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Sustainable Educational Robotics. Contingency Plan during Lockdown in Primary School

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Abstract: New technologies have offered great alternatives for education. In this context, we place robotics and programming as innovative and versatile tools that adapt to active methodologies. With the arrival of COVID-19 and lockdowns, physical resources were kept out of use, and the virtual lectures did not propose to incorporate these elements in a meaningful way. This recent situation raises as an objective of study the need to evaluate if robotics and programming are content that can be taught virtually in these circumstances, without physical resources and without face-to-face lectures. To do this, a mixed methodology consisting of questionnaires and interviews has been incorporated, aimed at primary education teachers, families, and primary education grade students. The results suggest that the virtualization of robotics and programming is a feasible and beneficial alternative for students, which allows the development of digital skills, while it is enhanced with the use of audiovisual materials and online resources. Even though face-to-face classes have other benefits not offered by virtualization, and teacher training needs to be up to the task to face this situation, it is a matter of time to respond to these situations and to guarantee a high-quality distance education.

Keywords: educational robotics; active learning; primary teaching; learning; confinement

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1. Introduction

Robotics and educational programming are related to multiple capacities of students such as the development of logical and linguistic abilities of children, in addition to providing a real scenario to apply curricular concepts [1,2]. In this sense, the introduction of Robotics has become an innovative and strategic element at the same time. On the one hand, it is versatile when it comes to using active learning methodologies (project-based learning, problem solving, gamification, cooperative learning, among others). All these methodologies empower students in their own learning and make robotics possible in an active learning atmosphere. On the other hand, introducing robotics in the classroom offers new alternatives for working with students in terms of computational thinking.

Educational robotics is not an independent discipline but a field that requires integration with active teaching methodologies. As proposed by Demo et al. [3], inquiry-based learning paths and problem-based learning are valid approaches to manage learning through robotics.

For these reasons, some schools work on robotics as a school project, not as a separate subject but integrating it with the materials of programming and robotics in the subjects of the curriculum [4]. Robotics is a privileged tool to achieve both underlined mental capacities and the development of didactic methodologies in which students are protagonists and artificers of their own learning.

During the academic year 2019–2020 and the current 2020–2021, a Robotics and Educational Programming Project has been developed at the Claret Las Palmas center in Primary Education. This has given us an action research context with different agents: students, involved teachers, and families. We have counted on them to work with different research instruments and to evaluate the impact of the project. Furthermore, this project is integrated in the University of Las Palmas de Gran Canaria (ULPGC) Innovation Project ROBOT-EDULPGC "Design, implementation and tests of a low-cost modular platform for educational robotics", which is part of the 2020 call for Educational Innovation projects of ULPGC. This university project has defined as its main objectives the design, implementation, and tests of an initial prototype of a low-cost modular educational robotics platform. The platform is flexible enough to be adapted, integrating different sensors and actuators, based on several education levels, taking as initial reference the levels of Early Childhood Education and Primary Education. It is a multidisciplinary project including four departments, two centers, one institute, and one research group from the ULPGC, 3 educational centers from Gran Canaria and the CEU Cardenal Herrera University in Elche (Alicante, Spain). In this sense, many actions are carried out. Consequently, a seminar on educational robotics was held with students from the university teaching profession. In this seminar, held online, the students have experimented with robotics as an educational tool, in addition to being able to see what the implication of teaching this online has. All these actions—projects in educational centers, research at the university, seminars with students, etc.—are part of the field of action of researchers. This team is made up of teachers from the school involved in the project, professors from the different named universities, and a master's student in educational technologies who has also participated in this study.

With the emergence of COVID-19 and its subsequent lockdown in Spain, including the suspension of face-to-face classes, we began to look for solutions for teaching in general and for the virtualization of the robotics project in particular. In this sense, the students and their families were sent different activities that were similar to those established in the robotics project in face-to-face teaching but using the Scratch Web application (https://scratch.mit.edu/) (accessed on 12 October 2020). Scratch is a free and accessible programming environment for a wide variety of users that allows knowing, interacting, and developing digital content in an intuitive and fun way [5]. In this way, they could remain connected to the project without losing the skills they had acquired as well as learn about another way of working with robotics. For the teachers involved in the project, it has been a challenge to maintain the continuity of the project. All these actions lead us to ask the following questions:

- Is it possible to carry out robotics even when students do not have physical robots in their hands?
- Is it possible to work on robotics when there are no face-to-face classes?
- What advantages and disadvantages do both models (approach to robotics in person or online) present?

This research has the goal of investigating these aspects and pointing out if robotics can be sustainable with children and primary school teachers in confinement or virtual classes.

The rest of the paper is organized in different sections: In the Materials and Methods (Section 2), the methodology used is exposed, as well as the resources applied in the research are described. In the Results (Section 3), the information obtained from the surveys and questionnaires carried out on the study group is analyzed. Finally, in the Discussion (Section 4), we contrast the data obtained and the publications contributions by other authors.

2. Materials and Methods

The research methodology of this study is mixed. The integrated robotics classes that were taught during 2019–2020 were fortnightly with each class group. This made it possible to be in contact with 10 classes and their tutors, 5 from the first year and 5 from the second year of primary school. The figure of the tutor in Spanish schools refers to the reference teacher in all stages. He is in charge of the management and communication between the family and the school, in addition to monitoring the evolution of the students. In primary (as is this case), he has most of the assignments with his students, including the robotics project, which is carried out jointly with a specialist teacher and with the presence of the tutor in these sessions. That is why the opinion of the reference teachers is so important for this research. With this population, together with students, families and teaching degree students, we have carried out a mixed research methodology that integrates the data in a triangular manner. In this sense, we can answer the questions from a broad perspective, taking qualitative and quantitative research into account. Within the mixed studies, we opted for a triangulation methodological integration strategy, seeking the convergence of results [6,7]. At the beginning of the project, in September 2019, we carried out a survey to know teachers' expectations in 1st and 2nd primary grades. A few months later, lockdown due to COVID-19 changed the perspective of the project. Virtualization of educational robotics appeared to encourage children to do the programming activities in their house. In June 2020, we searched the result of the evaluation of this project in its first year with different instruments. In this school year 2020–2021, the project continues growing in 3rd and 4th grade. Teachers answered questions about their expectations in these grades, and we carried out a seminar about robotics in education for teachers' degree students in ULPGC.

A timeline of the actions carried out is shown in Figure 1.

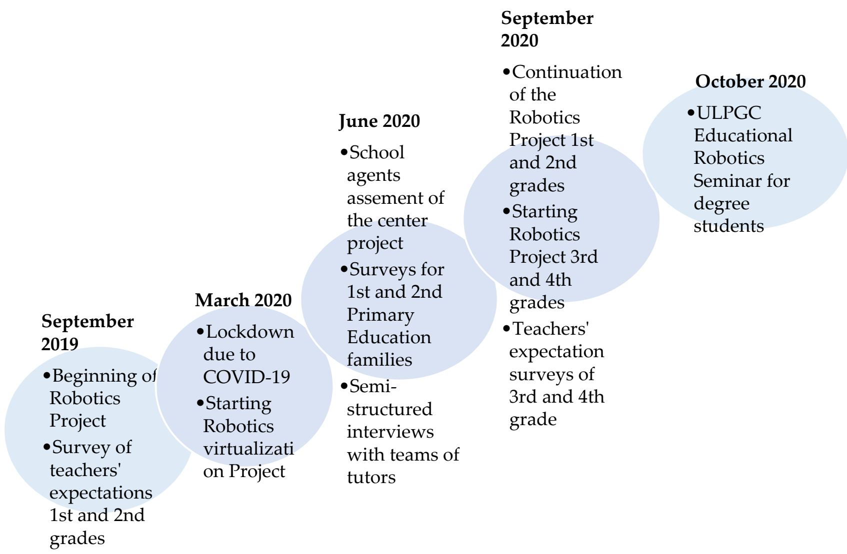

Figure 1. Timeline of actions carried out.

Taking as a reference the general framework described, as well as the active methodologies in conjunction with the development of educational programming and robotics, the following research instruments are proposed.

2.1. Surveys

We design different surveys with different sections to provide them to different agents involved in the introduction of robotics in the classroom. To validate the reliability of these surveys as suitable data-collecting instruments, Cronbach's alpha method was implemented, obtaining coefficients higher than 0.8 in all cases. These scores are considered as adequate according to authors such as Nunnally [8], who states that for early stages of a research, a value of 0.5 or 0.6 would be sufficient. Other authors, such as Huh et al. [9] consider that reliability value in an exploratory research should be equal to or higher than 0.6. Therefore, the surveys used as instruments in this paper count on a high reliability rate. These were:

- ○ 1st–4th grade tutors (sample: 22 tutors, Cronbach´s alpha: 0.826)

The objective was to compare the initial expectations of teachers in the 1st, 2nd, 3rd, and 4th grades of primary education, who were facing a project of these characteristics for the first time in its corresponding school year. The main opportunities to exploit in the development of the experience as well as expected difficulties were detected. A mixed research methodology (quantitative and qualitative analysis) has been used based on a survey that integrates three sections: general data, active methodologies, and knowledge about educational robotics and its integration into the education curriculum.

- ○ Families (sample: 44 parents, Cronbach´s Alpha: 0.877)

At the end of the 2019–2020 school year, we were interested in investigating the opinion and satisfaction level of the families involved in 1st and 2nd grade with the introduction of robotics in the school life of their children. We also asked about the lockdown period, in which their children had received material to work with robotics at home.

- ○ Teaching degree students—2nd Grade of Primary Education (sample: 127 students, Cronbach´s alpha: 0.877)

At the beginning of the 2020–2021 school year, a seminar was held online, which was based on the experience of the confinement with primary school students in the previous course. The seminar was oriented to lecturing concepts about magnitudes and geometry in primary school using robotics as an alternative tool. The survey includes both open and closed questions intended to check how the students have faced the seminar experience in terms of metacognition (learning to learn) and to judge differences with a face-to-face educational robotics experience.

In Table 1, we show that the questionnaires we conducted to the different agents were similar. In them, we can see the combination of quantitative and qualitative questions that later served us for the analysis and conclusions

2.2. Semi-Structured Interviews (Sample: 15 Tutors)

At the end of the 2019–2020 academic year, we conducted three semi-structured interviews with the 1st, 2nd, and 6th grade teacher groups to find out their impressions, advantages, and disadvantages of the inclusion of robotics or how the didactic proposal had been during the lockdown from March to June 2020.

With the data extracted from these instruments, we proceeded to analyze them in two different ways:

- Quantitative analysis: descriptive study using 15 questions divided into two sections (13 questions on a Likert scale and 2 questions that make up priority lists). The answers are analyzed defining age groups. The survey carried out is mainly focused on taking information from the teachers who taught the the 3rd and 4th primary grades, who will work on educational programming and robotics during this 2020–2021 academic year. It is as much about seeing which methodology might be more appropriate, as well as addressing the fact of building a robot versus using it. In addition, it seeks to detect the main aspects to consider when applying the methodologies, as well as to synthesize the advantages and disadvantages of the proposed integration.
- Qualitative analysis: The last section of the surveys draws conclusions from 3 open questions, addressing the main problems to achieve the applicability of the methodologies, together with an analysis of the advantages and disadvantages of the proposed integration. In addition, all the conversations maintained during the interviews were transcribed and analyzed. Once the transcripts of the classes were obtained and the information of the open questions in the surveys were organized, these data are the basis of the analysis of the study. From this analysis, the categories were formed, some inductively and others deductively, on the chosen topic: introduction of robotics and its sustainability during emergency cases.

Table 1. Surveys we conducted to the different agents.

1st–4th Teachers' Survey	Families	Teaching Degree Students
• Educational level in which you teach (mostly) • Sex • Age • Do you think that the integration of robotics and programming will enhance cooperative work in the classroom? • Do you believe that the integration of robotics and programming will help to enhance work by classroom projects (PBL)? • Do you believe that the integration of robotics and programming in the classroom will develop classroom gamification strategies? • Do you believe that the integration of robotics and programming in the classroom will favor problem solving by some of the students? • Do you think that the integration of robotics and programming in the classroom will favor the creativity of the students? • Indicate the priority according to applicability of the active methodologies integrating robotics in the classroom (from 1 to 5, with 1 being the most priority) (Cooperative Learning, Project-Based Learning, Gamification, Problem Solving, Creativity) • Indicate the priority of the issues that concern you in terms of the implementation cited (from 1 to 5, with 1 being the highest priority) (Pedagogical handling of the tool) • In general, what do you think is your knowledge of robotics? • In general, what do you think is your knowledge of programming? • Would you like to receive specific training in robotics and programming? • What extent do you think robotics and programming can be integrated with the curricular elements of the level? • Starting from a functional robot with instructions, I prefer to use a teaching guide to teach robotics and programming rather than prepare the teaching proposal myself • Being "1" a completely closed robot and "5" a robot that can be built by prefabricated pieces (Lego type), I think that at these levels it is preferable to use • I think it is important that robotics and programming are gradually integrated into the primary education curriculum • I would like robotics to be further promoted in the center with additional actions such as competitions, forums, etc. • In general, what advantages do you think the integration of technology in the classroom has? • In general, what drawbacks do you think the integration of technology in the classroom has? • You can comment here what you want in an additional way related to the integration of robotics in the center	• Level your child is at • Assess your child's motivation in relation to the robotics project in the classroom • Assess your child's motivation in relation to the robotics project during confinement • Do you think your child has learned more and/or better with this robotics project in the classroom? • Do you think your child has learned more and/or better with this robotics project during confinement? • Do you think that the integration of robotics has promoted cooperative work and project work in the classroom? • Do you think that the integration of robotics in the classroom has favored the creativity of the students? • Do you think that a fortnightly hour, integrated in the subjects, is enough for this project? • Would you like the project to continue in the next school year your child will be in? • In general, what advantages and disadvantages have you observed of integrating technology in the classroom? • You can comment here what you want in an additional way related to the integration of robotics in the school	• Educational robotics can be an effective tool in primary education • The training that I am currently receiving in my career adequately focuses me on the challenges that will be presented to me throughout my professional stage • What do you think about the implementation of educational robotics activities in primary education? • The seminar has helped me to better understand the elements of the geometry and measurement content blocks within the primary education mathematics curriculum • Educational robotics and the programming should appear explicitly in the curriculum • What do you think about the inclusion of educational robotics and programming within the curriculum? • The practical development of the activity has helped me to become familiar with the use of robots • The practical development of the task has helped me to familiarize myself with programming (directions, sounds and colors) and computational thinking. • What do you think? about the activity you have designed and its implementation in the primary education classroom? • In the adaptation of the task to virtual mode, the objectives of the task in face-to-face mode are maintained • The virtualization of the material (robots, mats, etc.) is suitable for working with educational robotics • What do you think about the advantages or disadvantages of a virtual mode compared to a face-to-face mode? • The elaboration of the explanatory pill serves to synthesize the knowledge that I have acquired in carrying out the task • The development of the explanatory pill helps me to acquire more digital competence • What do you think of the use of short videos as tools for the acquisition of competences by primary school students? • During the seminar, I have been aware of my own learning • The questions proposed in the metacognition ladder help to develop my critical and reflective capacity • What do you think about metacognition as a reasoning strategy in primary education? • Add any additional comments you want to make

3. Results

As we have mentioned previously in the Materials and Methods section, several resources have been used to obtain information on the topic addressed. This will help us to triangulate the information. That is, to know what the reality of the robotics project is, as well as its scope in confinement for various agents (teachers, families, undergraduate students) as well as the use of different instruments: interviews (sample of 15 teachers) and the questionnaires (sample of 22 teachers, 44 families and 124 teaching students). With these results, we will draw the conclusions of the three research questions posed above. For more information regarding the research resources developed, some tables with the questions asked to the different sectors studied are attached in Appendix A.

For the triangulation of results, following Aguilar and Barroso [10], on the one hand, it has been carried out by means of the triangulation of data. This is the use of different strategies and sources of information on a data collection allows to contrast the information collected. On the other hand, we have carried out methodological triangulation because we use qualitative and quantitative sources and various methods in the same investigation to raise information contrasting the results, analyzing coincidences and differences, and having a broad perspective of educational robotics. When organizing the results obtained from the questionnaires, we have categorized the responses into four different sections that provide us with information about robotics and programming as an educational medium and the possibility of working virtually:

1. First, we have started by analyzing the benefits of educational robotics for the future of students when used as a tool in the classroom.
2. Second, we continue with the study of the use of robotics as novel and motivating content for students and teachers.
3. Third, we have classified the information in the block related to the difficulties of educational robotics in the classroom according to the different respondents.
4. Finally, a comparison has been performed between the benefits and the difficulties of virtualizing robotics in education.

As we can see in Figure 2, each content block is divided into two subsections, where we analyze both the quantitative and the qualitative data, except for the Robotics Virtualization section where we propose the advantages and difficulties that they entail.

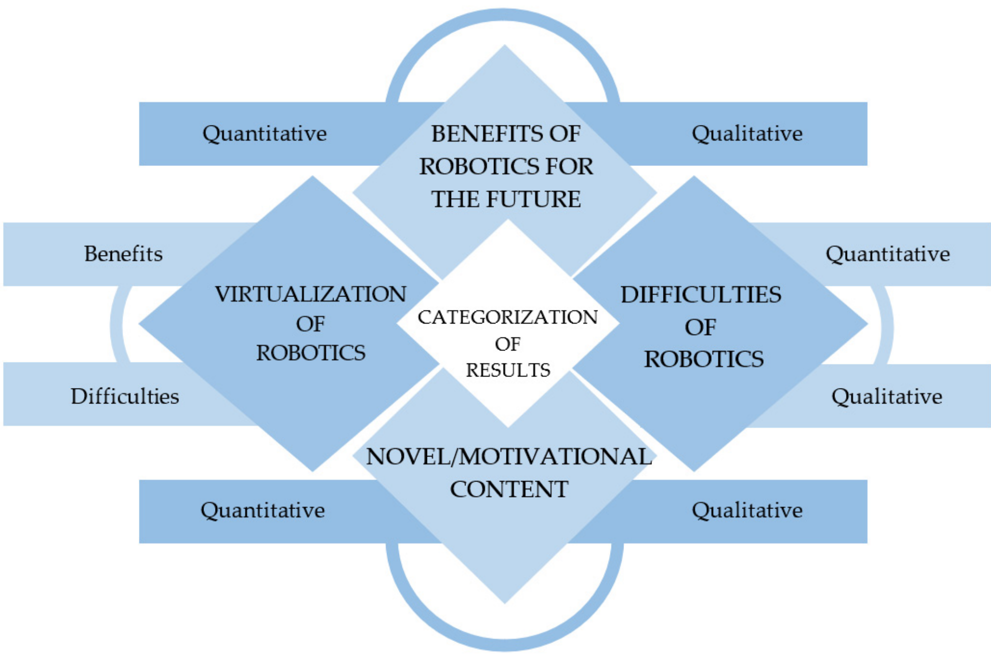

Figure 2. Classification scheme of the results obtained.

In next Figures 3–5, we present the survey results from families and teachers.

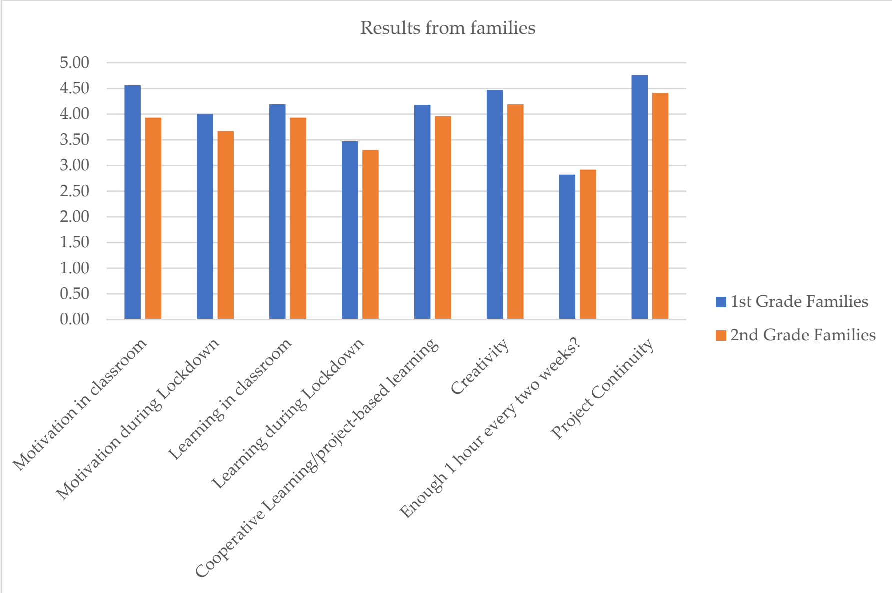

Figure 3. Survey answers from families.

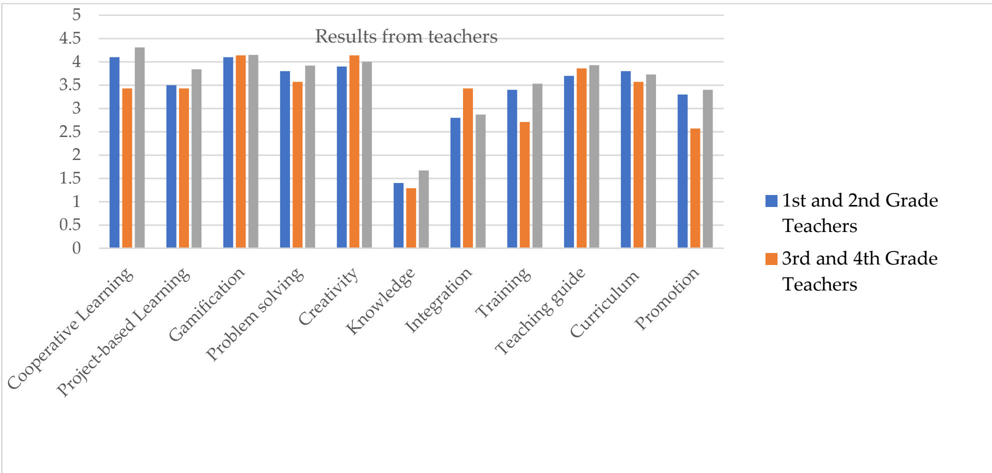

Figure 4. Survey answers of teachers.

3.1. Benefits of Robotics for the Future

In this section, we collected the data that offer information related to the benefits that robotics and programming can bring when used as a tool in for students. Responses are also focused on how much they believe that this type of methodologies positively contributes to the students, the teaching staff, and the primary education curriculum. These results have helped us to configure research question 3 in terms of the benefits and advantages of robotics.

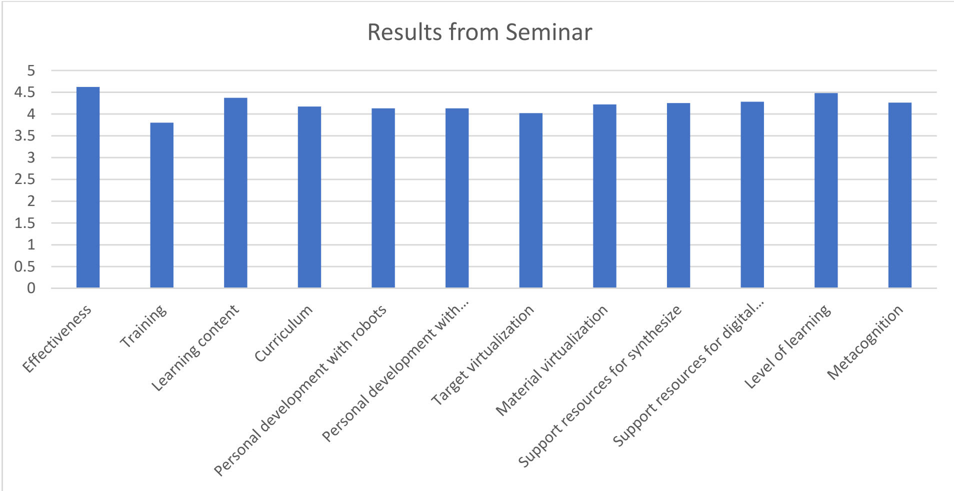

Figure 5. Survey results of degree students.

3.1.1. Quantitative Responses from Participants

Regarding the scores given by the students of the Educational Robotics Seminar shown in Table 2, their responses point to a general satisfaction with the project and with the benefits it entails for education, as well as the effectiveness that this type of resources has shown for their training staff regarding this issue. Respondents share the idea of introducing robotics and programming content into the primary education curriculum.

Table 2. Average of the questions asked to the students of the Educational Robotics Seminar (from 0 to 5, 0 is the lowest rating and 5 is the highest).

Identifier	Seminary Students (n = 124)
Effectiveness	4.62
Training	3.8
Learning content	4.37
Curriculum	4.17
Personal development with robots	4.13
Personal development with programming	4.13
Target virtualization	4.02
Material virtualization	4.22
Support resources for synthesize	4.25
Support resources for digital competences	4.28
Level of learning	4.48
Metacognition	4.26

The results of the surveys carried out by the teachers show their satisfaction with the robotics project in the classroom. In general, they consider that its implementation in the classroom allows the use of didactic methodologies and helps students to develop skills and attitudes. In addition, the teachers express their agreement to include the contents of robotics and programming in the curriculum and to promote this type of resource in education.

3.1.2. Qualitative Responses from Participants. Benefits of Robotics for the Future

When it comes to applying questions about the inclusion of these recent methodologies in schools, the answers share a clear statement. In the questionnaire carried out in the Educational Robotics Seminar—Measurement, Magnitudes, and Geometry, around 30% of the participants indicated the benefits that these resources would bring in the development of students' capacities for their future, and more than 65% provided reasons for incorporating robotics and programming content into the curriculum.

> It seems like a very good idea to me, since they are topics that not many know about and can be quite important and innovative. For this reason, it would be quite interesting, from my point of view, that they continue to do seminars of this type with a vision of the future that is carried out in a more practical way and that many end up using.
>
> (SEM_PROF_ULPGC)

> It seems very important to me because robotics is already being implemented in our present and above all it will be implemented in the future, therefore it is important to modernize the educational system and teachers. It is also a very original way for children to learn, be entertained, and have fun.
>
> (SEM_PROF_ULPGC)

In addition, some families found this type of activity very positive, confirming that it would help their children to function in a new work environment. In general, both sectors agree that these types of resources are necessary to update the education and curriculum, and to bring new meaningful experiences for students and teachers. In turn, the tutors consider that robotics is beneficial for the students and for themselves. On the one hand, it allows reinforcing the knowledge of different curricular areas, while on the other hand, the technology they mention lends itself totally to cooperative work, to the development of scientific–technological vocations, and even to the increase of social and creative skills.

> One of the great advantages of the integration of technology in education is that it can help us to promote teamwork. These new methodologies allow us to promote group work. The students will learn to collaborate and also, it is a great opportunity for them to support each other and adapt to the use of technology in the classroom.
>
> (INNO_TIC_3°_4°)

3.2. Novel/Motivational Content

This section collects the responses related to the adaptation of robotics and programming in various active methodologies, as well as the motivation generated in students using these resources in the classroom. This section has also been very important to answer the question of the advantages of robotics in both models, as well as to know if it would be possible, based on motivation, to carry out the robotics virtualization project.

3.2.1. Quantitative Responses from Participants

As we observe in the responses obtained by the teachers shown in Table 3, the data suggest that the use of robots and elements of educational robotics in the classroom awakens the motivation of the students. Teachers agree that the use of educational robotics (ER) develops and enhances students' creativity, being in the higher grades where it is considered that there is a greater development. In the same way, it happens with the integration of robotics as an element to work on gamification in the classroom, where 6th grade teachers consider this option very positively.

Table 3. Viability of educational robotics to incorporate didactic methodologies according to 1st, 2nd, and 6th grade teachers.

Identifier	1st and 2nd Primary n = 10	3rd and 4th Primary n = 7	6th Primary n = 5
Cooperative work	4.1	3.43	4.6
Project work	3.5	3.43	4.6
Gamification	4.1	4.14	4.4
Problem resolution	3.8	3.57	4.2
Creativity	3.9	4.14	4.2
Knowledge	1.4	1.29	2.2
Training	3.4	2.71	3.8
Integration	2.8	3.57	3
Teaching guide	3.7	3.8	4.4
Curriculum	3.8	3.43	3.6
Promotion	3.3	2.57	3.6

3.2.2. Qualitative Responses from Participants

Continuing with the benefits that robotics and programming provide within the classroom, we observe that most responses aimed at the creativity and motivation that this methodology can generate in students. Around 40% of responses received at the Educational Robotics Seminar were dedicated to this aspect, highlighting how innovative and dynamic its application can be in the classroom. Families also mention very positively the impressions they receive from their children when they participate into activities of this type.

> Children´s motivation by telling the tasks they have done.
>
> (ENC_FAM_1°_2°)

In relation to the 1st and 6th grade tutors, the vast majority agree that teachers are truly motivating tools that allow content to be developed through play and teamwork.

> A different tool that ... help us to deepen the content that is, and that ... is different for them, motivates them and will seem much more ... fun. And what we said before also helps new methodologies, right? What is cooperative learning ... the ones you named ... I think it is a tool, well, quite useful.
>
> (ENT_PROF_6°)

3.3. Robotics Difficulties

This section presents the drawbacks that are currently found in the knowledge and use of robotics in educational centers according to the different sectors that have participated in the surveys.

3.3.1. Quantitative Responses from Participants. Robotics Difficulties

When putting these contents into practice, teachers prefer to use pre-prepared teaching guides before creating their own proposals. The reason for this decision could be related to the results in the knowledge section. The data observed in Table 3 clearly demonstrate the lack of digital competence that teachers believe they have about robotics and programming, which was also evident in the interviews carried out. Digital competences in this field are deficient, and both teachers and family require training and knowledge to properly develop their potential. Some families mention their lack of abilities to help their children with homework because they do not understand how to guide them.

> It seems to me a very educational subject ... and the child likes it, but when it comes to doing it with the parents, we lack information to help the child 100%.
>
> (ENC_FAM_1°_2°)

3.3.2. Qualitative Responses from Participants. Robotics Difficulties

The conclusions we extracted from this aspect are relatively similar to each other. The greatest concern generated by respondents about the inclusion of robotics and programming in the classroom is the lack of knowledge, abilities and personal skills in this field. The teachers recognize that, even though it is very beneficial for the students to incorporate these new resources, their lack of competences in this area generates insecurities when it comes to carrying out the activities independently.

> I could be supporting, but I don´t see myself playing the role of the expert because I think you have to have a series of skills that I personally don´t have, I have another ... but that spatial vision, that speed ...
>
> (ENT_PROF_1°)

Another concern we observed has to do with the primary education curriculum. There are opinions against including robotics and programming content in the evaluation criteria. Some of them revolve around working in this field alternatively or even in optional activities inside school, since they do not consider that they are essential contents in the education of the students. Other participants highlight the high cost that it would imply for the centers to stock up on this type of technology, being an alternative that not all schools can afford.

> I think it is a good option. However, I think it could not be applied in all schools due to the diversity of economic situations that exist in them, and they limit many in the possibility of using this type of methodologies.
>
> (SEM_PROF_ULPGC)

> I could be supporting, but I don´t see myself playing the role of the expert because I think you have to have a series of skills that I personally don´t have, I have another ... but that spatial vision, that speed ...
>
> (ENT_PROF_1°)

> At first-rate eh ... being the first time that ... that I know ... that it applies ... I don´t see myself, unless I had continuous training and that ... I don´t see myself capable of ... taking it on my own. But, well, everything is trying too, right? but ... In first place, that someone else ... was the one in charge.
>
> (ENT_PROF_6°)

> But it is true that at first, we would need important advice, okay? Because, well, because nobody, I speak for myself, we have not done anything ... similar before.
>
> (ENT_PROF_6°)

3.4. Virtualization of Robotics and Programming in the Classroom

Finally, we compared the arguments and responses the participants have offered in terms of carrying out the educational robotics project virtually versus face-to-face lecturing, focusing on the benefits and difficulties that the telematics mode presents. When we ask ourselves if it is possible to carry out robotics even when students do not have physical robots in their hands and if is it possible to work on robotics when there are no face-to-face classes, this virtualization indicator and the data derived from it have been key to the conclusions in this regard.

3.4.1. Benefits of Virtualization

Regarding the benefits of virtualization, the first feature mentioned is that it is a very effective alternative to the lockdown situation caused by COVID-19. As some respondents agree, this alternative allows solving the problem of distance while working on the proposed content. In the Educational Robotics Seminar, the importance of carrying out activities in this way is discussed to find ourselves prepared for similar situations in the future. Another aspect that is also discussed as a benefit of virtualization is the fact of developing digital skills in greater depth, which is an advantage over face-to-face.

> One of the advantages of virtual mode is that it helps you develop your digital skills in greater depth.
>
> (SEM_PROF_ULPGC)

Another benefit of virtualization is that it can also be combined with multimedia resources (videos, images) in addition to tutorials or video conferences. This allows the objectives of the activities or the necessary information to be explained in detail, so that students can review it at any time if they have doubts.

It also highlights the fact that in a virtual way, it can be more affordable for some users, who do not invest time in transportation or money in resources. Everything is online, so everything they need is available in few clicks.

3.4.2. Virtualization Difficulties

Regarding the difficulties that the participants experienced with virtualization, a special mention is made to the lack of human contact and interaction between members and resources, and the lack of digital skills to solve the activities. Doubts cannot be resolved directly or instantly; participation and motivation can be improved, and in general, the treatment is colder and not so individual.

> In my experience, the face-to-face mode is much more effective when it comes to learning than the virtual mode, since in a virtual way it is more difficult to maintain concentration, resolve doubts, and interact with colleagues . . .
>
> (SEM_PROF_ULPGC)

Regarding the experience of teachers and families, the information is related to what is discussed in Section 3: Robotics Difficulties. Digital competences in this field are deficient, and both teachers and family require training and knowledge to properly develop their potential. Parents say their lack of abilities to help their children in their homework. This is because they do not understand how to guide them in some activities.

> It seems to me a very educational subject . . . and the child likes it, but when it comes to doing it with the parents, we lack information to help the child 100%.
>
> (ENC_FAM_1°_2°)

4. Discussion

For the three research questions that we proposed at the beginning of the paper, we found some interesting results. The general conclusion that we extract from the qualitative data of the different sectors is that robotics and programming are considered by the different agents to be potential tools to work in the classroom because of their multiple benefits. Its ability to generate motivation in students, its versatility to be included in different areas and methodologies, and its usefulness to develop skills and vocations that can help students develop and prepare for technological work in the future make educational robotics a great bet for schools and the education. In addition, it seems that robotics would be shown as a learning object or as a learning tool, even when this classification is not very clear because other attitudes and skills (creativity, problem-solving, critical, and collaborative thinking, etc.) can be learned with robotics [11]. Even when "robotics has sustained potential in education, it seems inevitable that new ways need to be found to integrate it into the school curriculum" [12].

Many studies have found this potential tool of robotics and programming for education [12–16]. However, when robots cannot be on students' hands or face-to-face because classes are suspended and we are in a lockdown situation, we should ask: Is it sustainable?

However, the virtualization of technological tools is found to offer good alternatives with benefits that satisfy users. Referring to the questions about having a robot in students' hands and using robotics when there are no face-to-face classes, virtualizing robotics and programming activities and projects allows this type of content to be taught by teachers to their students in situations where face-to-face interactions are not possible. Although working in person brings a series of advantages that virtualization is not capable of achieving, the results seem to be satisfactory. For future strategic planning of the curriculum and, in its case, in robotics, it is necessary to consider a student's timetable of learning and online learning habits. Respondents affirm that working digitally enhances their digital competence, in addition to allowing them to be flexible with their hours and that they are greatly enhanced with other digital resources such as explanatory videos and videoconferences. Furthermore, researchers found that learners can fight isolation through interactive, flexible, and supportive online learning environments, including and building relations with teachers and parents [14–16]. What is more, although the families appreciated the work done by the teachers, they do not always have sufficient ICT training. There are two issues that cannot be ignored regarding the virtualization of the robotics project, as has happened with education in confinement [17]: the existence and consequences of the digital divide (homes without access to electronic devices and broadband connection) and having to share these resources with the rest of the members of the family unit. On the other hand, there are doubts about the problem of teacher training in ICT and their resources to teach remotely.

Regarding the third question, advantages and disadvantages, this last aspect should be restructured, based on the participants' responses, to incorporate in meaningful and novel ways new elements in the curriculum in relation to robotics and programming. In the case of Spain, the addition of new alternatives is increasing progressively. Cabrera [18] compiles different proposals that have emerged in various autonomous communities. Respecting the incorporation of new content in computer programming and robotics, different regions such as Madrid, Castilla-La Mancha, Valencia, Navarra, or Murcia, among others, have incorporated compulsory and optional subjects and activities in their curricula. In the case of different educational centers in Catalonia, researchers analyzed the results of a study where they trained teachers in robotics content and designed action proposals during the school year. Their conclusions drawn demonstrated a high level of teacher confidence for the development of new content and an increase in students' qualifications [19]. New evaluation criteria in relation to this topic awaken and improve the development of digital skills of both students and teachers, making them able to cope with new challenges that until now have not had the opportunity or the ability to solve them correctly. In addition, something to be highlighted by the paradigm shift in the development of training experiences and the implementation of tools and technological resources for online teaching due to confinement has been to carry out collaborative and interdisciplinary actions online, favoring global citizenship and community impact (Martín-Barbero, 2020). In this sense, new avenues are opening in the virtualization of robotics for students and teachers [20].

Considering the aforementioned aspects, there are still some issues that need to be resolved in order to incorporate these new trends. The main concern is the lack of digital skills of teachers in this area, which generates insecurities when carrying out meaningful educational strategies. The study carried out by Betancourt-Odio et al. [21] confirms that there is a need to develop training related to digital skills that can explore beyond the selection and adaptation of digital resources so that teachers develop security in this area and can innovate through new technologies. Teachers require training to help them overcome this need for knowledge. As described by Martínez and Rodríguez [22], the main challenge is to train teachers in the education system based on programming, with the aim that in the future, they will be the ones who introduce their students to these fields. Some points of view add that either due to the lack of resources in schools [23] or to the scarce experience of handling this type of technology, the contents of robotics and programming could be included in an isolated way from the educational process, being reduced to extracurricular activities or optional.

Despite the great diversity of opinions regarding this topic, we can extract with certainly that robotics and programming is a new addition that awakes great curiosity and predisposition to join education. In addition, its inclusion reinforces the idea that a satisfactory development of skills related to computational thinking can be given in students of first educational levels [24]. It is a matter of time to train teachers and update their knowledge, so that great qualities can be developed in students through resources that increase their desire to learn.

Even when we have found some interesting results, this study presents some limitations. On the one hand, the study sample, in relation to the teacher interviews, is not very large. Therefore, a more robust population would be required to get conclusive ideas in this regard. Although once the confinement was over, the schools went from temporary solutions (such as the case of virtualization of robotics) to a normal school life, there are elements for reflection to adopt certain innovations [25]. On the other hand, we are concerned that the access to technology during confinement has not been equal for everybody as it is suggested in some researchers [26,27]. This access to a computer or tablet is absolutely necessary when online lesson occur. So, it is relevant if we bet for robotics in a virtual way. Another problem is that the study only considers the opinions surrounding robotics of parents, teachers, and future teachers. It is still necessary to investigate which are the results in student motivations, learning, and skill development. Therefore, we highlight the importance of research focusing on learning objectives or evaluation criteria to have stronger evidences for the future in relation to students and their performance in robotics.

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Appendix A

As we mentioned before in the Results section, we have disposed the tables that contain the questions we asked to the different groups of study. The different questions asked of both teaching staff and participants in the Educational Robotics Seminar are shown below.

Identifiers and questions asked to students of the Educational Robotics Seminar:

- Effectiveness: Educational robotics can be an effective tool in primary education
- Training: The training that I am currently receiving in my career adequately focuses me on the challenges that will be presented to me throughout my professional stage
- Learning content: The seminar has helped me to better understand the elements of the Geometry and Measurement content blocks within the primary education Mathematics curriculum

- ○ Curriculum: Educational robotics and programming should appear explicitly in the curriculum
- ○ Personal development with robots: The practical development of the activity has helped me to familiarize myself with the use of robots
- ○ Personal development with programming: The practical development of the task has helped me to become familiar with programming (directions, sounds, and colors) and computational thinking
- ○ Target virtualization: In adapting the task to virtual mode, the objectives of the task in face-to-face mode are maintained
- ○ Material virtualization: The virtualization of the material (robots, mats, etc.) is suitable for working with educational robotics
- ○ Support resources for synthesis: The elaboration of the explanatory pill serves to synthesize the knowledge that I have acquired in carrying out the task
- ○ Support resources for digital competences: The development of the explanatory pill helps me acquire more digital competence
- ○ Level of learning: During the seminar, I have been aware of my own learning
- ○ Metacognition: The questions proposed in the metacognition ladder help to develop my critical and reflective capacity
- ○ Teaching Staff:
- ○ Cooperative learning: The integration of robotics will enhance cooperative work in the classroom
- ○ Project-based learning: The integration of robotics will help enhance project work in the classroom
- ○ Gamification: The integration of robotics in the classroom will develop gamification strategies in the classroom
- ○ Problem resolution: The integration of robotics in the classroom will favor the resolution of problems by the students.
- ○ Creativity: The integration of robotics in the classroom will favor the creativity of the students
- ○ Knowledge: In general, what do you think is your knowledge of robotics?
- ○ Training: I would like to receive specific information on robotics
- ○ Integration: Level of integration of robotics with the curricular elements of the level
- ○ Teaching guide: When teaching robotics in the classroom, I prefer to use a teaching guide to teach robotics rather than prepare the teaching proposal myself
- ○ Curriculum: I believe that it is important that robotics and programming are gradually integrated into the primary educational curriculum
- ○ Promotion: I would like to see robotics and programming further promoted in the center with additional actions such as competitions, forums, etc.

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