18 hours to complement their formation.

– What communication tools could he use to develop the teaching-learning process? Each session of robotics is two and a half hours. At the first time, children need to know each others, for this reason, in all the session, they are going to work in groups and activities of interaction as games, oral presentations, etc are planned.

– What others tools could he use to stimulate the development of soft skills? In order to achieve the objective, The rules of behaviour are presented for everyone. These rules try to organize the

session and stimulate the participation of all of them in the same form. Groups are organized into the classroom and each member has an specific role (e.g. manager, logistics, builder and viewer), also each session the roles must be changed.

6.1.2 Defining the Project

The project is about Agriculture robots that can help in the land. This approach is going to be done in three steps:

A **Develop working strategy:** The project needs to experiment many things as kind of seed, earth, frictional

Table 11 Specific Topics of the discipline "Mechanics of EDUROSC-KIDS" to Virtual Robotics Club Course 2020

Thematic content: Mechanics		Session	Kind of Evaluation	Time
6. Project and construction	6.1 Mobile robots: definition, types of robots according to their locomotion.	2	Desing	1h.
	6.4 Design and symmetry: definition and importance, application in robotics.	1	Questionnaire	1h
7. Design and modeling	7.3 Building materials: recycling, complementary materials.			
	7.2 Materials and structures	1	Questionnaire	1h
	7.4 Structure properties: Definition, types and properties	2	Experiment	1h.
	7.5 Triangulated structures.			
9. Mechanisms	9.1 Axles and Wheels.	3	Memotest	45min
	9.2 Wheels: Definition, classification according to their application in the world	3	Questionnaire	1h
	9.3 Axles: definition, operation coupled to a wheel.	3	Pairs	1h
10. Gears	10.1 Definitions	3	Experiment	1h
	10.3 Principles of movement transmission	3	Experiment	1h
11. Gear-crank	11.1 Features of the mechanism: Gear definition, Crank definition	3	Experiment	1h
12. Pulleys	12.2 Principles of movement transmission	3	Experiment	1h

Table 12 Specific Topics of the discipline "Electronics" to Virtual Robotics Club Course 2020

Thematic content: Electronics		Session	Kind of Evaluation	Time
Electricity	Circuit	4	Questionnaire	1h
	Direct current and Alternating current	4	Pairs Game	1h
	Electrical Resistance, current and Voltage	4	Simulations	1h
Energy	Mechanical Energy	5	Questionnaire	1h
	Potential Energy	5	Questionnaire	1h
	Kinetic Energy	5	Questionnaire	1h
14. Sensors	14.3 Perception Light based sensors	5	Pairs Game	1h
15. Actuators	15.1 Movement and Action	6	Questionnaire	1h.
	15.2 Motors and Servomotors	6	Experiment	1h

force and others. Considering these variables, aspects as methodology and content is necessary to define. About the Teaching methodology, the project is going to develop by Golden PBL [22]. The schedule of course is shown in Table 8. According the schedule, it was chosen specific thematic fields of EDUROSC-KIDS to develop the challenges. The Table 9 shows the thematic fields of Programming discipline chosen to learn them this topic.

B **Import Knowledge and Background of the Context:** The selected topics were categorized based on its relevance to the project and the level of knowledge needed

C **Develop Specific Theoretical Concepts from Curriculum:** It was chosen a set of topics to include in the project. Also, they were refined based on the planning of the project.

6.1.3 Performing Evaluation

In order to analyze the comprehension and learning of the children, the variables of the rubric for educational robotics on competition-based projects is used [40]. Figures 10, 11, 12 and 13 show the progress of 4 students of the summer cycle 2020, considering Programming as discipline and Control sentences and electronics with the theme of sensors

as the thematic field in EDUROSC-KIDS. In this case, the children had three sessions of programming: 3, 5 and 7 session of the general schedule and the content is explained in Table 9. After each session, the rubric was applied and Figs. 10 to 13 show the learning progress.

6.2 CASE 2: Virtual Robotics Club UCSP

A second experiment described here came up when the COVID-19 pandemic has forced to change everything around the world to be done in virtual format, on the web. In order to continue the learning, the UCSP's Club figured out to continue with Robotics Sessions with children. This section describes the application of this approach to Robotics learning, over the same methodology above.

The virtual Robotics Club is a course defined in 12 sessions. In this case two groups were defined (G1: 6-9 and G2:10-13). The environment definitely is influenced by the pandemic however, to keep children in peace and calm is a very important issue. In this sense, the main message for them is thinking in the future and how the technology could help to improve the life in time of pandemic and also after it.

Table 10 shows the schedule of the virtual course in the Robotics and Society discipline of The EDUROSC-KIDS. Also, the table defines the number of sessions that each content was planned with, a kind of evaluation of

Table 13 Specific Topics of the discipline "Programming" to Virtual Robotics Club Course 2020

Thematic content: Programming		Session	Kind of Evaluation	Time
16. Programming Aspects	16.1 Algorithms	7	Flowcharts	1h
	Computational Thinking	7	Pseudo-codes	1h
	Unplugged Techniques	7	Experiment	1h
	16.2 Flow Control Statements	8	Simulation	1h
17. Programming Techniques	17.1 Advanced Algorithms	9	fill in the blanks	1h

Table 14 Specific Topics of the discipline "Control" to Virtual Robotics Club Course 2020

Thematic content: Control	Session	Kind of Evaluation	Time	
18. Navigation	18.1 Dynamic	10	Experiment	1h
	18.2 Localization	10	Questionnaires	1h
	18.3 Exploration	11	Simulation	1h
19. Tele-operation	19.1 Tele-operated Robots	12	Simulation	1h

it, and the time to be spent (Fig. 5). The tools used in the virtual course were Google Meet and Nearpod. Each session tries to explain the specific content defined by EDUROSC-KIDS. The evaluation was done by using our rubric [40]. Figure 6 shows the 2 variables used: (1) Simple and Complex Mechanisms and Systems of the Design; and (2) Design Process in Robotic and Society discipline.

About the Mechanics discipline, Table 11 shows the content of the virtual course, with the session number, a kind of evaluation, and also the time. To face the virtual education, sessions on Mechanics were used with recyclable material and using simulations. Figure 5 illustrates with photos some of the children experiments.

About Electronic discipline, Table 12 defined the content of the course. However the content of 4 and 5 sessions are not include in EDUROSC-KIDS for G1 because they are implicitly in topics as "14. Sensors" and "15. Actuators". So, they are included by the first phase of develop of project: *Setting up Environment*. Tables 13 and 14 show the contents of the last sessions.

All of topics that were chosen of Edurosc-Kids help us to guide our projects. In this sense, we explained that in a specific project is very important to set up the environment and variables, after that, we need to decide the strategy of teaching. This process is iterative to improve the learning and improve the results.

Specific grades after the evaluation of topics Mechanics, Electronics and Programming in the two sessions can be seen at Figs. 7, 8, and 9 respectively.

7 Results and Discussion

In order to apply our proposal, for each one of experiments we choose specific content of EDUROSC-kids to organize the topics to teach. After it, with the methodology proposed, it was organized the process to teach. Two experiences are described here: Case 1 - Summer Club; and Case 2: Virtual Club.

In this methodology it was explained three main steps: 1)Setting up the environment; 2) Defining the project; and 3) Performing evaluation. In all experiences that we explain specified details as the environment that is very important to set up the planning of the robotic project.

About the first step in our first case, the children live in Arequipa-Peru and they share a lot of things as culture,

Fig. 7 Grade after the evaluation of Topic Mechanical in two sessions
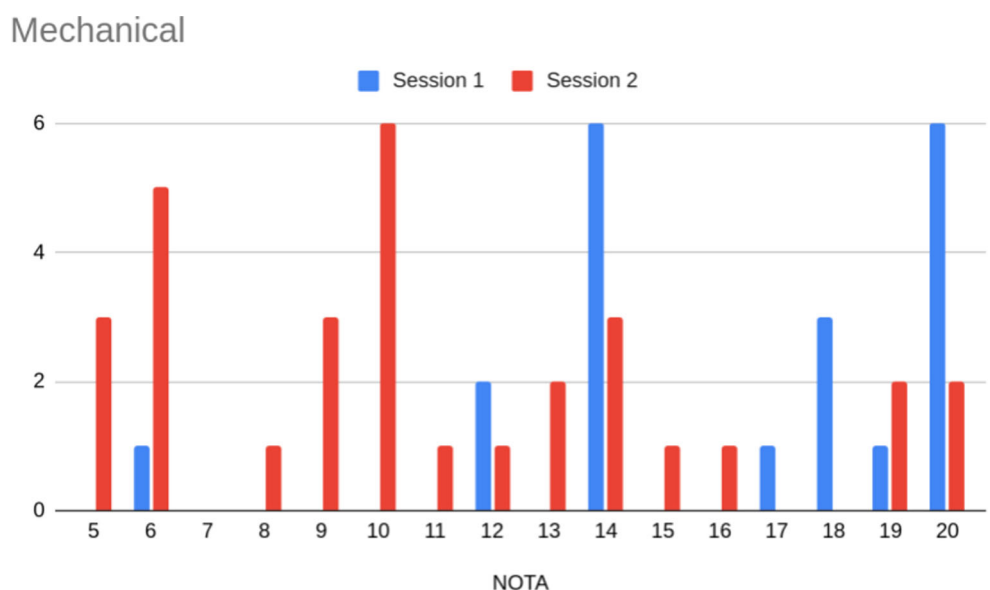
Fig. 8 Grade after the evaluation of Topic Electronics in two sessions
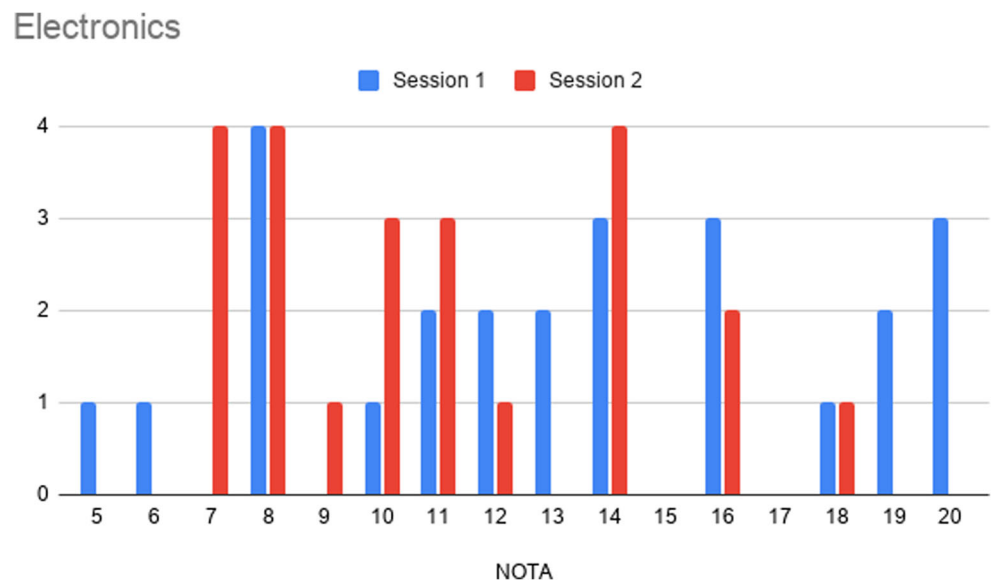

traditions and specific things of their environment. In our second case, the environment is very important too. In this case, the course was virtual and everyone has lived the pandemic in some specific moment. In both cases we have chosen a real problem as health or agriculture. After that, the topics were defined and developed based on the study plan from EDUROSC-Kids.

About the second step, the teachers have developed guides to figure out our courses and the working strategy was based on the problem-solving approach. In other situations it is possible to use other strategies as trial-error or exploratory learning approaches. Jung et al. [24] explained in many proposals other strategies, however, for all of them

it is very important to define and set up the environment and their variables.

About the third step, we evaluated our experiences and showed the progress of learning, for the children, in different topics of robotics as mechanic and programming. We used an evaluation method proposed by Rodriguez et al. [40] and with this evaluation we could compare features as working group and other soft skills. Jung established seven factors to involve Children's Robotics Learning and we set up all of them. Figures 10, 11, 12 and 13 show the progress of learning in a specific topic into the study plan with a real problem that could be agriculture (case 1) or health (case 2).

Fig. 9 Grade after the evaluation of Topic Programming in two sessions
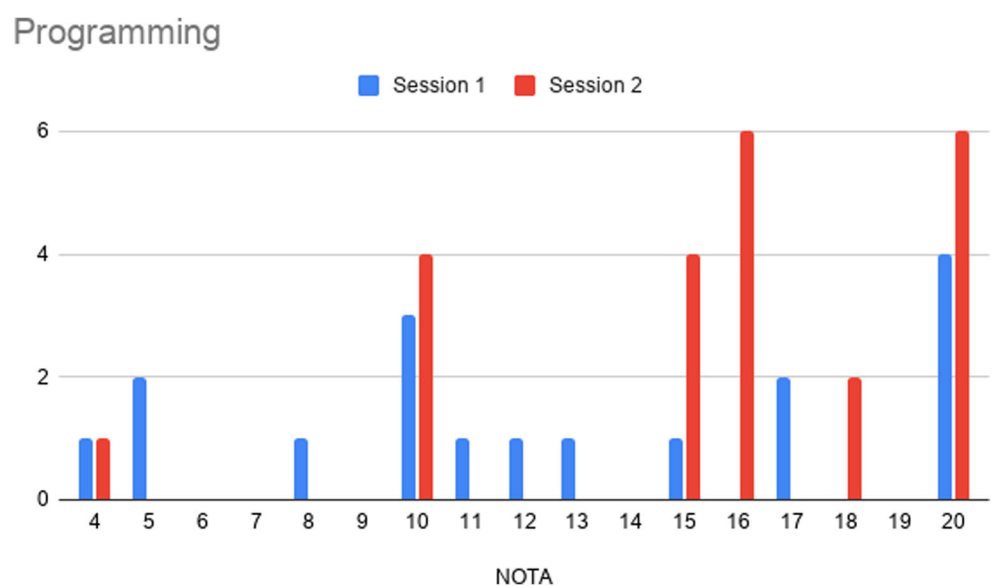
Fig. 10 Progress of students in G1 a total of eight sessions of which four were about programming topics. The red bars represent the percentage of children who are in progress, the yellow bars represent the expected achievement and the green bars the outstanding achievement
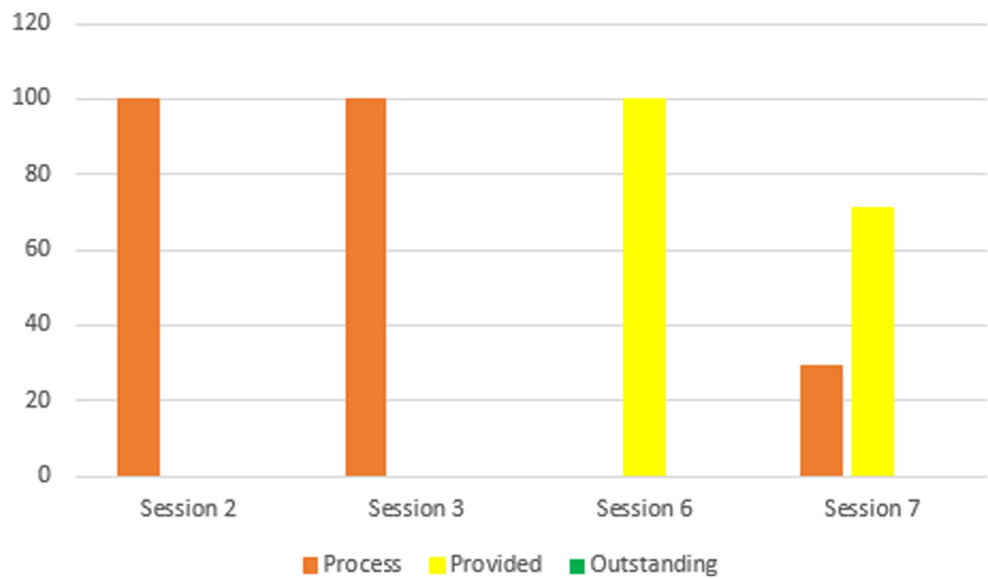

8 Conclusion

This paper proposes a methodology for developing projects with application of a standard (EDUROSC-Kids) curriculum. This proposed methodology is geneeral and it can be applied with any Educational Robotics curriculum. Also, there were presented several experiences of using this process, including the EDUROSC-Kids curriculum [34] over the rubric proposed by Rodriguez-Siu et al. [40].

This work brings valuable contributions, mainly the practical result is that it is possible to formalize the process of teaching-learning in Educational Robotics in both paradigms (teaching Robotics contents itself and teaching other disciplines with Robotics). In this case, this

paper proposes a formalization that can be used both for teaching robotics as a main focus and for teaching other topics using robotics as a tool, that means for teaching using robotics as a secondary focus.

We notice that there exist several approaches for Educational Robotics. Nevertheless, most part of them is related to new hardware approaches and with the use of some specific hardware. On the other hand, the approach of this paper is more general and can be applied with any curriculum, hardware, and evaluation rubric. This includes curses on Robotics for undergraduate and graduate level and also on training courses for the Industry 4.0, for example. This proposed approach in conjunction with the EDUROSC-Kids curriculum and the evaluation rubric are

Fig. 11 Progress of students in G1, a total of eight sessions of which five were about programming topics
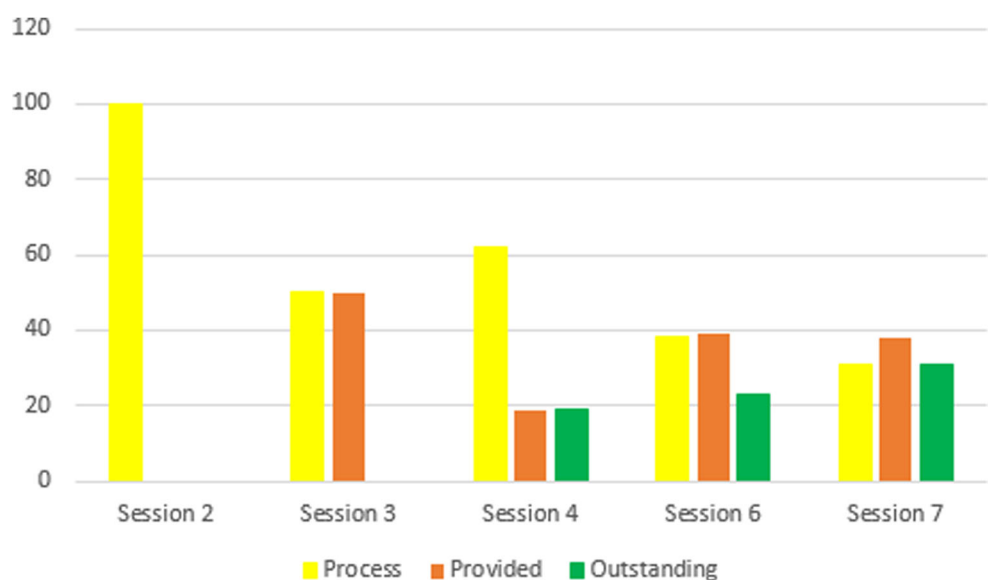
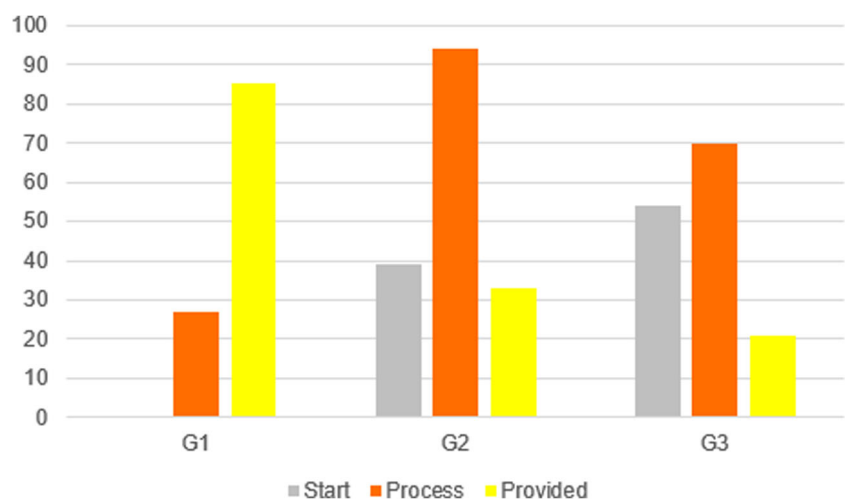**Fig. 12** Progress of students in G1, a total of eight sessions about programming topics
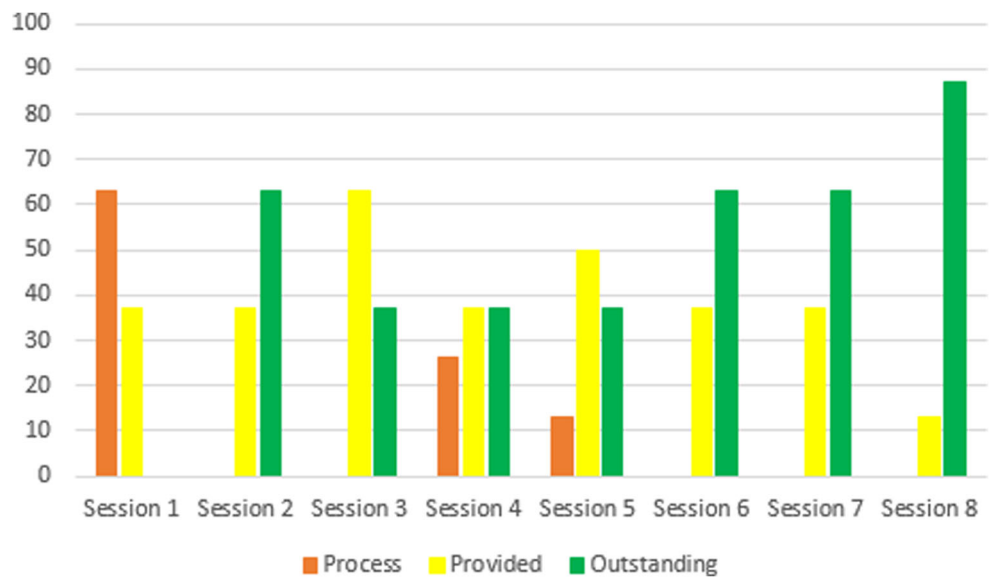
examples of generic tools, enough to be applied both in online education and traditional classroom-based education, besides on training courses. So their better formalization here is also a contribution of this paper to the Robotics community. We notice that they are able to be applied both with specific hardware or with simulated environments, as for example the sBotics (https://weduc.natalnet.br/sbotics/) [13], which is our next goal. The last tool has been used in the Brazilian Robotics Olympics and it has more than 18 thousand accesses for downloading currently. Both tools can be used in combination for a better spread of Robotics in the world, without the need of having hardware.

As explained in the beginning of experiments, the results reported here have been done mainly with children and youngsters from primary school to high-school, which can be considered two first stages (in the K-12). However we have done and are compiling experiments with teachers training on a continuing education paradigm, in Brazil,

that we will be reported in another paper, because it has several new issues that arrived since this one was done and we should provide a better study on it. In this case, the contributions will be mainly on the adaptation of the evaluation strategy, which has been changed since then. As said this is subject for our very first future work.

To this end, with the proposal of this work, we are able to do learning in both models, with the robotics as main focus paradigm or with the robotics as a secondary focus paradigm. So, hopefully this approach allows teachers and instructors in Educational Robotics to achieve their objectives successfully. Finally, just a note to practitioners of Educational Robotics in order to follow a standardized process for planning and executing their projects as a way to successfully achieve their objectives. And, to notice them that this recommendation is valid for both paradigms (using Robotics as a tool for teaching or teaching Robotics).

Fig. 13 Progress of learning of Programming discipline

Declarations

Conflict of Interests There are no conflicts of interests nor competing interests for this work.

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