Primary Level Young Makers Programming & Making Electronics with Snap4Arduino

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Abstract. The main goal of this study is to show that young makers (8–12 years old) are able to start programming & making electronics with Snap4Arduino, and that this is a way to have (already trained) Makers for secondary level education. We have performed a feasibility study of the Snap4Arduino as an educational tool for elementary school students. The study has been conducted as part of a certified course carried out by the Pamplona's Planetarium where different skills such as learning to learn or sense of initiative and entrepreneurship were evaluated through a PrBL project based learning methodology. Cooperative learning was achieved focusing on teamwork attitude and behavior.

Keywords: Snap4Arduino · Young makers · Primary education

1 Introduction

It is worthwhile to start saying that "times have changed". Today's Young people are growing in the full digital period. His development goes with the technology, which allows them to adapt easily to any advance. That is why Education has to move along continuing the progress, and has to reinvent itself every day. We have to focus on those Youngers, as they have been living surrounded by technology. At present society calls them Digital Natives. The term "Digital Native" coined by Mark Prensky appoints to this age group (mainly young people) that has grown in a digital and technological framework (computers, Internet, Smartphones, MP3, etc…) and that uses those devices and media in a completely natural way.

1.1 Methodological Issues

Some teachers use from time to time ICT in class. Others have replaced the tools they used to use by technology that does the same kind of activity, and therefore the learning outcomes do not change. This is why the use of ICT has to go hand by hand with a change in the applied methodologies.

Sousa [1] carried out several studies where he verified that knowledge acquired or learnt after 24 h for one student is of 5% for lectures, 50% for group discussions, 75% for practical experiences and 90% for teaching to peers.

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Following this matter, two of the most extended methodologies are Problem Based Learning (PBL) and Project Based learning (PrBL). Both have the same approach, both are authentic, both use constructivist learning approximations, both are student centered and include the role of the teacher as a guide. Such strategies (PBL & PrBL) are normally used in technology for education lectures and the main aim is to involve students in research processes and in technological problem solving.

Mettas & Constantinou [2] argue that both are used in a combined form and that are complementary. Blumenfeld et al. [3] think that PrBL learning with projects where the students have to deal with finding solutions to non-trivial problems, making and refining questions, discussing ideas, making predictions, designing plans and/or experiments, gathering and analyzing data, drawing conclusions, disseminating their thoughts and results to peers and creating new ideas or improving products and processes.

We need to change methodologies and at the same time, we need to implement new educational strategies that promote the effective development of the key skills & competencies of the XXI century; one good way to do that is introducing/using computer programming in schools.

1.2 Technological Issues: From Scratch to Snap4Arduino

Previous reflections and bringing programming into the scholar curriculum made popular the use of educational visual programming platforms like Scratch.

Scratch is a free programming software available for several devices, either offline (to be downloaded and installed) or online (through a browser). Such software has been developed by a group of researchers of the Lifelong Kindergarten Group at the media Lab of the Massachusetts Institute of Technology (MIT), supervised by Dr. Resnick. For Resnick [4] one of the best advantages of Scratch related to other similar platforms is his attractiveness and accessibility, which allows anyone starting programming for the first time.

Scratch is an educational tool, but at the same time has a huge ludic potential. As says Prof. Maria Moriana Coronel about one experience with Scratch with Primary school pupils (http://programamos.es/una-clase-de-programacion-con-scratch-para-ninos-de-1o-de-primaria/):

"Pupils we are working with are very Young and have no experience in designing and programming with Scratch, and to understand the difference between playing and learning is not so easy. We observe that the experiences they have with digital artifacts are in general very passive, they receive information or follow instructions to play. That is why the first time with Scratch they think that is a game and are trying to know how to play, what are the rules, what the cat can do or where the button to start playing is. When they discover that they can create their own games the interest, emotion and curiosity arise: Scratch is a game that makes games!"

For Salido [5] a game is a vehicle to allow pupils to learn in a natural and funny way, at the same time requires following specific rules, and enhances social communication. Six years old kids imitate acts, guided by an adult or peers, and some years after they manage to identify a situation and to assume the rules to follow. To assume and reinforce the use of rules reflects an important level of self-assertion that shows clearly the build up of a social integration process.

It is clear that the game and the emotions have a direct relation that we have to exploit. Since Goleman [6] talked to us about Emotional intelligence, we have to know and to manage emotions personal and socially, because it is closely bound to motivation. A person is emotionally intelligent in the measure he can improve his own motivation.

Another tool that has started to be used at educational level is Arduino. It was created with the goal of providing an easy to use and cheap platform to teach electronics at the design high school of Ivrea (Italy). The developers & partners are the Italian Massimo Banzi and Gianluca Martino, the Americans Tom Igoe and David Mellis and the Spanish David Cuartielles, and they decided to make their design open using a Creative Commons license. They protect their authorship and the brand name, but the hardware, software and Doc are open and free, and therefore it is possible to download the circuits' design files or the software source files and the users can modify and share their stuff.

In fact the limitation with Arduino is our mind, as the simplicity of this platform allows to non-expert people in electronics to use and control in their designs electronic devices, in an affordable way.

Moreover, in the last years, a new tool, which is a kind of union between Scratch and Arduino, has been created and it is called Snap4Arduino. The roots of Snap4Arduino can be found in BYOB (Build Your Own Blocks), which is very similar to Scratch but with more possibilities as a programming language. Then BYOB has evolved to a new version called SNAP that finally has been modified in order to be able to work and interact with Arduino (mostly with all the different types of Arduino hardware). Snap4Arduino is constantly being revised and developed at the Citilab of Cornella (near Barcelona, Spain) by the Eduteca research group. The main partners are Victor Casado, Jordi Delgado, José García, Joan Güell and Bernat Romagosa while Ernesto Laval, JensMönig, Frank Hunleth and Mareen Przybylla are the main collaborators.

To date we did not find any paper explaining experiences in the use of Arduino at the primary school.

1.3 Educative Issues and Main Goals of This Paper

In the last 4 years, we have managed to create a sustainable network of schools and a significant group of persons working in a coordinated way with robotics, in primary and secondary education levels. The Educational authorities support our work, we have established also a link between the university, the schools and the Planetarium of Pamplona, in order to work as well in the school, and out of the school (Planetarium plays the role of Science and Tech Museum). The work we present here has been done within this context.

We believe that it is possible to work with appropriate materials and methodologies in several different scenarios. In all cases it should be possible to work either standard curricula topics or key competencies (or both). The target competencies in our case are:

- Linguistic communication
- Mathematical competence and basic competences in Science and Technology
- Digital competence
- Learning to learn

- Social and Civic competences
- Sense of Initiative and Entrepreneurship

Also the curriculum in the case of Primary level (years 4 and 5) in Navarra region has included, a few years ago, a specific section referring to programming within the Math's curriculum: "Use of tools and programming languages for problem solving".

The general goal of this paper is to point out the usefulness and benefits of Snap4Arduino as a didactical proposal in Primary school level. As there are neither scientific evidences nor papers about Snap4Arduino at this educational level, we have collected objective and practical data on this matter and we have set up a certified course in the Planetarium of Pamplona for kids on those ages.

We have as well some other specific goals.

First, we want to analyse if Project based learning is a valid approach and gives good results for teaching Snap4Arduino to Primary school kids. PrBL methodology is very commonly applied in primary school pupils. Moreover, Snap4Arduinos is a tool that allows a wide range of activities of investigation. We feel natural to combine them and is one of our hypothesis.

Secondly, we would like to assess Snap4Arduino as a tool to be used in a scholar context. As we have already said, in the Math's curriculum for primary level (in "processes, methods and attitudes" within the Math's section) it says that the contents should include "Integration of Information Technologies and the use Languages and tools for programming in the learning processes". Therefore, we have to estimate if Snap4Arduino could be a tool to be used for achieving such purposes.

Thirdly, we need to check if pupils can manage basic electronics. The basic functions of Snap4Arduino are also in Scratch (and therefore already used in primary level), but the advanced ones need to design basic electronic circuits and to understand basic electronic concepts. Electronics is not included in the primary curriculum, so the fact that the pupils should be able to manage such part is an open issue

In the rest of the paper, we present the details of the course (materials, methodology and teaching details), then we present and discuss the results of the pilot course. The paper ends with some conclusions and future ideas.

2 The Course

The course had a duration of 12 h divided into 4 sessions (3 h each, 10 h30–13 h30 with a small break). We made it during 4 consecutive Saturdays (April–May 2016) in the Robotics room of the Planetarium of Pamplona. Diana Gonzalez responsible for digital & technological training at Planetarium was helping and observing during all the sessions and was in charge of the camera for pictures and videos.

The main goal of the course was to check the viability of Snap4Arduino as a didactical proposal in primary education.

2.1 Participants, Materials and Methods

The course was covered with 18 participants out of 20 available; 14 boys and 4 girls, within a range of age between 8 and 12 years. Most of them had already some basic knowledge on Scratch (they had already participated in one Scratch course in the planetarium), which was very helpful for the progression of the sessions. Due to that and because we had this information some days before the course, we decided to focus on the advanced part of Snap4Arduino which interacts with the Arduino hardware (Arduino UNO).

The material used has been:

- Computers: one per group
- Arduino UNO board
- Arduino IDE and Standard Firmdata
- Kit Arduino
- Every Project written in a paper
- Document with image rights
- Surveys
- Pictures & Videos camera

The general methodological approach was Project Based Learning. We believe that self-learning through a continuous investigation or research process is the best way to acquire knowledge. The teacher has to provide the necessary tools to achieve this aim. The knowledge acquisition is much more powerful if the student reaches the conclusion on his own (instead of just being given it to him by the teacher).

At the beginning of each session, they have been provided with a project to develop it. The third first ones were more concrete or closed projects, as the main goal was to learn basic knowledge and skills with Snap4Arduino. The last project was completely open and they had then the possibility to apply any of the acquired knowledge and even to make new things. This last project is in fact the core of the PrBL methodology. To carry out the last project they had to investigate, to explore, to "touch", to try, to fail and to try again, etc… no doubt, it was a successful experience for them and for us.

They were divided into 5 groups of 3–4 pupils each: by doing that we assured that every group had a computer, an Arduino board and one Arduino kit. Moreover, teamwork was one of the competencies we wanted to promote, in order to check how they can help each other and the whole group capacity for programming. Alonso et al. [7] state that 1×1, one computer for every pupil, is not necessarily better than one computer for a group of students as there is no a direct relation between the quantity of available technology and their effect on the teaching learning processes.

The division criterion for the groups was the age, provided than in every group there was at least one pupil with Scratch previous knowledge. Doing that we wanted to check if applying such methodology and teamwork it was possible to achieve a cooperative learning.

2.2 Course Structure: Sessions with Different Projects and Different/Common Goals

Every session was divided into seven parts: specific objectives of the session, planning the activity, description of the project, specific material to be used, expected outcomes, activity development, results and discussion of the current session.

The specific objectives for the whole the course are:

1. To learn the basics of Snap4Arduino
2. To construct basic electronic assemblies
3. To use basic functions to activate/deactivate digital outputs for Arduino UNO board
4. To use basic functions to activate/deactivate analogic outputs for Arduino UNO board
5. To use DC motors and to understand their up and running
6. To design small projects using all the previous learnt knowledge

Session 1 (objectives 1, 2 and 3): The traffic lights. Simulating traffic lights using several costumes in Snap4Arduino. Practical application, electronic assembly and programming the Arduino UNO board to design and operate a traffic lights model (see Fig. 1).

Session 2 (objectives 1, 2 and 4): The colors lamp. Mounting a lamp with an RGB led and applying different signals to every lamp pin depending on the position of every potentiometer in order to get the mix of the colors of the RGB led.

Sessions 3 and 4 (objectives 1, 2, 5 and 6): The car and our project.

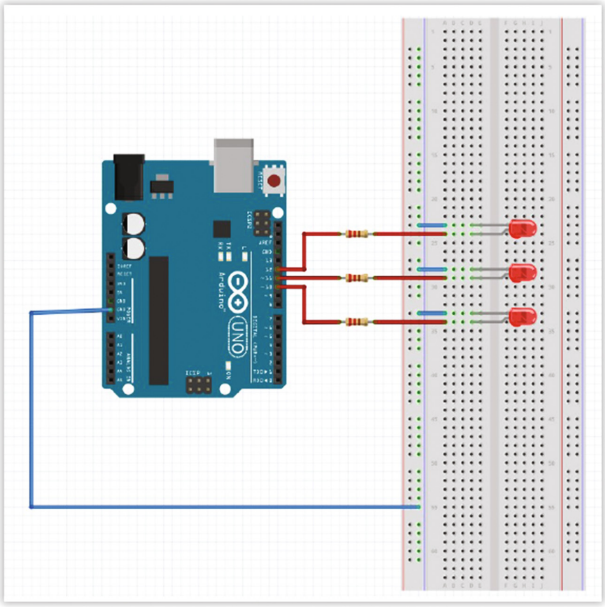


Fig. 1. The traffic lights board assembly (session 1)

The car: mounting and programming a car with DC motors with reduction in order to obtain forward, backward, left and right movements using an H bridge and programming everything in Anap4Arduino (see Fig. 2).

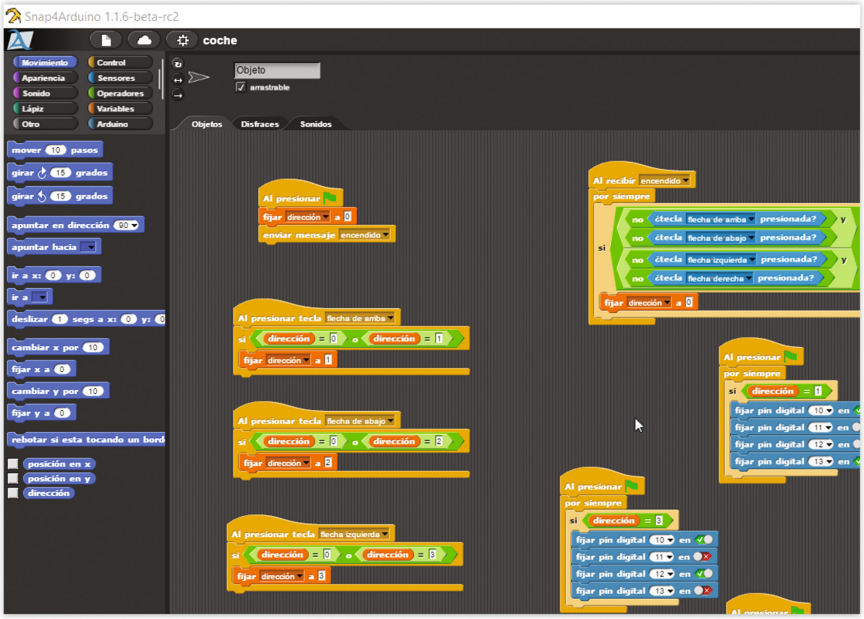


Fig. 2. Visual interface for Snap4Arduino (very similar to Scratch)

Our project: Open project using some of the already seen activities.

3 Results and General Discussion

3.1 Results and Teaching Within the Course

The obtained results in terms of the teaching experience, the solved problems and the expected outcomes were really challenging. Table 1 shows the main outcomes.

The main idea at the beginning was to leave every group to work "ad libitum", but we had some problems with team working, detected at the first session and therefore we had to apply a new strategy. We defined several different roles (demanding different skills and tasks) and everyone switched roles (see Fig. 4):

- moderator for the group management,
- mouse operator to control the mouse
- the assembler: responsible for the electronic board assembly

Table 1. Expected objectives for every session

Sessions	Expected objectives/outcomes
Traffic Lights (Digital Outputs)	Fully accomplished for all the groups
RGB Lamp (Analogic Outputs)	Electronics problems when assembling the board for the youngest group and programming difficulties for all the groups (division & potentiometer)
The car (DC Motors)	Difficulties to understand the electronic concepts (H Bridge) for all the groups. After assembling the board a detailed explanation was needed on the whiteboard (see Fig. 3)
Open Project	Challenging results and projects: • Spaceship lighting, with several color leds (UFO like) • Space invaders with red and green leds (blinking or continuous beam depending on the game) • A Story where a character has got a lantern (yellow led) • Doll jumping on a trampoline and lighting different color leds depending on the jump direction • Door with lock that opens/closes when the user plays the right/wrong piano song (servo motor for the lock, paper for the door and Snap4Arduino for the piano song)

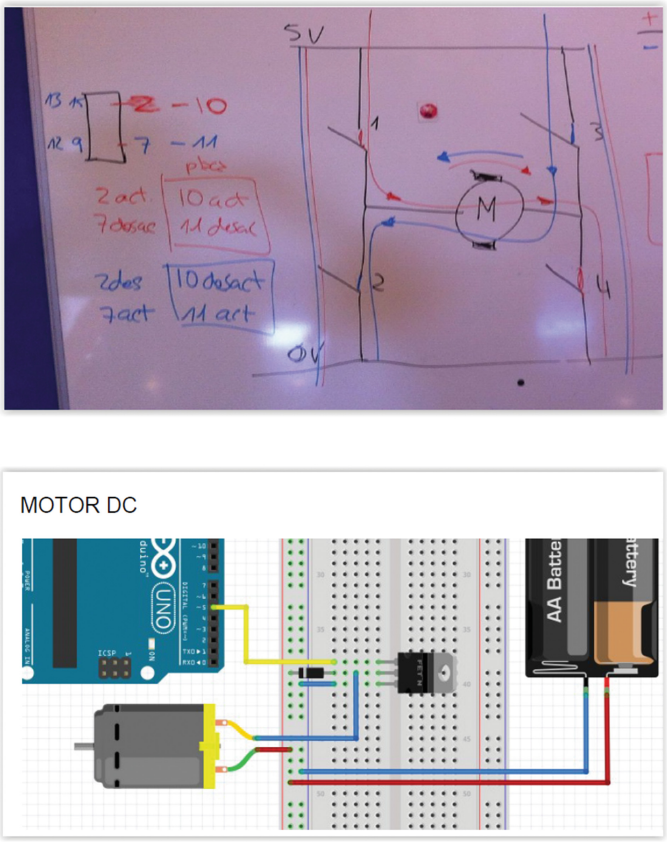


Fig. 3. Difficulties to understand electronic concepts (H Bridge) in session 3 for all the groups: needed explanations on the whiteboard

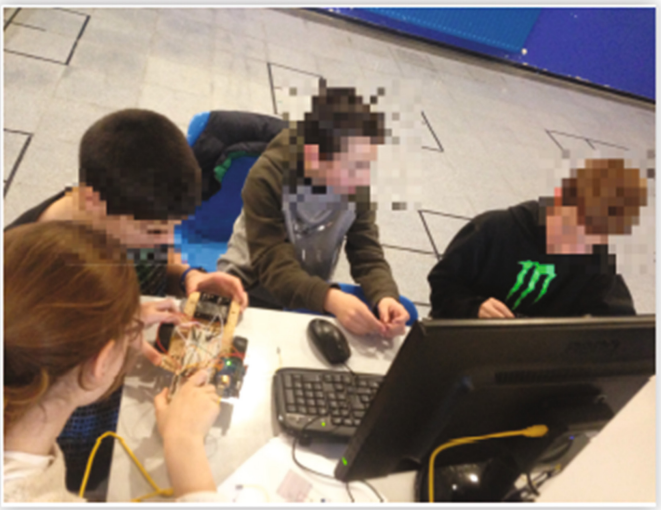


Fig. 4. Cooperative teamwork with different roles and skills

3.2 Importance of the Previous Background

As we have said before, primary students are really digital natives and they have huge skills in digital competency, as they have been all their life interacting with computers and technology. Nevertheless computers and digital artifacts are for them stuff for playing and do not see them as possible tools to learn or doing other things.

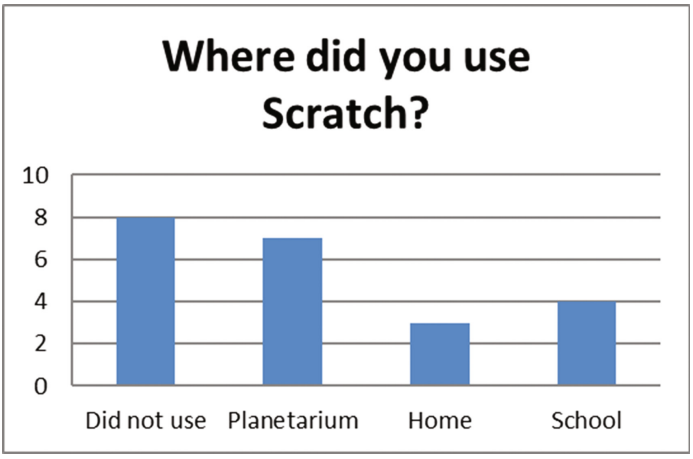


Fig. 5. Previous background in Scratch

The first day only 16 pupils came to the session. Eight of them had already used Scratch. Most of them in a course at the Planetarium but even four have used it at school and a few at home.

Working groups where organized to include at least one person with Scratch background for several reasons. First of all for achieving the objective of being able to work with Snap4Arduino: the language and interface of Scratch is nearly the same and therefore not every group was starting from scratch. Secondly, the fact that one of the pupils had to explain things to their mates was a wished didactical situation, where everybody could learn, specially the one who had to explain things to the others.

Most of the pupils had already had positive previous experiences in computer programming; the results of the pre-survey show this fact (Figs. 5 & 6).

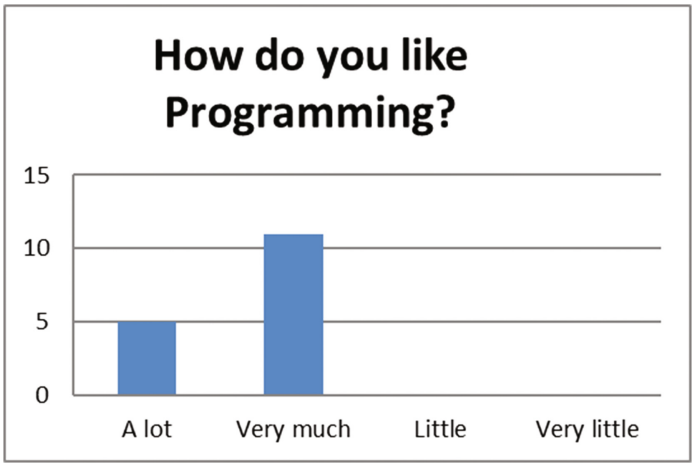


Fig. 6. Previous background in programming

3.3 Methodological Issues: Pupils Programming with a PBL Approach

In Fig. 7 we can see that most of the pupils were expressing positive feelings when they were programming all together in every group. The four pupils that were no expressing any feeling is because it was the first time they were programming.

Analyzing the teaching and learning of the 2 first days, and more specifically the sentiments and attitudes the pupils were expressing, we felt that the results could improve; i.e. more pupils will express more positive feelings when programming, which in fact is what happened during the last 2 sessions.

Having chosen PrBL as the methodology was a success. It has been possible and very pleasant to work with and we have managed to make a constructivist learning with Snap4arduino.

The four projects were designed ad hoc for that purpose. They had to "try and experiment" and "investigate" to achieve the projects. As we have already said, the first projects were closed ones (we were proposing what to do and the final goal). However, the last one was completely open as they have to decide what to do and what was the

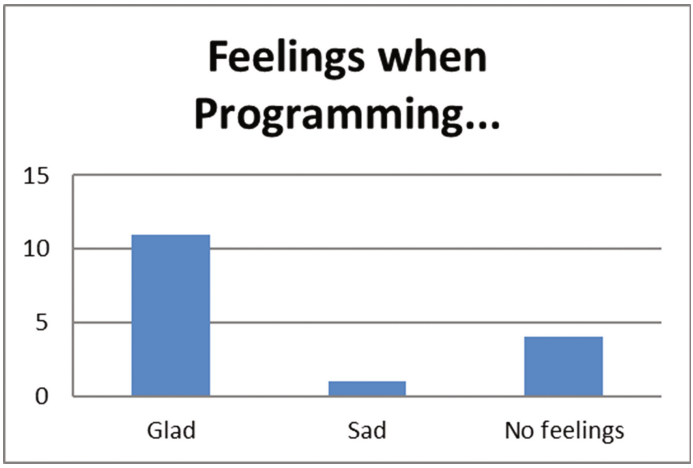


Fig. 7. Their feelings when programming during the course…

aim of the project. The methodology and the way the four projects were designed has been central to get the successful results we had. Pupils associated the projects more to a game than to an ordinary class; therefore, they could express fun, joy or amusement feelings. This can be seen on the results of the survey of the last day (Fig. 8).



Fig. 8. Learning and playing

One of the main advantages of working through projects is that you can apply them to a wide range of ages and topics. It is true that depending on the age group or the previous knowledge, you may have limitations, but you can apply the projects in many possible different scenarios.

3.4 Curriculum and Key Competencies

It has been shown that in this case the electronics concepts and board assembly were important difficulties for the pupils; even it was the most difficult aspect during the course. Primary education curriculum does not include any electronic contents, but we have observed nevertheless that they are able to assimilate basic concepts in this area. Even that the electronic circuit assembly on the board was a heavy task, they managed to make it and, much better, they were able to re-use the projects with other practical ideas a few hours later. In our opinion, this shows that it is possible to introduce basic electronics assembly at the end of the primary level education. The key point is to start with basic things and then to go deeper, with more complicate concepts or assemblies.

We think that Snap4Arduino is a tool that provides many possibilities when working with Arduino hardware and we believe that including also basic electronics in the curriculum (not only computer programming) could be a great idea.

Seeing the results of the projects after four days, we can say that the "joint tool" Snap4Arduino/Arduino is a valid and reasonable tool that could be introduced into the classroom. All the pupils, at the end of the course, agree that programming with electronics is a way of learning.

The other point we would like to outline is the one related to the key competencies that every kid has to acquire during the primary education level (before to get into the secondary level).

Any reader of the paper can see that during the course we have been working mostly all the competencies (except the cultural expression and awareness one). In fact, depending on the project we propose to carry out to the pupils, we may be working some key competencies. Combining appropriate projects, we should/could be able to work all the key competencies. When designing projects, we argue that we do not have to think only about the contents we want to teach, but also what competencies we want to work as well; an adequate progression in every key competency will be very important for their future labor and social life. For example, in our case and during the course we had to introduce different roles for every partner of the group because the pupils needed to work more the civic and social competency.

3.5 Pupils' Course Satisfaction

The last point we would like to note is the global satisfaction after the course. They expressed a relevant satisfaction and most of them where ready to apply for another course if possible. See Figs. 9 and 10.

Not only pupils were satisfied, also some parents were delighted with the course and they were asking for more information as they were interested in introducing such kind of courses at schools (as extra scholar activity). The planetarium of Pamplona was also very satisfied with the course and they have organized a second course with the same contents and methodology during summer 2016.

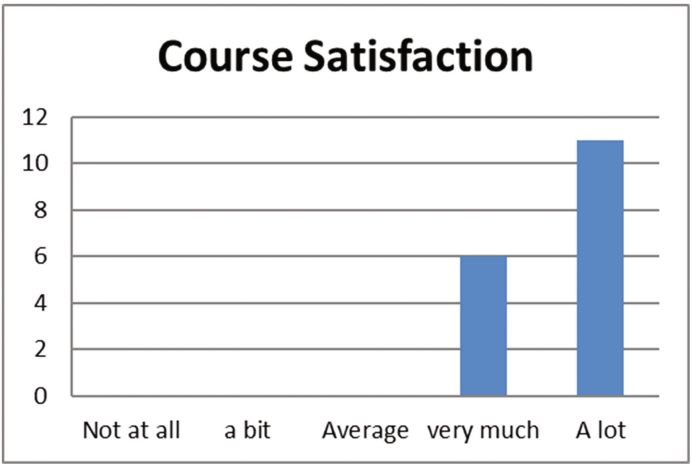


Fig. 9. Positive feedback from the pupils.

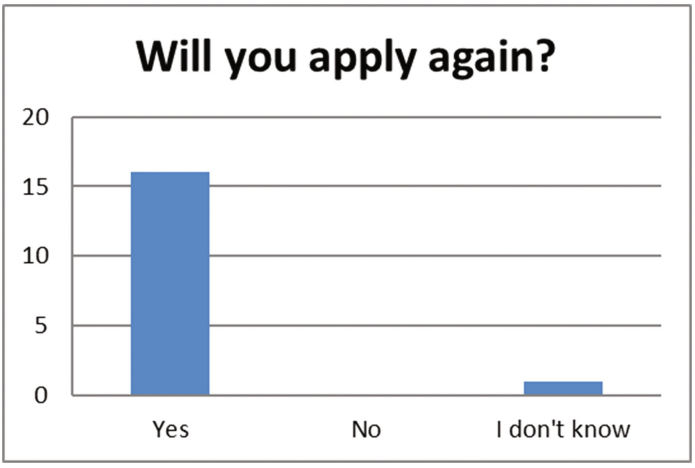


Fig. 10. Ready to continue….

4 Conclusions

The overall satisfaction score was of 8,3 (out of 10) and 100% of the students concluded that "programming is a valid learning method". We agree with them.

After the study, we conclude that Snap4Arduino is an applicable tool for an elementary school's syllabus. It achieves all the contents, evaluation criteria and learning standards established in the education curriculum of the region of Navarra. Moreover, it is a versatile tool that can be applied to all elementary school levels.

We consider that PrBL is the right methodology to work with Snap4Arduino as it allows that every pupil can discover all his potential through investigating or inquiring and applying trial and error method, which provides a significant learning.

Snap4Arduino unlike Scratch gives the opportunity to bring ideas to the real life using programming and basic electronic assemblies.

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