NXT Workshops: Constructionist Learning Experiences in Rural Areas

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Abstract. This paper will present the educational initiative called *NXT Workshops* implemented at the International Centre for Advanced Technologies (CITA). Its aim is to promote an attractive and dynamic view of science and technology in rural areas. At pedagogical level, arguments are given to establish the main learning theory upon which these workshops are based, being this theory "*constructionism*". Equally, their objective is to remark the importance attached to project-based learning in robotics for developing technological fluency. Generally speaking, some progress has been observed with regard to team work, in areas such as taking responsibility and developing creativity and self-esteem, as well as the ability to learn from challenges and to express opinions clearly. These first results of the study allow robotics to be considered a key factor in the development of personal competences in the new century.

Keywords: competence, technological fluency, constructionism, educational robotics, LEGO Mindstorms NXT.

1 Introduction

A series of institutions and authors (The Partnership for 21st Century Skills, UNESCO, [1], among others) emphasize the fact that the competences required for addressing the challenges of the new century are different to those existing a decade ago.

Being the term *competence* polysemous and widely discussed, in this paper only a definition will be provided with. According to [2], it is "the faculty of using the knowledge, skills and attitude needed to carry out different activities in an adequate manner, reaching an appropriate level of quality and effectiveness."

Considering this, in addition to technical or methodological knowledge, competences also include relational and social aspects, in other words, emotional and communicative abilities. Thus, which are the competences needed nowadays?

The Partnership for 21st Century Skills (P21) advocates for critical thinking, digital alphabetisation, creativity or collaboration skills, which according to this organization are essential to live in a more competitive world. Similarly, UNESCO published a list

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of characteristics which workers in the 21st century should have: communication, creativity, initiative, flexibility, information, responsibility, sociability and technology. In addition, Howard Gardner [1], originator of the theory of multiple intelligences, describes five cognitive capacities which should be developed to cope with the new century. He calls them "*the five minds for the future*": disciplined mind, synthesizing mind, creative mind, respectful mind and ethical mind.

One of these factors which has rapidly changed our lifestyle and keeps on changing it at an amazing pace is technology. Subsequently, it seems logical to use digital technology to develop the aforementioned competences. Today [3] it is a fact that education must allow learners to take and use technology, as well as to make them be interested in acquiring a deeper knowledge of theoretical-practical issues involving new technologies, human beings and environments. When students go through the experience, simulating the real world, they discover the importance underlying practice, the execution of all the productions and constructions.

Therefore, now we need to reconsider the question of how we can make the most of their potential in education. In this context, the prominent researcher at the Massachusetts Institute of Technology, Mitchel Resnick asserts that it is necessary to develop what he calls *technological fluency* to use the real potential of the new digital and multimedia tools, "To be truly fluent in a natural language (like English or French), you need more than phrase-book knowledge; you must be able to articulate a complex idea or tell an engaging story – that is, you must be able to "make things" with language. Analogously, fluency with new technologies involves not only knowing how to use technological tools, but also knowing how to construct things of significance with those tools [4]."

Bearing these arguments in mind, this article focuses on the use of a technology which has rapidly changed from being exclusive of the industrial and university field into becoming available in homes and pre-university education. We are talking about robotics, especially about an initiative implemented in rural areas called *NXT Workshops* (Talleres NXT) and promoted by the International Centre for Advanced Technologies (CITA, http://www.citafgsr.org/cita/), Fundación Germán Sánchez Ruipérez (local cultural foundation) and Ayuntamiento de Peñaranda de Bracamonte (Peñaranda de Bracamonte Town Council) in Salamanca, Spain.

In this article the structure will be laid out as follows. Under sections 2 and 3 the education principles implemented at the NXT Workshops will be presented. Related to these principles, a specific example "*Red Planet NXT*" will be provided with under section 4, where a detailed explanation of the methodology will be given. The methodology used can be divided into three phases: workshop design, workshop execution and workshop assessment. Under section 5 the first research results will be pointed out. Finally, a set of conclusions will be analysed and a line of research for future studies will be mentioned.

2 Constructing for Learning

Seymour Papert created a view of learning which he called *constructionism*, being this concept his personal idea of Piaget's constructivism, who was his teacher. What

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is really important for him is the role which constructions play in the world (a sand castle on the beach, a robot or a computer program) as support for constructions of the mind. In his own words "I have adapted the word *constructionism* to refer to everything that has to do with making things and especially to do with learning by making, an idea that includes but goes far beyond the idea of learning by doing [5]." *Constructionism* is also known as a theory of education which promotes the use of digital technology in education [6]. According to Ruiz-Velasco [7] it is mainly: "Constructivism + technology = Constructionism."

There are three concepts which can be implicitly found in Papert's constructionist theory, providing learners with better construction opportunities:

- *Objects to think with*. It is an object which can be used by an individual in order to think about other issues, using for that purpose his own construction of that object.
- *Public entity*. These are constructions which can be shown to others, discussed, examined or tested. This created object strengthens constructionist learning powerfully by sharing it publicly with others.
- *Microworlds*. It is a very small world, in which learners can explore alternatives, prove hypotheses and discover facts which are true with regard to that world.

Taking into account the abovementioned reflection, "according to constructionism the best environment to learn is a microworld which contains objects to think with (computers, among them) and the students' public entities which are in the process of constructing" [6].

It should be pointed out that Seymour Papert went beyond issuing a constructionist theory; he worked on creating *objects to think with* which can implement a significant change in the way children learn. Together with a team of researchers at the Massachusetts Institute of Technology, they developed the well-known programming language LOGO in 1967. After that, their constructionist ideas on learning interested LEGO Company and, collaboratively, they designed an interface which allows construction and programming to become connected, resulting in the commercial line LEGO Mindstorms in 1998. The simple use of the LEGO Mindstorms kit is due to the fact that no electric or electronic knowledge is required and therefore its use has increased in the education field. "Imagine being able to build a complete robot, including sensors, motors, gears, gearboxes, structures, and being able to program it, and configure it; and all that without welding, drilling, gluing or inserting screws. Well, that is exactly LEGO-Mindstorms, an easy and simple way of learning robotics and building your own robot [8]."

Having said this, from our point of view, *LEGO Mindstorms* is today the most effective material to start experimenting with robots and to focus on the academic aspect of learning.

3 NXT Workshops as Microworlds in Learning Processes

Papert's *constructionist theory* provides us with grounding in education for the NXT Workshops, considering that microworlds in learning processes allow participants to

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improve their understanding of technology, as well as to foster their skills and develop creativity. The name of the workshop is related to the *objects to think with* used at the workshops, the new model for the construction of LEGO Mindstorms robots called *NXT*. Traditional LEGO pieces are contained therein, allowing learners to build different robotic structures, and also can be found external sensors for perception, motors for the movement of robots and the NXT micro-computer for programming their actions. These perceptions and movements are the language which robots use to communicate with their environment.

It is important to state once again that the aim of the *NXT Workshops*, as well as that of educational robotics in general, is not precisely to teach learners to be robotics experts but to develop the essential competences to be successful in the present world, as several research studies and authors have pointed out [3] [7] [9] [10] [11].

The didactic use of the educative LEGO Mindstorms NXT kit reaches a wide scope, as it is a versatile tool and can be used in various ways depending on the objectives of the activity. This could be seen at the *NXT Workshops* which already took place and where participants designed a great variety of creative constructions, including for example, animals, humanoids (alpha rex), F1 cars, robots scoring a basket, other robots competing in the traditional "stealing the handkerchief" game or in sumo wrestling, or even robots having the ability of drawing.

4 Methodology

"The organizations of the Knowledge Society will undergo constant change. They are organizations where people will work in teams and grouped in teams [12]." Thus, project-based learning is the active work methodology at the *NXT Workshops*. A project is: "the set of search and research actions aimed at solving a problem or at improving an existing reality, for which purpose it is necessary that actions are conducted and done in a fixed period of time and that the needed resources are available in order to obtain the wished accomplishments [13]." The work organised in projects at the *NXT Workshops* is aimed at promoting collaborative learning; said learning [14] is one of the most powerful tools to develop the competence of *learning to learn*.

The methodology used for organising these microworlds [15] is divided into three phases: design, execution and assessment of workshops. In the *design* phase several aspects are considered: topic choice, game board design, robot design and construction, facilities, materials, level of difficulty (beginner, intermediate, advanced), writing of the didactic guide and time line of all the activity. The *second phase* is related to the development of the activities included in the time line. The *assessment phase* provides us with feedback from participants about the workshop effectiveness, apart from drawing up and enriching its structure for future sessions.

In order to better understand this section, we will use the last workshop *Red Planet NXT* as an example, as it was also shown in the event Campus Party Europe taking place in Madrid.

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4.1 First phase: workshop design

The *topic or microworld* must motivate and inspire participants, thus on this occasion a space adventure has been chosen. The workshop *Red Planet NXT* was designed in order to promote the importance of space exploration by developing an exploring robot inspired by present rovers in Mars, using the Lego Mindstorms construction kit. This activity allowed participants to live the experience of controlling their own exploring robots to carry out different tasks on the surface of a faraway planet.

This aspect also involves establishing the tasks which the robot must execute at the final competition. For the first time at these workshops the robot must do more than one task, which consists of: exploring, picking up floor samples, water search, access to objects and communication. Each task requires a description, a mark and general rules, such as a starting point and possible penalties.

An important aspect is the *design of the game board*, where the different tasks which should be carried out by the robot will take place. In this case, the robot will need to interact in a game field which represents our *Red Planet NXT*. A modular game board is chosen, consisting of 6 agglomerate sheets of 40 cm x 120 cm, covering a total surface of 240 cm x 120 cm (Fig. 1). To make our scenario more realistic, mountains and rocks have been made out of plaster.

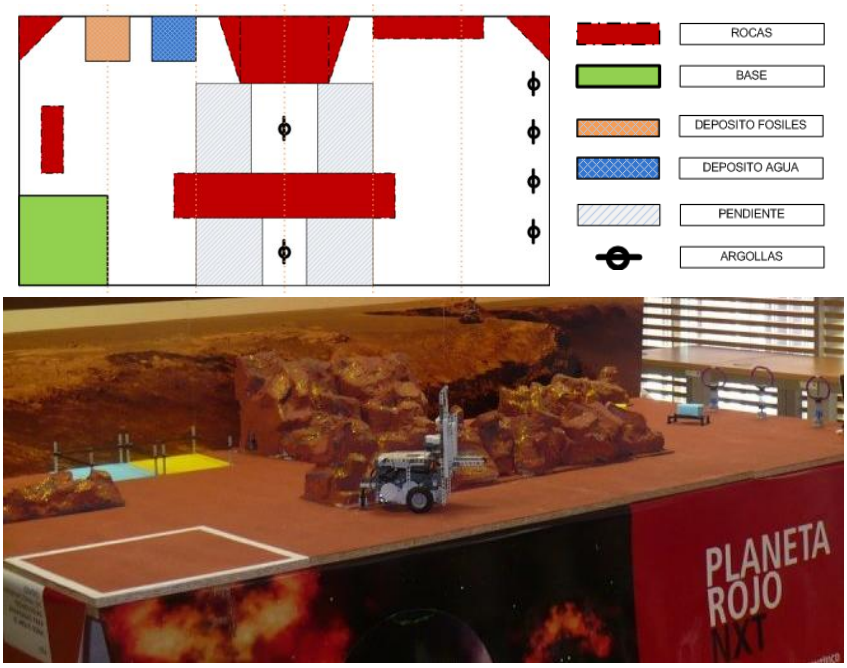

Fig. 1. Game board at the *Red Planet NXT Workshop*

Another key factor is the *design and construction of the robot*. From our own experience a combined design was chosen, that is to say, a guided process to make the

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design step by step plus free creation. For that purpose, a mobile base was made available to all groups (identical for all). It must be able to move around the game board- later some additional elements may be included. These will be created by the children, as they will help them execute the different tasks. Nowadays Internet allows us to get Lego Mindstorms-based robots construction guides, which are very useful for education, as it is the case of the mobile base of this project, where we use the *Forklift* (http://www.nxtprograms.com/forklift/steps.html), as it meets the objectives of the workshop. This factor is limited by the fact that the amount of work kits available will fix the number of groups at the workshop.

You can find the didactic guide including the time line, as well as more information in Spanish, under (http://robotica.citafgsr.org/images/planeta_rojo.pdf). As can be noted, many of the points are related, but the more time spent on this phase, the better results can be expected in the other phases.

4.2 Second phase: workshop execution

We know that we need a series of steps to build a robot so that it can carry out its tasks. All this process requires hard work by instructors and participants: from designing it, to building the mobile base, in addition to assembling the different elements, programming it and testing the robot until the accurate characteristics are suitable. Let's see now how this phase was developed at the *Red Planet NXT*.

This workshop had 18 participants (between 7 and 15), only one girl among them. For the first time three boys living out of the village attended the workshops, which shows a true interest in robotics. There were 6 teams in total. The timetable of the workshops covered three hours during six sessions taking place on Saturdays, with the following time line:

- *Session 1*: course presentation, game board assembling and teams creation; new students are provided with an introduction to the pieces of the LEGO kit.

- *Sessions 2 and 3*: building the robot and carrying out the research activity: *WebQuest*. The guided construction of the *forklilf* was executed with no difficulties whatsoever, and the creative part (Fig. 2) can be considered as a sample of the imagination young people have, as they added pieces to the robot so that it could pick up rings and take them to the base. The *research activity*, according to previous surveys, is the activity boys like least. However, we consider that it is necessary for them to have these experiences (research team work, summarising, presenting results in public) since they are young, as they are very valued in adult life. On this occasion, instead of the usual sheets to make a summary, we used digital technologies and a *WebQuest* was proposed to them, that is to say, an educational tool in order to do digital research. This contains resources mainly from internet, as it promotes the use of superior cognitive skills, cooperative work and students' autonomy (http://robotica.citafgsr.org/WebQuest/WebQuest.html).

- *Session 4*: introduction to NXT-G programming. Throughout this part of the Workshop it was observed how easy it was for them to understand concepts after instructors had explained to them the basics of *NXT-G* programming and after they had ascribed behaviours so that they could afterwards be executed by the robot. It was

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so clear and natural to them that they invented the behaviours they wanted their robot to do. It is advisable to lock the internet connection during this session.

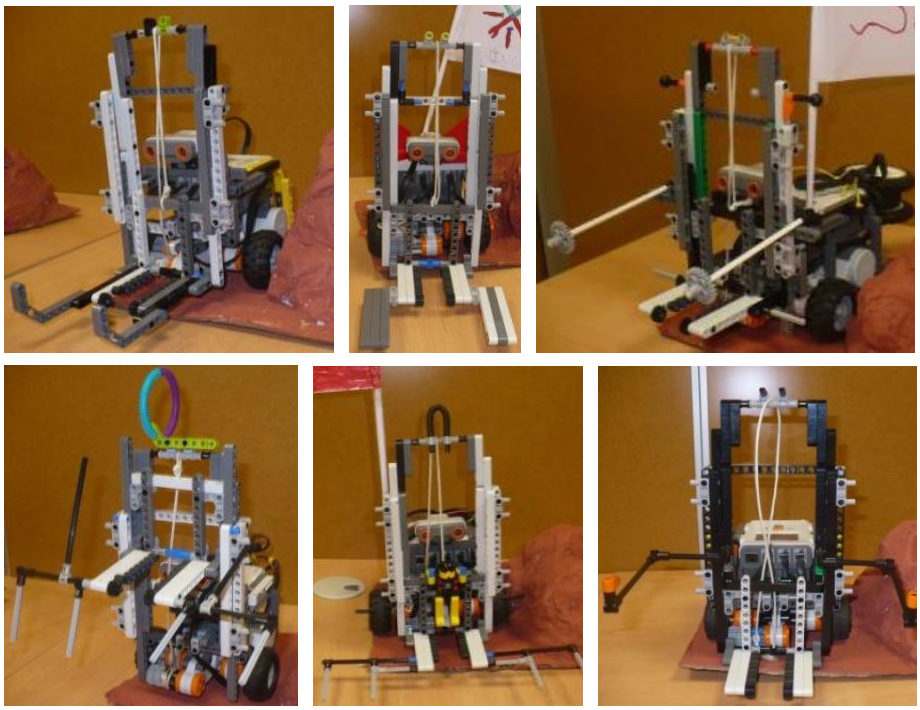

Fig. 2. Robots created at the *Red Planet NXT Workshop*

- *Session 5:*bluetooth remote control through and robot tests. Conversely to previous NXT workshops, where the robot was autonomous, in this case the robot was controlled by the computer [16] or another NXT [17] in order to simulate space exploration. Each team will decide which way they will use to control their robot at the final competition. For that reason, during tests they kept changing the speed of the motors until they found the best option for their robot.

- *Session 6*: board assembling and previous tests (morning) and exhibition. At the *Red Planet NXT exhibition*, as usual, participants grouped in teams presented the topic research briefly, being the topic the Planet Mars on this occasion. They introduced a new aspect, as they used digital support (PowerPoint) for their presentation. This was freely chosen by the children, as a consequence of the WebQuest proposal and of the internet connection. Later the awaited moment finally arrived and each team controlled their robot, all of them completed the tasks and the time was the key factor to nominate the winners. Finally, certificates were given to the three best teams reaching the best marks when completing the tasks, having designed the best robot, having carrying out best team work and best research project. All participants also received a certificate of attendance.

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Sharing on the internet is an important factor today and *NXT Workshops* have their own website under CITA: http://robotica.citafgsr.org/, as well as pictures under http://www.flickr.com/photos/citafgsr/page2/. Several resources can be found there: workshops which had been previously organised, activities and their corresponding photos, comments and videos about the evolution of all *NXT Workshops*.

4.3 Third phase: workshop assessment

On the one hand, *assessment* is the opportunity for participants and the instructor to judge the quality and success resulting from the workshop. Assessment actions were implemented in the last session, one of them was organised by CITA through a digital survey, which young people loved. The data collected can be grouped into three categories:

- *Course development* (organization, content, audio-visual means, facilities, duration, time table, didactic material, workshop results).
- *Instructor* (methodology used, promotion of team work, communication).
- *Participant* (motivation level, content assimilation, covered expectations, suggestions).

On the other hand, at this workshop a PhD research started with regard to several aspects related to educational robotics, the confirmation of certain measurement tools and a survey which may help us understand which of the participants' abilities and skills turn out to be improved throughout the Workshop.

5 Results

This workshop obtained a result of *9,17* out of 10, as all participants answered that they had liked the activities proposed and that they would like to take part in a robotics workshop again.

One of the challenges which had to be dealt with at the *NXT Red Planet* was the difference of age and experience of the participants involved – from beginners to advanced learners who had previously attended all the robotics workshops which had taken place. However, as sessions went by it became evident that they helped one another and among teams, resulting in an enriching experience. It is advisable, nonetheless, to prepare additional activities for the teams who finish first.

Although it is not possible to issue generic statements about the accomplished competences of each participant, we can highlight the following data. According to the results from the survey (Table 1) carried out at the last *NXT Red Planet* workshop, where 16 participants (2 children could not attend the activity) were asked about which aspects were improved after having taken part, over 10 youngsters valued positively an increase in: taking responsibility and developing creativity, self-esteem, as well as the ability to learn from challenges and difficulties and to express their opinions clearly. Moreover, 15 participants accepted they made progress at team work. Conversely, more than eleven children did not perceive significant changes in aspects related to their ability to accept others' ideas and to analyse the consequences

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of their decisions before taking them. Generally speaking, these results are consistent with those found in the aforementioned research studies, which have also confirmed the positive effects that educational robotics has for promoting different competences.

Table 1. Results from survey carried out at *NXT Red Planet Workshop*

*Answer **sincerely** which characteristics you think contributed to improving your skills after taking part in the NXT Red Planet Workshop:*	*No, same as before*	*Yes, it improved*
Taking responsibility.	4	12
My creativity, now I can innovate.	3	13
My ability to listen to others.	5	11
My ability for team work.	1	15
My ability to accept others' ideas.	11	5
My self-esteem, now I believe more in myself.	3	13
My ability to learn from challenges and difficulties.	4	12
Now I analyse the consequences of my decisions before taking them.	12	4
My self-confidence for solving new and complex problems.	6	10
My ability to keep on when I do not obtain the wished results.	6	10
Expressing my opinions and feelings clearly, without offending others.	4	12

6 Conclusions and Future Research

In this article the methodology implemented at the NXT Workshops has been presented. For that purpose, the *NXT Red Planet* workshop, which was organised as an extracurricular activity at CITA, has been used as an example in order to make robotics available to the general public.

Everyone needs to live their own experiences, hence the importance of extending activities such as *NXT Workshops* to children and young people especially. This is due to the fact that these workshops allow them to get to know science and technology associated with games, as well as to acquire or improve the competences which are so needed to be successful in the present world.

While robotics is included in school *curricula* just like in other countries, more institutions like CITA are needed, as their aim is to remove the *technological fluency* gap, in rural areas mainly.

In constructionist terms, the *NXT Workshops* would be *microworlds* which include the *LEGO Mindstorms NXT* technology as *objects to think with*, allowing learners to build robots which become *public entities* throughout the learning process, and even at the contest or final exhibition before their families and friends as an audience.

According to the results obtained at the Workshop, most of them highlight new skills which were acquired, such as improved team work skills, as well as higher levels of responsibility, creativity, self-esteem and the ability to learn from challenges and difficulties, as well as expression of opinions.

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Research in this field raises new questions, as some authors point out that an exhibition must be the last step of educational robotics activities due to the negative feelings arisen when losing at a competition. Is this right? And if it is wrong?...

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