Using Educational Robotics with Primary Level Students (6-12 Years Old) in Different Scholar Scenarios: Learned Lessons

Alfredo Pina[1], Gabriel Rubio[2] and Ainhoa Moreno[3]
[1]*Math & Computer Engineering department, Public University of Navarra, Pamplona, Spain*
[2]*Filology & Language Didactics department, Public University of Navarra, Pamplona, Spain*
[3]*Colegio Cardenal Ilundain, Avenida de Don Marcelo Celayeta, 117, 31014 Pamplona, Spain*

Keywords: Educational Robotics, Real/Virtual Robots, Key Competences, Standard Curricula, Primary.

Abstract: In this paper, we describe the experiences we have been carrying out the last years using educational robotics in classroom at the primary level, mainly with boys and girls from 6-7 to 12-14 years old. We have set up a constructivist Problem Based Learning Approach in order to use robotics to teaching/learning key competences and standard curricula topics. We have introduced the possibility of working with virtual robots as well as with real robots. In order to achieve that, firstly we chose real robots (Beebot and Lego Mindstorms NXT/EV3 respectively). Secondly we implemented software tools for the virtual robots using either our own developed software or Scratch or Byob/Snap, and thirdly we designed different projects and materials that could work with all those technological artifacts. Afterwards, and in order to validate such tools and such methodological approach, we used all of them in three different educational environments: firstly in a series of teacher's training summer courses (11, 12 years old, in August from 2012 until 2016), secondly in the First Lego League (FLL) contests (10-14 years old, which took place from 2009 until 2016) and then with a teacher's teams network we promoted (7-14 years old, consolidated in 2014- 2015 and still in place up to date). The results are promising as we have managed to create a sustainable network of schools and a significant group of people working in a coordinated way. The Educational authorities support our work and we have set up a binding agreement between the university, the schools and the Planetarium of Pamplona, in order to work both in the school and out of the school (the Planetarium plays the role of a Science and Technological Museum).

1 INTRODUCTION

1.1 Context and Literature Review

Rocard's report (where the main issue is that the European countries are experiencing serious shortages in the scientific labor market) claims that "a reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science".

Teaching programming at the primary level is a critical issue as it is stated in the Report of the joint Informatics Europe & ACM Europe Working Group (Informatics education: Europe cannot afford to miss the boat, April 2013, http://europe.acm.org/iereport/). The report (focused on primary level students) makes a clear difference between Digital Literacy or Digital Competencies and Education in Informatics (specific science behind information technology, characterised by its own concepts, methods, body of knowledge and open issues).

In the last years, Educational Robotics has been introduced as a powerful, flexible teaching/learning tool stimulating learners to control the behaviour of tangible models using specific programming languages (graphical or textual) and involving them actively in authentic problem-solving activities (Alimisis et al, 2010).

Inquiry Based Learning, Problem Based Learning, Constructivist or Constructionist learning paths are valid approaches to manage Learning through robotics (demo, Moro, Pina & Arlegui, 2012).

Nevertheless, we do not need always to use physical robots to create real learning environments.

Scratch is a visual programming environment that allows users (10-12 years old) to learn computer programming while working on personally

Pina, A., Rubio, G. and Moreno, A.
Using Educational Robotics with Primary Level Students (6-12 Years Old) in Different Scholar Scenarios: Learned Lessons.
DOI: 10.5220/0006381501960208
In *Proceedings of the 9th International Conference on Computer Supported Education (CSEDU 2017) - Volume 1*, pages 196-208
ISBN: 978-989-758-301-8; ISSN: 2184-5026

meaningful projects such as animated stories and games (Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010). It has been shown in (Arlegui, Moro & Pina a, 2012) through a sequence of documented examples, some engaging learning experiences for using Scratch to have an initial, deeper robotic experience before starting with a physical robot.

Using BYOB (Harvey & Möning, 2010)), through the construction of suited custom blocks and, in some cases, of supporting service scripts, and including several fundamental robotic sensors, a rather complete 2D robotic simulator has been presented in (Arlegui, Moro & Pina b, 2012). Some practical experiences were implemented using BYOB and LEGO NXT robots for primary level are presented in (Arlegui, Moro & Pina, 2013). Currently all these tools have been adapted and extended to SNAP and EV3.

Some of the different experiences of robotics found in the literature, describe the kind of robots and didactical approach they use, others focus on the different applications contexts and there are a few that describe research studies on using robotics in Education. The literature review has been organized in three main blocks related with scholar experiences, robotics clubs/ camps or competitions and miscellaneous aspects.

Benitti (2012) has shown that educational robotics has an enormous potential as a learning tool, including supporting the teaching of subjects that are not closely related to the Robotics field. This study points out that there are no studies on the experiences of using robotics with students aged 11-12 (neither for less age). Another important question for us is that he demonstrates that there are no empirical research involving the use of low cost robots in education (most of the experiences are using Lego NXT).

Bers, Flannery, Kazakoff & Sullivan (2014) argue that engaging in construction-based robotics activities, children as young as four can help to learn a range of concepts related with computational thinking, robotics, programming and problem solving. Even the early childhood classroom is not typically a place where we find students programming robots, with the availability of developmentally appropriate technologies it is possible, and the result may be the technological fluency for our youth students. The authors show in this paper that with age-appropriate technologies, curriculum and pedagogies, young children can actively be engaging in learning programming. Parents, educators, policymakers and researchers are responsible to assure that our children receive the technological education needed for healthy development and successful future.

Fridin (2014) presents “Kindergarten Social Assistive Robotics (KindSAR)”, a novel technology that offers kindergarten staff an innovative tool for achieving educational aims through social interaction. The basic principle of constructivist education is that learning occurs when the learner is actively involved in a process of knowledge construction. In this study, storytelling was used as a paradigm of a constructive educational activity. An interactive robot served as a teacher assistant by telling prerecorded stories to small groups of children while incorporating song and motor activities in the process. Their results show that the children enjoyed interacting with the robot and accepted its authority.

Johnson (2003) was stating some questions already not completely answered about teaching with robotics at the schools. The main question he had at that moment was: if we could show that robotics has sustained potential in education, we should integrate it into the curriculum. Currently a few scholar curriculum include robotics. In Sweden for example, in 2006 a study (Hussain et al, 2006) shown that it was possible to use Robotics at school for improving Maths learning and they were able to demonstrate that it was true. Most of the issues in applying robotics as a learning tool are today well known. For example, Pitti et al. (2014) made a study in Latin America and Spain about the perception of teachers (from Schools and Universities) and most of the issues are explained (like methodology, types of robots or teachers & school’s needs). The results could be easily generalized to other parts of the world. Focusing on Europe in 2010 some experts (Bredenfeld et al, 2010) were stating that the long-term goal is to make robotics in education stronger, more serious and evaluated and thus sustainable in order to achieve increasing technology competence of young people and to attract them for technical professional careers.

Some of the educative experiences in applying robotics we can found are in schools like the study that made Chin et al. in Taiwan (Kai-Yi Chin et al, 2014). The main conclusion was that using educational robot-based learning systems in classrooms demonstrates a significant advantage for students, by improving overall learning interest and motivation. We have several examples of educative experiences for University undergraduate students (Jung, 2013; Riek, 2013; Alvarez, Larrañaga, 2016), but the results in such contexts cannot be applied to primary school.

If we switch to other fields of application, robotics has shown a great value in complementary education through the use of it in Contests, Competitions, Clubs or Tech Camps at earlier ages. The motivation to do such activities can be that robotics can provide a vehicle for guiding primary and secondary school children toward an effective understanding of programming and engineering principles (Petre et al, 2004: He et al, 2014)). It is a way to encourage and promote computing and engineering education among its young generations, and in particular for female students (Alhumoud et al, 2014). The lack of interest in Science and technology among young people is a fact and robotic events help to try to change such potential problem (Riedo et al a, 2012; Chan et al, 2013).

There are other important issues to take into account if we want to manage to introduce robotics education at schools. Teacher's schools training and supporting is a key aspect and sometimes this can be done out of the school, for example in robotic festivals (Riedo et al b, 2012). Another key factor is to get the engagement of the families in such processes (Cuellar et al, 2013) or event to try to create collaborations between universities and schools. In (Bers et al, 2005) an example is given; the approach involves the creation of partnerships between pre-service early childhood and engineering students to conceive, develop, implement and evaluate curriculum in the area of math, science and technology by using robotics. The type of robots we can use is also very important. In general, we need to have a robot every 3-4 students and the cost of it can be high. In (Korsh et al, 2013) they present the 10 Dollar Robot Design Challenge to encourage new designs for extremely low-cost robots that can be made globally available to attract primary and secondary- level student interest in engineering. Related with that we may use also virtual robots (as we propose in this paper). It has been stated the need of having direct manipulation environments for learning (Slangen et al, 2010), like robots. Nevertheless, other virtual environments could be used for such purposes.

1.1 Aims of Our Work

Analysing the previous state of the art we can observe that only a few of the educational robotics initiatives are addressing the target ages we are working with (6-12 years old). So the double hypothesis of our paper is, on the one hand, that learning using digital and real technological artefacts (robots in this paper) can be done at earlier ages and on the other hand this learning can be done with almost all kind of students' groups and in different contexts and course formats.

In order to carry out such objectives we have developed an Educational/Pedagogical theoretical framework. Based on such framework we have constructed a learning model producing specific materials and proposing a methodology to be used during the teaching/learning process.

In this paper we give an overview of such a model and we show and discuss three practical cases where we have applied it (first cycle of primary school, summer course and the teachers' team network). The results are analysed and discussed in order to give answer to the hypotheses and to summarise other findings and reflections.

The rest of the paper outlines the theoretical framework, explaining the didactical and technological tools we use, and how we can create materials for both virtual and real robotics teaching/learning environments. Then we describe the teaching/learning activities we have carried out, showing the experimental results. The following section (discussion) focus on how the results contribute in reaching the stated research goals. The paper ends with the conclusions and future work section.

2 THEORETICAL FRAMEWORK AND EDUCATIONAL MATERIALS

2.1 The Didactical Approach & Technological Tools

Our learning strategy consists of a Project Based Learning (PBL) approach, which means that we will be working on planned specific projects. Meanwhile, our intention is to promote and carry out Inquiry Based Learning (IBL) Activities. The methodological approach is based on the Constructivism Theory of Learning. The way to combine those three aspects is:

- to propose different Projects as the main educational material,
- for every Project we need to propose several Problems to be solved, starting from a simple problem, and when the problem is solved we propose the next one, very similar, but with one additional issue to be solved/learnt: constructivist path
- During the solving process we need to guide the students, offering alternatives but not solutions…just hints…. promoting self-learning or Inquiry Based Learning.

We propose to use different technological tools (software & hardware). In general, we use Scratch/BYOB/Java simulator and BeeBot robots in the first primary cycle (6-7 years old) and BYOB/SNAP and Lego Mindstorms NXT/EV3 robots in the third cycle (10-11 years old). In both cases we are using a graphical formal programming language and we have several programming tools and tips to make the necessary blocks or procedures (primitives) in order to implement the previous didactical approach.

More details of the didactical framework can be found in (Arlegui et al, 2013); you can find also more details on how to use Real Lego Robots, virtual robots and sensors created with BYOB in order to make constructivist PBL learning paths for 11-12 years old students. We outline in the next section an example of how we can do a similar thing for 6-7 years old students, integrating PBL, IBL, soft skills, teamwork, logical programming, key competencies and curricular topics.

2.2 Example: First Primary Cycle (6-7 Years Old)

The public school Cardenal Ilundain, one of the schools we are working with belongs to the British Educational Programme, which is worldwide recognised as a leading educational centre of excellence, and as a key innovator in British and Spanish bilingual and multicultural education. British schools in Spain must follow not only the Spanish national curriculum but also the UK syllabus and almost half of the lessons are taught in English; mandatory those subjects: Science, Maths and Literature. One of the key features of the Science British syllabus is the importance it gives to apply the scientific method, in which the educational robotic experiences fits perfectly.

We have been working with the above mentioned school for two years with Robotics in the first cycle of Primary level (6-7 years). The first year only one teacher participated in the program with one group of 24 students. In the second year there were 6 teachers involved and 3 groups of students (75 students). The robotic activities have been combined with Programming in Scratch and with playing with logical games. In fact one group is splitted in three and in parallel they work in turns in one of the 3 activities proposed. Robotics is in this way integrated with the rest of "thinking & programming" activities and at the same time smaller groups work with any of the activities. In this way you need more teachers and more room; in fact, they are using the classrooms and other common areas of the school (the hall) and at the same time some parents are engaged in helping the teachers in order to be able to monitor the different groups.

We use the mini robot Bee-Bot, ad-hoc prepared mats and Scratch (figures 1 & 2) in order to work with the curricular topics and key competencies by means of programming robots or simulators. Bee-bot is a big bee with buttons on its back produced by the TTS group. The bee can be programmed by pushing the six buttons on its back to make it move forward or backward (15 cm), turn left or right a quarter of a circle ("a pizza" for the children), start to move after one or several buttons have been pushed one after the other or all of the previous commands can be deleted.

Scratch includes several features which can be attributed to usual robotic behaviours. Carefully exploiting these features makes it possible for a student to have a significant experience of 'virtual' robotics in a 'virtual' environment. Therefore, before working with a real robot, the most important aspects of robotics can be easily taught. In our case we have developed a simple simulator of Bee-Bot robots with Scratch. It is very simple but it allows us to have an alternative to real robots.

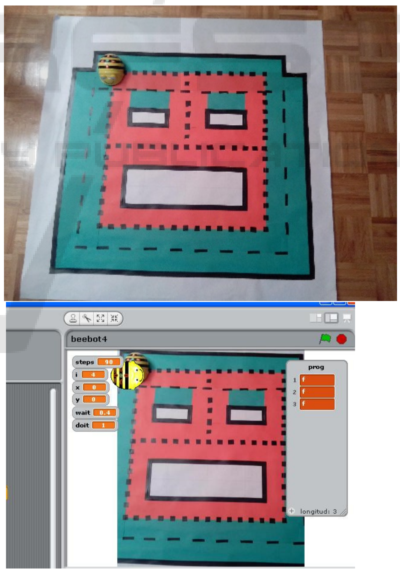

Figure 1 and 2: The BeeBot robot, one mat and both integrated within the Scratch environment.

Bee-Bot is suitable when making linear movements, but if we need to make curved trajectories the physical Bee-bot robot is not valid (in general robots are not very precise with curved trajectories). For that we need to use Scratch to create primitives that can follow curve trajectories (see figure 3)

Finally, we have implemented one complete Bee-bot simulator with Java in order to be able to work both in virtual or real environments. The main reason for that is that we have a limited number of robots, so the use of Scratch and/or the simulator helps to make all the students to work on the same activity in different stages. Before starting designing the activities, there is a planning process to set the contents, the objectives and the assessment. The main goal is to be able to work on curricular topics, key competences and soft skills (as mentioned before).

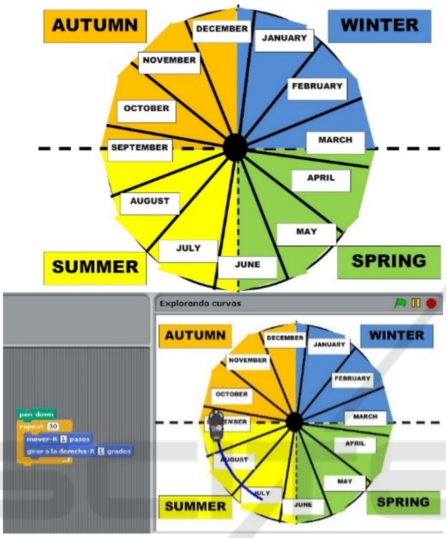

Figure 3: A "seasons" mat and one Scratch simulator for curve trajectories using this mat.

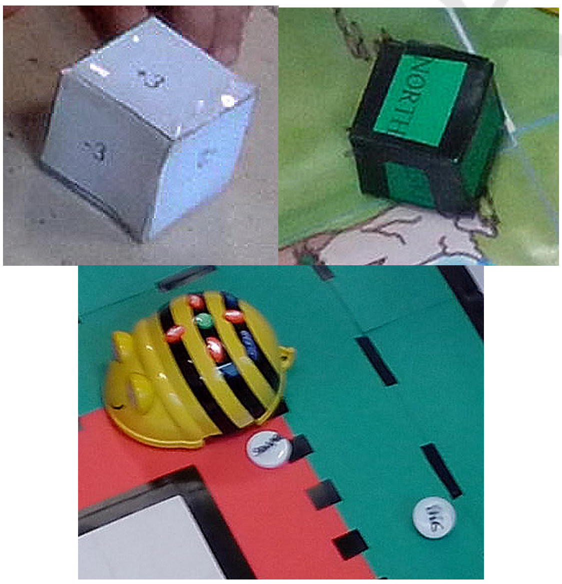

Figure 4: Materials: dices, the robot and one mat.

We are using 12 Bee-bots, mats, spinning-wheels, dices and counters (figure 4). Except the robots, all the objects are "student made materials". At this moment we have several "educative kits" to work on several topics: "**Solar System**"with mat and spinning wheel;"**Desert Island**" with mat, dice and spinning-wheel; "**A Year Round**"with mat and 2 spinning wheels depending on the aim of the activity; "**Navarra, our region**"with mat, dice and spinning wheel;"**Basic Maths**" with mat and dice; "**Easy Geometry**" with mat and counters; "**Object relative position**" with mat and cards.

Flexibility is a key aspect of this approach, allowing students to participate individually, in pairs or small groups (see figure 5) in order to complete a task guided by the teacher and working for an extended period of time, to investigate and respond to a simple or more complex questions, problems, or challenges. Pupils are engaged in a rigorous process of asking questions, using resources, and developing answers. They are allowed to make some choices (about the movements or paths) which contribute to develop their knowledge on basis of exploration and experiences.

Figure 5: Working in small groups & Observation as the assessment process method.

The first day students meet the robot, PBL methodology is again applied. The teacher does not say anything so they show their own expectations, then they have the opportunity of touching and also they are guided through small challenges and attainable goals. They discover different possibilities that the Bee-bot offers or the lack of them (impossible curved trajectories). Next step is to reach an agreement and set the rules to use the robot: handle with care, take turns....etc. Beginning in such way we generate interest and curiosity, thus they are ready to tackle future activities. Observation has been until now the assessment tool used (figure 5).

3 RESEARCH METHODOLOGY

The employed research methodology is case study. Using the previous didactical ideas, we have organized/followed different learning activities in order to collect data to support or no the paper hypothesis.

3.1 Description of the Experiments

The three formats and different contexts we have been working with are:

- First Lego League competition (FLL) (2010-2015)
- Summer courses open to teachers and students (10-12 years old) (2012-2014)
- Schools Network (and teacher's teams) making robotic projects at the primary level (10-12 years old). In the network we have at least one case where a team of teachers who are working at the first cycle of primary level (6-7 years old). (2013-2015).

The FIRST Lego League (also known by the acronym FLL) is an international competition for elementary and middle school students (ages 9-14 in the USA and Canada, 9-16 elsewhere). In fact, in Navarra we have mostly students between 10 and 14 years old.

Each year the contest focuses on a different real-world topic related to Science. There is a scientific project related to the chosen year´s topic to be developed and presented. The robotics part of the competition involves designing, building and programming the Lego robots in order to complete certain tasks. Once the tasks have been completed, you get some points. The students work out solutions to the various problems they are given and then go to regional tournaments to share their knowledge, compare ideas, and show their robots completing the tasks.

We have a 2-week summer course. During the first week "trainees" are trained by lecturers in a very practical way ("making projects"), with several theoretical reflections or insights. The second week the trainees have to apply their newly acquired knowledge with students (about 5 students for every teacher) and they have to teach/guide them through the project's completion (4 days). Then the 5th and last day we all gather at the Planetario of Pamplona, where every group of teacher/students has to explain what they have achieved by means of demos of the virtual robot and the physical one. For that event the families and general public are invited to participate.

The families of the students agree on participating in such training teacher's course by means of letting their children to participate in the course and getting involved in the learning process (in fact for the students it was a kind of Tech Camp).

The courses have been organized in collaboration with the Public University of Navarra, Planetarium of Pamplona and the Education Department of the Navarra Government (Educational Authorities).

After the first summer course (August 2012) we have decided to deep dive in the experience but in this case with the regular teachers and the regular classes of the educational system in Navarra. The aim was to involve not only teachers (we wanted more than the summer course) but also the schools (including school principals) and the Education department of Navarra Government (educative authorities). Trainers from UPNA participated as well.

The proposal was put forward for every academic year and organized as follows:

- First stage (September-October): Trainee's training (Lecturers and Teachers)
- Second stage (November-December): The teachers' teams design a robotic project to be carried out with their students at the schools.
- Third stage (January): All projects are discussed in one seminar, where all the teachers participate. At the end of this stage every team of teachers know their project and also the materials needed like software and robots.
- Fourth stage (February-May): every team of teachers organises and teaches the practical lessons with their students (an agreed number of lessons).
- Fifth stage (June): All the completed projects are discussed and shared during a seminar where all the teacher's teams participate.

3.2 Data Collection Process

After several years working we have collected data related to those experiences; the main aspects we have focused on and therefore measured (with different surveys at different times) are:

- Gender, Age and Number of people participating (students & teachers)
- Type of schools
- Frequency and amount of time they work on robotics
- Relation with standard curriculum
- Motivation of the students towards science & technology
- Methodology and learning strategies
- Competences they work
- Outcomes of the students

Table 1: Summer Course survey for teachers & for pupils.

Q1	Date of the course	Q8	Course expectations	Q1	How did you like the course?
Q2	Timetable	Q9	Contents Interest	Q2	Did you learn a lot?
Q3	Lenght of the course	Q10	Course Syllabus	Q3	What did you miss?
Q4	Course Location	Q11	Speakers Rating	Q4	Will you repeat a summer course?
Q5	Classrooms facilities	Q12	Material's quality	Q5	If yes, on what topic?
Q6	Technical facilities	Q13	Course Interactivity		
Q7	Personal Attention				

The participants in the surveys are teachers or coaches involved in the robotic training activities (Summer Courses, FLL and Schools Network), the students that have been following the robotic activities (Summer Courses and Schools Network) and the families (Summer Courses).

In all the cases we have gathered all the information about number, genre or age of the persons involved, contextual scenarios and other general information. Apart from that we have used specific surveys for teaching-learning information. We explain those surveys in the next paragraphs.

To collect data about the summer courses we have used 2 questionnaires just at the end of the course, one for the teachers another for the students.

Table 2: Summer Course survey for families (motivating stem activities).

Q1	Have your son/daughter made similar courses afterwards?
Q2	Do you think that robotic activities have improved their motivation on Maths and/or Sciences?
Q3	Do you think that robotic activities have improved their motivation on technology and/or Computer Science and/or Programming?

To complete that after the third edition (in 2014) we have made a survey to the families, to know if the course has been perceived by them as a turning point in motivating the students towards science and technology subjects. Moreover, we have also measured separately the global satisfaction for teachers and students after every course.

Regarding the First Lego League we have collected qualitative and quantitative data regarding the last tournament (2014-15) among the coaches. The main specific questions are organized around several topics like key competences involved in the training, didactical approaches, curricular topics related with the activity and outcomes of the students. The following tables show the questions we have used (the answers are in a 5-likert scale except in the case of curricular topics; in this case the teachers used check box being able to choose one or more topics).

Table 3: Key Competencies survey.

Q1	Linguistic communication
Q2	Mathematical competence and basic competences in Science and Technology
Q3	Digital competence
Q4	Learning to learn
Q5	Social and Civic competencies
Q6	Sense of Iniciative and Entrepreuneurship
Q7	Cultural Awareness and Expression

Table 4: Didactical approaches survey (5-likert scale) & Curriculum topics related with the robotic activities (multiple checkbox).

		Q1	Natural Sciences
		Q2	Social Sciences
Q1	Inquiry based Learning	Q3	Mathematics
Q2	Structured Learning (step by step)	Q4	Mother language
Q3	Project Based Learning	Q4	Foreign languages
Q4	Problem Solving Based Learning	Q5	Arts Education
		Q6	Technology
		Q7	Others

Finally, and related with the school's network, we have collected qualitative and quantitative data after two complete years working with them. Nevertheless, some of the schools were working before, and others have been integrated within the network in the last months. We have used the same questions that in the previous case of the FLL that have been answered by the teachers.

Table 5: Outcomes of students (gain in motivation, competencies, skills, etc…).

Q1	Motivation towards Maths and/or Sciences
Q2	Motivation towards Technology and/or Computer Science
Q3	Team work capacity
Q4	Analysis capacity (i.e. Problem decomposition)
Q5	Abstraction capacity (i.e. Generalizing solutions)
Q6	Initiative and Autonomy
Q7	Creativity and innovation when searching for solutions
Q8	Explaining and arguing problems and solutions
Q9	Persistency when achieving goals, overcoming difficulties
Q10	Specific programming concepts (Loops, Ifs, etc..)

4 RESULTS

The three issues of the summer courses (August 2012-2013-2014) had a total number of 36 teachers (average age of 34,52) and a total number of 126 pupils. The satisfaction degree for the teachers is 9,13 (10-scale) and 3,59 (4-scale) for the pupils.

During the FLL 2014-15 28 teams from Navarra, Aragon and La Rioja were participating in Pamplona. About 51 coaches were involved and the teams had about 224 students.

4.1 General Results: Age, Gender, Type of School and Working Language

The age and gender information is shown in the next figures. For the summer courses, the age of the students has been evolving from 2012 (where we did not have any students of 10 years old) to 2014 (where some of the students from 2013 where repeating the course during 2014). For the FLL we only have range ages. The schools' network is the only experience where we have 7 years old pupils. In the case of gender, we see that the results are clearly different depending on the context of application.

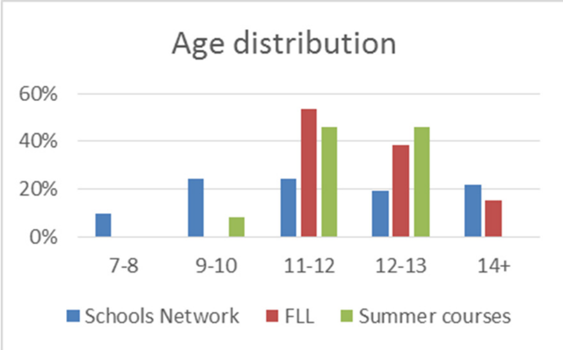

Figure 6: Age comparison.

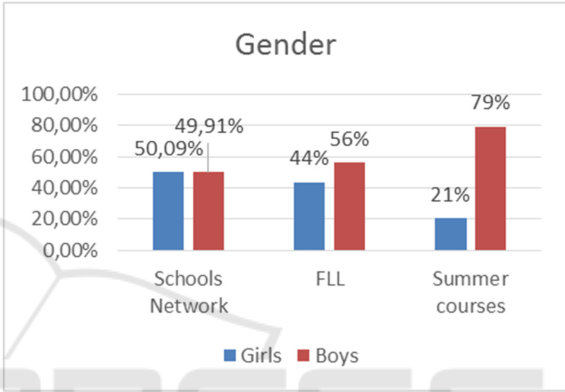

Figure 7: Gender comparison.

Navarra has a long history of private subsidized schooling, and those schools are integrated in the educational public system. They are similar to a charter school, nevertheless they have to follow the same general rules about curricular aspects that the rest of the public schools. Another important feature within the educational system in Navarra is that we work with two official languages, Spanish and Basque; in the last years English has also been introduced as a third linguistic approach at the schools.

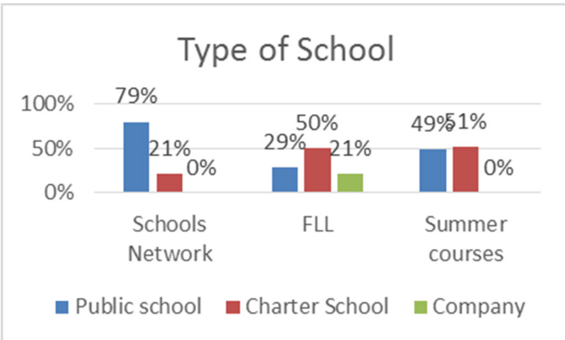

Figure 8: Type of school comparison.

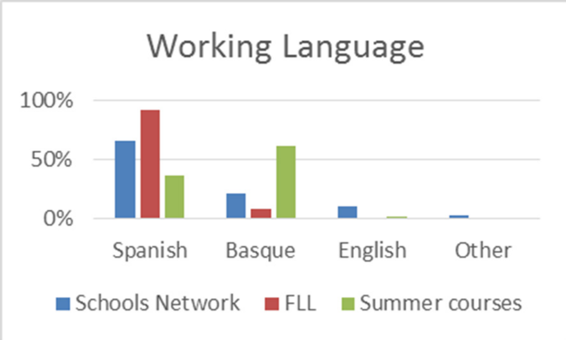

Figure 9: Working language comparison.

4.2 Teachers, Students and Families' Feedback for the Summer Course

After every summer course edition, we get feedback from students & teachers through tests. Teachers gave us their opinion about course organization and teaching learning contents. In general, they are happy with both issues (between 3.5 and 4 and between 3 and 4, out of 4 respectively). Pupils are very happy with the course and have different opinions on it (figure 10). After the third issue (2014) we have made a survey to the families in order to get some feedback from them, a few years after the course in some of the cases. Only 35% of the families answered to the survey, and 60% of the families agree that the course increased their motivation towards Math & Sciences and technology & Computer Science.

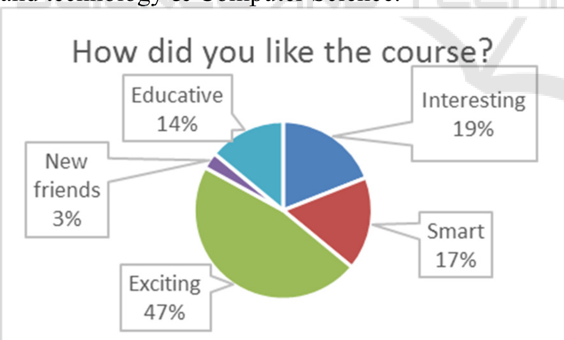

Figure 10: Students survey for the summer courses.

4.3 Didactical Approach, Curricular Topics, Key Competencies and Students Outcomes for the Schools' Network and the FLL

First of all, we can see in figure 11 (FLL in Blue) that Educational Robotics can be a "tool for learning any Key competency" (not only Digital or Math competencies). And thus can be done using different didactical approaches.

Secondly we can observe in figures 12 & 13 that the teachers have managed to work several topics (apart Computer Science and Math) through Robotics. At the same time the teachers have considered that the students, through the robotic activities, are improving their outcomes in several critical aspects that are not only related to Computer Science nor to the Curriculum.

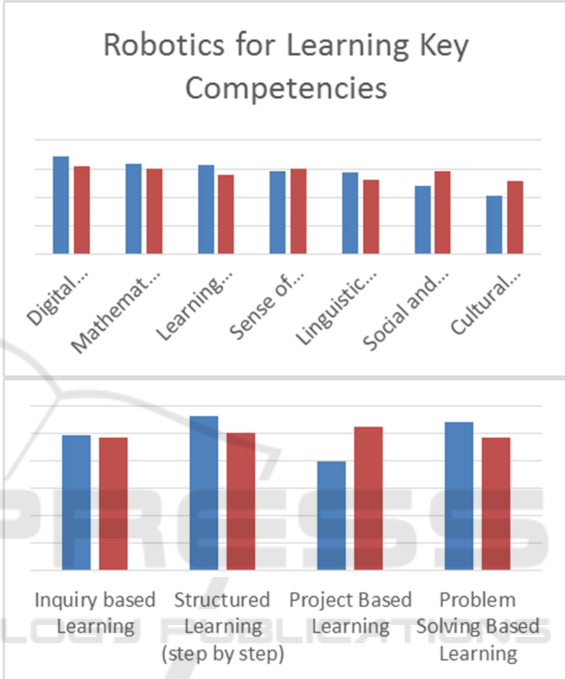

Figure 11: Competencies & Didactical approach.

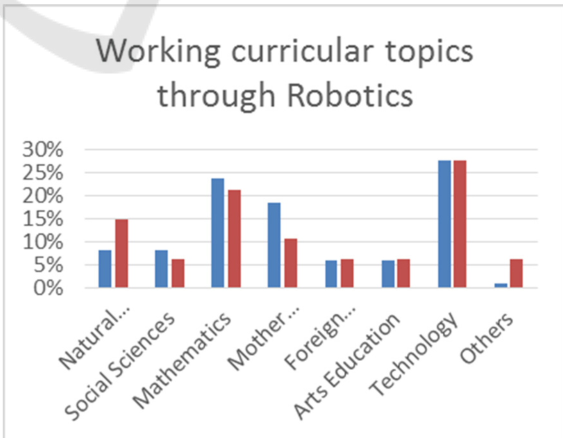

Figure 12: Learning & Students Outcomes.

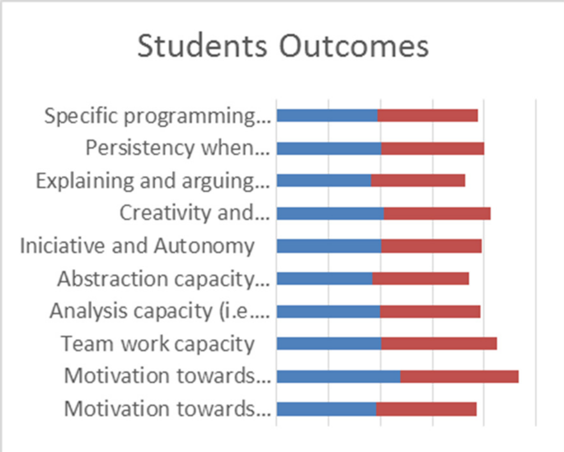

Figure 13: Learning & Students Outcomes (cont.).

5 DISCUSSION

We have categorized the results trying to answer two broad questions: What is the student's profile: gender, age, language or kind of school? Influence on the learning processes? Answering these two questions will give us valuable information to measure to what extent learning using digital and real technological artefacts (robots in this paper) can be done at an earlier age, with almost all kind of group of students, and in different scenarios.

5.1 What Is the Student'S Profile: Gender, Age, Language or Kind of School?

For the first question, the results of the surveys that have been carried out show clear differences.

Gender: the presence of female students in voluntary experiences (as FLL or Summer Course) is small. For the Summer Courses we had an enrollment of 21% female students and 79 % male students. In FLL teams we discovered that the female participation was slightly higher than 30% while the male one was of 70%. In comparison, in the Network of Schools the female presence was 50%. This data has to be analyzed in close relationship with other questions that were asked in the Network Survey and FLL Survey: Girls and Boys are equally motivated? Here, while the FLL coaches responded yes in 38% and no in 31% of the answers, in the Network of School teachers chose 52% of the answers were affirmative and only 17% of them negative. Another 31% of teachers said the answer depended on individual features as: perseverance, curiosity...

Age: within the Network of schools, students are younger. 50% of the FLL teams are in 10 to 12 range and the rest (50%) up to 16. Nevertheless, most of the students in Network of Schools scenario are from 7 to 11 years old (68,54%), and the rest are up to 13 or early 14 (41,46%). So we are finding here a younger population that is facing programming problems and topics with teacher's guidance and at an appropriate level for them. When we asked teachers if this approach should be continued 100% of the teachers said yes.

Type of school: the percentage of public schools enrolled in the Network is 77,27%. That is the opposite of what happened in FLL, as non-public (charter schools) enrolled in it are 79,31%. Most of the schools in Network of Schools are, therefore, public schools whereas most of the schools enrolled in FLL are non-public schools. From the point of view of educational policies, this fact is remarkable and supports the efforts done to spread educational robotics through this Network, as the impact in areas and population where charter schools are not reaching now can be achieved

Working language: The surveys show differences in this aspect, as well. According to the answers received, most of the teams are working in Spanish in the FLL (92,30%). Nevertheless, under the Network of Schools, this percentage is lower (65,5%) and reflects better the reality of the Navarrese educational system, where Basque and English are strong vehicular languages. Besides, in the case of Basque, is one of the official languages in the region. For this reason, it is quite relevant that 20,7% of students in the Network of Schools has Basque as working language, and 10,3% English.

5.2 Teaching/Learning Processes

For the second question, learning outcomes, the surveys left interesting considerations. First of all, it has to be said that by learning outcomes we are including two major areas: basic competences (as defined by the EU and the Spanish educational laws) and a set of observable gains or general outcomes as motivation towards Maths and/or Sciences, motivation towards Technology and/or Computer Science, team work capacity, analysis capacity (i.e. Problem decomposition), abstraction capacity (i.e. Generalizing solutions), initiative and autonomy, creativity and innovation when searching for solutions, explaining and arguing problems and solutions, persistency when achieving goals, overcoming difficulties, specific programming concepts (Loops, Ifs, etc..). Teachers or coaches, depending on the survey, selected in Likert scale up to 5 the intensity they thought the educational robotics program they were involved in was impacting in their students or teams.

About **general outcomes**, FLL results show that for most coaches, the learning outcomes observed were more focused on teamwork (maybe an influence of the competition context), whereas Network results showed the importance of perseverance, which is an important individual value that is responsible of most of dropouts. As PISA (Program for International Student Assessment) data shows, perseverance, drive and motivation are essential for doing well in and out of school (Skills for Social Progress: The Power of Social and Emotional Skills, OECD Skills Studies, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264226159-en). It is highly remarkable that the second important outcome in both cases is creativity and innovation. In Network Survey, student autonomy scored very high too. We could say, from the results, that the general learning outcomes that arise working in both settings with educational robotics, demonstrate that "hard skills" closely related to computing or mathematics are only a small part of the picture. In fact, social skills compound another big part of the picture and further empiric research should be done in this respect to discover how these skills are influencing other areas of learning in educational robotics programs.

Regarding **basic competences**, FLL results highlighted STEM and entrepreneurship -influence of contest rules probably-, and the Network results preferred Digital Competence, which is speaking about a more global approach to educational robotics inside schools. In any case, both surveys selected in second place the competence selected in first one in the other survey. That points a total agreement about the main competences impacted.

Table 6: learning Competences and Outcomes.

	Competences	
	First	**Second**
Network	Digital	STEM
FLL	STEM-Entrepreneurship	Digital

Outcomes	
First	**Second**
Perseverance	Initiative, Creativity, Autonomy
Teamwork	Creativity, innovation

In order to provide more insights into this issue, it is interesting to check the answers to the question "Robotics for working curricular topics". In the top five list, in both scenarios Technology and Math are at the top, as expected, but Mother Language is the third one in Network Survey and fourth one in FLL results. Again, we have to consider and shape adequately this fact: learning through robotics implies other transversal and social skills that have to be bore in mind while planning and designing didactical units.

Apart from these two big questions that have been discussed, the results gave us relevant information about the way teachers and coaches are organizing their Teaching-Learning process. Although our learning strategy preferred is Project Based Learning, which means that we are going to work on projects and we want to promote an Inquiry Based Learning, with a constructivist/constructionist path in the background, we discovered that structured or step by step learning, is a popular strategy in both settings. Maybe, the nature of the contest tends to organize learning as projects but, then, uses step by step learning as a way to scaffold teamer's progress. In the case of Network results, it has to be subject of further research why step by step learning is so prominent.

Table 7: Didactical approach comparison.

	Motivation	
	Math/Sciences	**Computing-Tech**
Network	96%	62%
FLL	61%	76,90%

Methodology	
First	**Second**
Structured Learning	Problem Based Learning
Project Based Learning	Structured Learning

6 CONCLUSIONS

All the participants agreed on the fact that the educative materials end the proposed learning methodology is suitable to be used in classroom or out of the classroom. The trainees (school teachers) have adapted the materials and methodology taught by trainers (lecturers) to their own situation (schools pupils).

The use of both technological tools with the methodological approach, the constructivist PBL, has allowed us to create flexible materials to teach the school teachers who will also use them with the be teaching learning activities used by pupils in the classroom.

We have showed that it is possible to work with such materials and methodology in several different context. In all cases it was possible to work with either standard curricula topics or key competencies.

Finally and hypothesis related, through the description and analysis of the different experiences we have find out that it is possible to do the educational robotics we propose at earlier ages (starting 6-7 years old) and in different contexts (in school, out of the school, summer courses or tech camps, competitions, etc…). Every scenario has his own features and outcomes and all of them seem necessary and complementary.

REFERENCES

Alimisis, Arlegui, Fava, Frangou, Ionita, Menegatti, Monfalcon, Moro, Papanikolaou, Pina (2010). Introducing robotics to teachers and schools: experiences from the TERECoP project. Proceedings of Constructionism 2010 (Aug. 2010).

Demo, G. B., Moro, M., Pina, A., &Arlegui, J. (2012). In and out of the School Activities Implementing IBSE and Constructionist Learning Methodologies by Means of Robotics. In B. S. Barker, G. Nugent, n.

Grandgennet, & V. I. Adamchuk (Eds.), Robots in K-12 Education: A New Technology for Learning (pp. 66-92). IGI Global.

J.Maloney, M. Resnick, N. Rusk, B. Silverman, and E. Eastmond (2010). The Scratch Programming Language and EnvironmentACM Transactions on Computing Education, Vol. 10, No. 4, Article 16.

J. Arlegui, M. Moro and A.Pina (2012). How to enhance the robotic experience with Scratch. Proceedings of Constructionism 2012 (Aug. 2012).

B. Harvey, J. Mönig (2010). Bringing “No Ceiling” to Scratch: Can One Language Serve Kids and Computer Scientists?.Proceedings of Constructionism 2010 (Aug. 2010).

J. Arlegui, M. Moro and A.Pina (2012). Simulation of Robotic Sensors in BYOB. Proceedings of Robotics In Education 2012 (Sept. 2012).

J. Arlegui, M. Moro and A.Pina (2013). A PBL approach using virtual and real robots (with BYOB and LEGO NXT) to teaching learning key competences and standard curricula in primary level. TEEM '13 Technological Ecosystems for Enhancing Multiculturality (2013), pp 323-328.

Benitti, F.B.V. (2012). Exploring the educational potential of robotics in schools: a systematic review. Computers & Education, 58 (3), pp. 978-988.

Bers M. U, Flannery L., Kazakoff E.R., Sullivan A. (2014). Computational thinking and tinkering: exploration of an early childhood robotics curriculum. Computers & Education, 72 , pp. 145-157.

Fridin M. (2014). Storytelling by a kindergarten social assistive robot: a tool for constructive learning in preschool education. Computers & Education, 70 , pp. 53-64.

Johnson J. (2003). Children, robotics, and education. Artif Life Robotics (2003) 7:16-21.

Hussain H. et al. (2006). The effect of LEGO Training on Pupils’ School Performance in Mathematics, Problem Solving Ability and Attitude: Swedish Data. Educational Technology & Society, 9 (3), 182-194.

Kathia Pittí Patiño et al. (2014). Using Robotics as a Learning Tool in Latin America and Spain. IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, VOL. 9, NO. 4, NOVEMBER 2014.

Bredenfeld et al. (2010). Robotics in Education Initiatives in Europe - Status, Shortcomings and Open Questions. Proceedings of SIMPAR 2010 Workshops, Intl. Conf. on Simulation, Modeling and Programming for Autonomous Robots, Darmstadt (Germany) November 15-16, 2010, ISBN 978-3-00-032863-3, pp. 568-574.

Kai-Yi Chin et al. (2014). Impact of Using an Educational Robot-Based Learning System on Students’ Motivation in Elementary Education. IEEE Transactions on Learning Technologies, VOL. 7, NO. 4, October-December 2014, pp. 333-345.

Seul Jung (2013). Experiences in Developing an Experimental Robotics Course Program for Undergraduate Education. IEEE Transactions on Education, VOL. 56, NO. 1, February 2013, pp. 129-136.

Laurel D. Riek (2013). Embodied Computation: An Active-Learning Approach to Mobile Robotics Education. IEEE Transactions on Education, Vol. 56, NO. 1, February 2013, pp.67- 72.

Ainhoa Alvarez & Mikel Larrañaga (2016), Experiences Incorporating Lego Mindstorms Robots in the Basic Programming Syllabus: Lessons Learned. J Intell Robot Syst, DOI 10.1007/s10846-015-0202-6.

Petre et al. (2004). Using Robotics to Motivate ‘Back Door’ Learning, Education and Information Technologies 9:2, 147–158, 2004.

He et al. (2014). Teaching K-12 Students Robotics Programming in Collaboration with the Robotics Club. 4th IEEE Integrated STEM Education Conference.

AlHumoud et al. (2014). Using App Inventor and LEGO mindstorm NXT in a Summer Camp to attract High School Girls to Computing Fields. 2014 IEEE Global Engineering Education Conference (EDUCON), pp. 173-177.

Riedo et al. (2012). Analysis of Impact of an Annual Robotics Festival, Proceedings of the 2012 IEEE International Workshop on Advanced Robotics and its Social Impacts, Technische Universität München, Munich, Germany, May 21 - 23, 2012.

Chan et al. (2014). Integrated STEAM Education through Global Robotics Art Festival (GRAF), 4th IEEE Integrated STEM Education Conference.

Riedo et al. (2012). Involving and training public school teachers in using robotics for education. Workshop on Advanced Robotics and its Social Impacts, Technische Universität München, Munich, Germany, May 21 - 23, 2012, pp. 19-23.

Cuellar et al. (2013). Robotics Education Initiative for Parent-Children Interaction. 2013 IEEE RO-MAN: The

22nd IEEE International Symposium on Robot and Human Interactive Communication Gyeongju, Korea, August 26-29, 2013. pp. 364-365.
Bers et al. (2005). Teaching Partnerships: Early Childhood and Engineering Students Teaching Math and Science Through Robotics. Journal of Science Education and Technology, Vol. 14, No. 1, March 2005, pp. 59-73.
Korsah et al. (2013). The African Robotics Network and the 10 Dollar Robot Design Challenge. IEEE Robotics & Automation Magazine • March 2013, pp. 116-118.
Slangen et al. (2010). What pupils can learn from working with robotic direct manipulation environments. International Journal of Technology and Design Education, Springer, Vol. 21, Issue: 4, Pages: 449-469.