RoboSTEAM project the pilot phases

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ABSTRACT

Digital society demands very qualified professionals ready to this environment challenges. This makes necessary to foster the development of competences related to such context such as Computational Thinking or STEAM related skills. However, this is not an easy task, especially because integrating subjects that covers the necessary topics and competences. New active pedagogical approaches are required and this what RoboSTEAM project provides. The application of Challenge Based Learning and Physical Devices and Robotics facilitate the so named twenty first century skills. The project has been developed by several universities and schools and one of most critical parts was testing the methodology and tools, this was done into pilot phases that are described in the present work. The results show that there are important differences between partners socioeconomical context, but that the outcomes of the project are flexible enough to be applied successfully in any of them.

CCS CONCEPTS

• **Applied computing** → Education; • **Computer systems organization** → Embedded and cyber-physical systems; Robotics; • **Social and professional topics** → Professional topics; Computing education; Computational thinking; Professional topics; Computing education; K-12 education.

KEYWORDS

STEAM, Computational Thinking, Robotics, Physical Devices, Evaluation, Pilots

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1 INTRODUCTION

Current society demands professionals adapted to the digital society. This means that they should have achieved what is known as 21st century skills and they should be flexible enough to deal with a changeable context. This makes especially necessary to facilitate the acquisition of such skills through the integration of STEAM related activities in the present educational pathways and to foster competences such as Computational Thinking [1–3]. Both tasks are hard, it is not enough to include some technology subjects in the educational plan, the development of these competences must be something included in all the subjects and the best way to facilitate this is using active methodologies and using engaging tools for the students [1, 4, 5].

In this sense there are different projects and trends that promote the development of these competences and STEAM integration. Some aim to engage and facilitate teachers and policy makers materials and guides to develop new integrated STEAM approaches, such as ENQUIRE [6], Mind the Gap [7], PRIMAS [8], Scientix [9], KIKS [10]. Other are more focused on facilitate knowledge and content exchanging such as STELLA [11] or GRID [12] or CONTEXTEuroSTEAM [13]. Finally, some of them deal with STEAM perception among students such as YOSCIWEB [14], STEM Alliance [15], inGenious [16], RAISE [17] or W-STEM project [18, 19].

RoboSTEAM is a project that deals with these topics. It is an Erasmus+ Strategic Partnership project that involves 8 partners from 4 different countries (4 schools and 4 universities) with the aims to define a methodology and a set of tools that help learners to develop computational thinking by using/programming PD&R in pre-university education stages. The project will also improve teacher education, providing them with a framework for easy STEAM integration in different educational contexts, by providing guidelines for good practices and lessons learned adapted to those contexts. All these products will be tested in different countries and cross-validated in different educational institutions [20]. This will be done through a set of pilots and by the exchange of students and teachers between the schools involved in the project.

In this paper we would like to present the two project pilot stages. They began on the M12 of the project and were scheduled to finish around M20 the problem was COVID-19 pandemic situation that causes a change in this initial plan. 2 will describe the pilots, their aims, the stakeholders involved, and the assessment tools applied. 3 presents the challenges addressed by each partner. 4 show some of the obtained results. Finally, some conclusions are posed in 5.

2 THE PROJECT PILOTS

This section describes RoboSTEAM pilot descriptions, for more information about them it is possible to review the project management handbook [21] or the reports for activities 3 [22] and 4 [23].

2.1 Pilot Phase 1

This stage was defined in the project proposal as activity 3 or A3: "it will launch the testing of both RoboSTEAM methodology and PD&R testing kits. During this pilot the 5 secondary schools are involved with their students from 12 to 16 years old. The pilots consist of a first diagnostic phase, later challenges will be posed for small students' groups, and finally the results will be analyzed. During the diagnostic phase all students in the previous commented range of ages will fulfil a questionnaire about their perception about STEAM and how it is taught in their school. After this, 4 challenges will be posed to a class of secondary students. They will solve these problems and the results will be analyzed and compared with the students that do not participate in the challenge. Indicators to be used could include: the time employed, the grade obtained, the external people involved, the assessment of computational thinking and STEAM related competences acquisition by using the instruments and methods defined in O1, and students self-perception about the experiment" [21].

The activity was scheduled to be completed between project months 9 and 17 although this task was delayed because it requires for the results of previous activities completed during the first year and because COVID-19 [24, 26, 26–36]. In most of the cases this has meant to delay the end of the pilot stage or to have to complete it in smaller groups or virtually [37].

2.2 Pilot Phase 2

This stage is defined by the project proposal as activity 4, it consists of: "A4 will launch a second testing stage. The secondary schools will be involved again. They should develop the same activities than in Pilot 1, and the same students' groups are involved in the challenges. In this case students can choose the instruments, methods and tools from other socioeconomic contexts present in RoboSTEAM environment. The idea is analysing how PD&R kits work in a different socioeconomical context. Later the results will be compared with students that do not participate in the challenges, and with the results obtained during Pilot1. The indicators to be used are the same of Pilot1" [21].

The pilot stage was scheduled between months 12 and 19 although, as in the previous case the pilot was delayed because the dependency with other project results, that were also delayed because of the late beginning of the project, and because of problems associated to the COVID-19 pandemic situation that arose on month 18 of the project. In this case the classes included in the pilots were discontinued, and the partners should look for ways to finish both this pilot phase and pilot phase 1. This meant in most of the cases to use virtual tools or to finish the piloting in smaller groups [37]. In fact, in the case of pilot2 in most of the cases should be delayed until month (after the authorization of the agency for extending the project). The schools commented that they must devote more time in preparing and conducting classes in online mode and later with social distance, so it was not possible to complete the pilots on time. Another change in the pilot is that due to COVID-19, the pilot 2 was concluded in the next academic year 2020/2021 instead of 2019/2020, so some students were not in their institutions and therefore other students are involved [23].

2.3 Sample of involved stakeholders

Pilots have been divided in several phases, the first pilot include a diagnosis phase that involved a great number of students, the rest of the pilots are more reduced an involved less people. The environment where the pilots took place were five schools from different socioeconomic environments. They are described in Table 1, that also includes a description of the students involved distinguishing between the diagnosis phase and pilots and the staff and researchers involved (labeled as Other) in each case. In the case of Portugal there are two schools,

It should be noted that in Pilot 2 and due to COVID-19 not always is possible to involve the same students that in the Pilot 1, in some cases it is possible to include more students but in other cases they have left the school.

2.4 Instruments employed for describing and assessing the pilots

During one of the project meetings (Karlsruhe Transnational Meeting) the different kits and challenges gathered during the project were evaluated. Considering the project proposal each partner should address a challenge with a kit in the first piloting stage, but in the second challenges and kits should be exchanged.

Given this situation the partners decide [38]:

a. The granularity of the challenge to be addressed. During the academic course, given the restrictions of each institution learning plan, the better length for this experiment was that of a mini-challenge. The granularity should be the same or it would not be possible to compare the results in each institution. The possible levels of granularity have been discussed previously in [39].

b. Each partner of the piloting institution will address the mini-challenge they proposed in the first staged (more information about the challenges is described in the next sections).

Table 1: Stakeholders involved in the project pilots

School Name	Diag.Phase	Pilot1	Pilot2	Teachers	Other
I.E.S. Eras de Renueva (Spain) – I.E.R	308	13	13	2	0
Carl Benz School Karlsruhe (Germany) – CBSK	13	17	17	1	6
Agrupamento de Escolas Emídio Garcia (Portugal) - AEEG	227	16	31	5	4
Colégio Internato dos Carvalhos (Portugal) - CIC	462	12	25	2	0
University of Eastern Finland (Finland) - UEF	32	10	5	2	0

c. For the second piloting phase it is decided to exchange nano-challenges instead of mini challenges. Because they are easily addressable by the teams, considering the number of hours employed and the equipment and teachers' availability in each institution. ERAS nano challenges can be exchanged with KIT and AEEG, CIC nano-challenges can be exchanged with Finland and vice versa. AEEG nano-challenges can be exchanged with ERAS.

Regarding the instruments employed to assess the challenges the initial agreement between the partners was to establish some basic indicators and instruments to use [38]:

- As indicators the partnership agreed to use the time employed to complete the challenge, the number of persons involved in each team and the grade (that could later be compared with previous editions of the same subject).
- As evaluation instruments the partnership agreed to use the following [40]:
- The STEM Semantic Survey is a 25-item instrument that measures interest in science, technology engineering and mathematics as well as interest in STEM careers more generally. The Career Interest Questionnaire is a 12-item instrument that measures interest in careers in broad science areas [41]. It is applied during at the diagnosis phase and during the pilot with the experimental groups, in this case the people involved in the pilots will use the instrument before the first pilot and at the end of the experience. A link to the form is available here: https://forms.gle/vNQ8QCXkgtdTDGP57.
- Computational thinking test. It is an instrument initially aimed at Spanish students between 12 and 13 years old. It includes several to evaluate different areas related with computational thinking. The test has been properly validated and from the initial version of 40 items length it was depurated to 28 items [42]. It is applied at the end of the pilot 2 to see the computational thinking level of the students.
- Co-Measure Rubric. This instrument is defined for researchers and educators to use to assess student collaboration, at the individual level, when students are working in K-12 STEAM activities. It has been validated through several iterations and has been published [43]. During the project it is applied to assess the collaboration between team members in the pilot activities, but also during the exchanges when the students from the different schools have worked together. The STEM Semantic Survey will be used in the diagnosis phase [41]. Most of the partners need to ask for permissions and some of them to translate it and upload it to another platform different from Google (a google link to the form is available here: https://forms.gle/vNQ8QCXkgtdTDGP57.. Besides, this test will be employed in a pre- and post-test with the students implied in the challenges. In the post-test, also some questions regarding motivation. In addition, a computational thinking instrument to be used after the piloting that includes several CT dimensions. It is decided to use the if/else dimensions (from the conditionals section) and do/until dimension (from the loop section) because they are most related with robotics.
- Finally, teachers will also use a rubric to assess other competencies development.

3 THE CHALLENGES ADDRESSED BY THE PARTNERS

In this section we describe the challenges addressed in the project pilots by each of the schools attending to the templates defined in [39] to minimize the tables a facilitate readability we describe all the mini-challenges for pilot 1 and only some nano-challenges for pilot 2.

3.1 Pilot1 Mini-challenges

In the following subsections we include the template for the mini-challenges of each school and a brief description.

3.1.1 I.E.S. Eras de Renueva. The pilot carried out in I.E.S. Eras de Renueva in the context of RoboSTEAM project was carried out from October 2018 t0 January 2019. It involved 13 students 6 Female and 7 Male, with an age from 15 to 16, from three subjects: Control and Robotics, Technology and Coding.

3.1.2 Carl Benz School Pilot1. The pilot was held with trainees of the Carl-Benz-School Karlsruhe, a vocational school located in the city of Karlsruhe, for the professional fields of vehicle and metal engineering (commercial-technical field), in the framework of the German dual system of Vocational education and training. Specifically, it is developed with students of the course "Metal Engineering". The participants involved in the pilot were 17 trainees of metal technology/engineering as well as 6 university students of engineering pedagogy bachelor and master level to teach and support them as mentors.

3.1.3 Agrupamento de Escolas Emídio Garcia. This pilot was carried out in an Arts context, so the students were not so customed to technology and programming, to facilitate the development of the pilot it was carried out at the same time than the exchange C3 [44], that also with students of the IES Eras de Renueva. The challenge was carried out by 7 Art Portuguese students (5 boys and 2 girls), 4 Science and Technology students (3 boys and 1 girl) and

8 Spanish students with an educational background related to technologies (4 girls and 4 boys); all of them are fifteen-year-olds. There were four groups which were made up of Portuguese and Spanish students: all of them with mixed abilities concerning STEAM related competences. Therefore, the groups were heterogeneous. The teachers monitored the ongoing challenge and assessed students' performance and competences acquisition based on Direct Observation. Teachers also considered the students' perception about the experiment to assess the Co-Measure Test. Moreover, each group appointed a spokesperson to give testimony of the experience.

3.1.4 University of Eastern Finland. The pilot 1, in University of Eastern Finland, was carried out in the Teacher Training School. Pilot was arranged as extra course for students interested in robotics and international student exchange. Interested students made applications to course and the group involved was chosen by teachers. Students were not required any knowledge of computational thinking or robotics. The participants in the pilots were 10, distributed in groups of 3 or 4 persons. Main goal of the challenge addressed was to design, construct and program a mobile robot using Hummingbird-kit with the aim of improving senior citizens life.

3.2 Pilot2 Nano-challenges

In this section we describe the different nano-challenge that one partners gather from the others and adapt to their context to carry out Pilot2.

3.2.1 I.E.S. Eras de Renueva. I.E.S. Eras de Renueva carried out the second pilot with the students of the first one. The students did not have previous knowledge about Robotics, although all of them acquired basic skills regarding electric circuits in Technology class (1ºESO). The mini-challenge to be addressed was chosen from the use of heat sensors employed in the Wildfire challenge developed by AEEG during the pilot1. The challenge was adapted but the concepts to manage it are similar.

3.2.2 Carl Benz School. In this case in the framework of the mini-challenge make it shine what the partners have done is to adapt the challenge defined by the I.E.S. Eras de Renueva of using a led to the context of the smart textile. It includes the teaching blocks 2, 3 and 4 defined for the original challenge. Teaching block 2 at developing a general basic understanding of computer science concepts and processes, including LED on and off task; this included above all an understanding of algorithms, i.e., if-then-relations. Theoretical knowledge was planned by playfully introducing students to the first principles of computer science by guiding a 'robot' (person) through the classroom with the help of simple control commands (right, straight ahead, turn 90° to the left). The first basic ideas of loops were also discussed. In teaching blocks 3 and 4 the basic concepts of computer science already mentioned in block 2 were deepened and the students' projects were designed in groups and the 'smart textiles' were completed as far as possible. This implied the development of a circuit, the coding of the functionality of the work piece as well as a manual implementation by sewing and gluing.

3.2.3 Agrupamento de Escolas Emídio Garcia. This pilot2 was carried in COVID situation in the context of RoboSTEAM project from 19th November 2020 to 5th January 2021 at AEEG. It involves a challenge choose from the used by IES Eras during the first piloting phase. It was carried out by two classes. The class D is attending eleventh grade (secondary level) in Sciences and Technologies. It is made up of 21 students (17 boys and 4 girls), the average age is 16 years old. The Art class (11th E) is made up of ten students at the same age as the Sciences and Technologies student. Due to the restrictions related with this pandemic context, it was not possible to gather students from the two different classes. Being so, the Art students did the artwork and class D, after being given the art crafts.

The Art students created their art crafts individually, during Design A classes. Regarding Class D, it was split into 6 groups, yet, because they had to keep social distancing, these groups worked mainly on Monday free afternoons (2 groups at a time – each week); the final step of the challenge was achieved during Physics and Chemistry classes. All groups showed mixed abilities concerning not only STEAM related competences but also hands on tasks. Therefore, the groups were heterogeneous.

AEEG also created a Team for the project on the official school Learning Platform (Microsoft Teams) on which the communication between both teachers and students had a quite good flow. It was also used to store all documentation and evidence (mainly photos) of the ongoing project.

3.2.4 Colégio Internato dos Carvalhos. Pilot 2 was carried out at Colégio Internato dos Carvalhos, by students of the Electronics and Telecommunications course. Due to the pandemic situation, the time available for this challenge was too short and implemented with some restrictions. In this case they choose the challenge of University of Eastern Finland regarding Well-being of senior citizens defined for pilot1. In this case they adapt the challenge to the development of a dance robot that develops a choreography synchronized with the music in a limited space. The main objective is for the robot to perform a dance according to the music, that is, perform a choreography synchronized with the music in a limited space with the idea of amusing older people with health and mobility restrictions. The constraints for the robot were the following: 1) The chosen music had to have a time between 30 seconds to 1 minute; 2) The robot had to act on a 2-meter by 2-meter square; 3) The choreography should be representative of the music; 4) The robot's movements should be synchronized with the music; 5) All groups had the same time to develop the dance robot.

3.2.5 University of Eastern Finland. The pilot 2, in University of Eastern Finland, was carried out in the Teacher Training School but due, COVID-19 situation caused that part of the group finished their elementary school during the course so only 5 students carried out the course to end.

Main goal was to design, construct and program a mobile robot using Hummingbird-kit. They used challenge template as basis of the work described for pilot 1, but they concentrated on challenges defined by CIC in pilot phase 1. Students were able to use different materials for construction. After designing students programmed mobile robots.

Table 2: Pilot indicators

Results for Pilot 1			
School	Time	N-Nano challenges	Average
I.E.S Eras de Renueva	20h	4	5,00
Carl Benz School	9h	3	3,00
Agrupamento de Escolas Emídio Garcia	35h	3	11,66
Colégio Internato dos Carvalhos	20h	3	6,66
University of Eastern Finland	30h	3	10,00
Results for Pilot 2			
School	Time	N-Nano challenges	Average
I.E.S Eras de Renueva	20h	7	2,85
Carl Benz School	6h	2	3
Agrupamento de Escolas Emídio Garcia	8h	5	1,6
Colégio Internato dos Carvalhos	20h	1	20
University of Eastern Finland	30	3	10

Table 3: Diagnosis phase results per schools

Area	IER Grade	CBSK Grade	AEEG Grade	CIC Grade	UEF Grade
Science	4.45	4.52	4.69	4.60	3.49
Math	4.30	-	4.21	3.86	3.58
Engineering	4.37	4.29	3.84	4.26	3.40
Arts	3.99	-	4.00	3.83	3.65
Technology	4.47	4.75	4.51	4.80	4.09
Career	4.65	4.23	4.77	4.62	3.72

4 RESULTS AND DISCUSSION

Regarding the results there are different possible indicators and instruments for the assessment of the pilots, in this case we are going to focus on times to carry out the challenges, in an overview of the STEAM semantic survey results, in the products and in the teachers' perceptions.

There are different metrics, but an interesting one can be the time employed by the students to complete the challenges. In this case is difficult to quantify if a group has or not finished beyond the observation of the completion by the teacher but a general statement of the time devoted for the challenges can be seen in Table 2. In addition, we have included in this table the number of nano-challenges addressed and the average time per nano-challenge.

In the table it is possible to see that for the first pilot the time devoted per partner for the pilots goes from 3 hours required by the CBSK to 11.66 required by AEEG. It depends in many cases of the experience of the partners with the technology and the methodology and in the heterogeneity of the groups. In the case of the former they have been working with similar methodologies and all have the same background while in the latter the students come from different institutions and some of them (those with form ARTs) have different knowledge background. In the second pilot phase, there are to approaches some complete nano-challenges with their kits when they have developed the skills and therefore the time is reduced such as for AEEG or IER and some have done a more complex challenge such as CIC. In addition, it is interesting to consider the number of students involved and how they developed the work, that in the COVID-19 pandemic situation is not as in the first pilot. For instance, in some as CBSK and UEF they maintain the working methodology, but other such as AEEG distribute the work between teams to achieve a final goal, this means that the student should not address the whole challenge, but a part.

Other interesting issue is to know the landscape of students' perceptions about STEAM, this is achieved with the STEAM Semantic Survey and the results per partner are shown in Table 3

From the information gathered in this diagnosis phase we should comment [37]:

- In Spain school the values about the perception regarding the five areas is higher than the average value, with more relevant values in Science and Technology. Arts has he lower value and for the students a career with based on any of the areas is attractive.
- In Portugal there are two schools, one with a background more related to arts (AEEG) and other with a more related with technology (CIC). For both values are higher than the mean and are especially relevant for Science and Technology. However, it should be pointed out, that in AEEG the value for arts is higher than in the rest of the involved schools. For the careers as in Spain the tendency is a positive perception towards careers with the background on these areas.
- In Germany, as commented, the form was adapted so only Science, Engineering and Technology was studied and the results are like the ones obtained in Spain and Portugal, although with lower values for careers

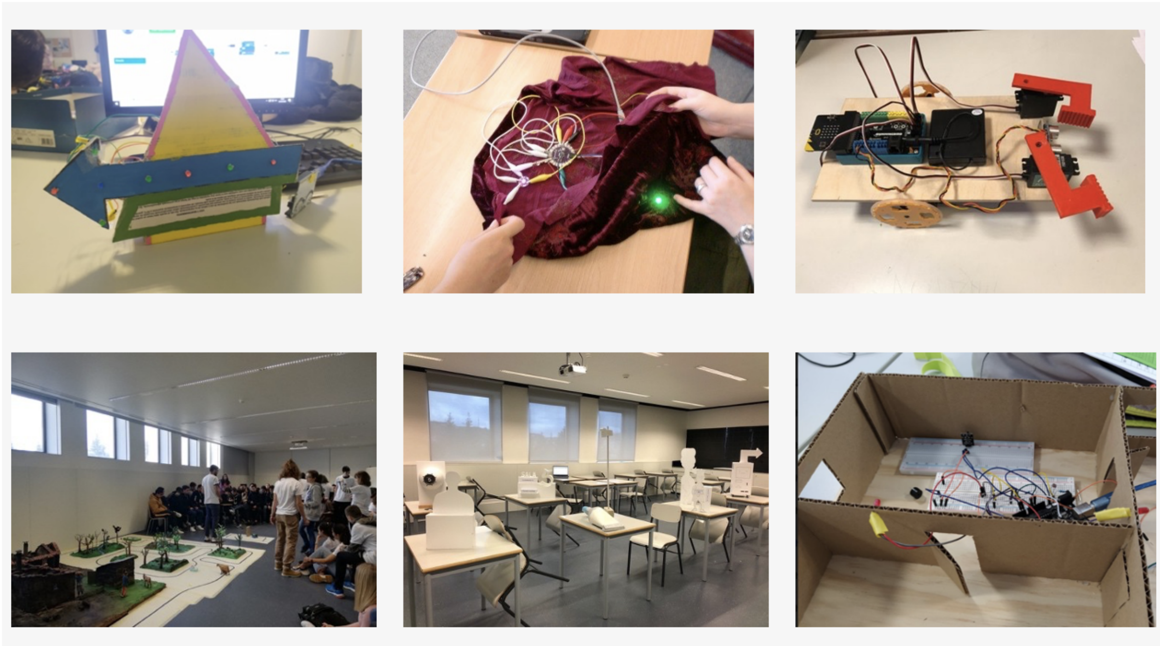

Figure 1: Results of pilots1 and 2 in the different schools involved.

- In Finland the values are lower than in the other countries, especially in Engineering, which is probably because the educational model in this country. The most positive value is Technology in this case.

Finally, Figure 1 shows some of the results achieved during the first and second pilots and some videos can be found at: https://drive.google.com/file/d/1PEfz4Ufh1dcYPRwUoXsFMxvJwMfw_MHD/view?usp=sharing

Finally, it is interesting to gather some of the teachers' perception. In general perceptions were positive, the methodology was agile, and it allows the students to think not only in a task but in the general project. For some of the teachers (those from arts) the technology was a difficulty, but by mixing different students groups this problem was overcome and the results were quite satisfactory. In addition, some teachers argue about the difficulty of using the assessment instruments and in addition those required by their organization. In fact, partners such as UEF cannot apply some of the instruments and CBSK cannot consider all the parts of one of them.

5 CONCLUSIONS

Robotics in preuniversity education is used as the way to develop computational thinking skills and introduce to coding [45–50]. This work describes RoboSTEAM pilot phases, a key element of this Erasmus+ Project to test both the methodology and validate the results obtained during the project. The results have shown that a Challenge Based Learning Approach using Robotics and Physical Devices can facilitate students' development of specific competences even with students from different fields. It has also shown the differences between different educational contexts, such as the flexibility to introduce new instrument or the way in which the students work together. Approaches such as RoboSTEAM facilitate overcoming these problems and make possible prepare the students to work together to solve a problem with a global point of view independently of the context in which it has been defined.

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