Robots & NEE: Learning by playing with robots in an inclusive school setting

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***Abstract*— In this paper the authors summarize a set of tasks devised as part of a doctoral thesis for two teachers training workshops involving eleven teachers in a distance e-learning approach. Data were collected by teachers enrolled in the workshops, in Portuguese and Brazilian schools with access to educational robotics sets while working with pupils with special educational needs. The project benefitted a total of 26 students with six different special educational needs who have been asked to assemble, programme and interact with a prototype of Lego® Mindstorms® robotics. The collected data helped confirm that educational robotics promotes learning and social inclusion through playing and project learning.**

Keywords — Educational Robotic; Lego® Mindstorms®; Inclusive School; Play in education.

I. INTRODUCTION

It is estimated that there are 150 million children with Special Needs Education (SNE) in the world [1].

There are several educational strategies for working with students in inclusive contexts, but thanks to the emergence of Educational Robotics (ER) several authors have explored the potential of this tool [1] [2] as a therapeutic aid that promotes inclusion in the classroom and acquisition and consolidation of learning [3]. Such is the case of the UARPI project - Using Assistive Robots to Promote Inclusive Educations [4] that works the motor skills and the augmentative and alternative communication through a virtual robot and a robot Lego® Mindstorms®, of the IROMEC project featuring ten games scenarios tested with different special needs children [5] and of the ROBOSKIN project which uses a humanoid robot to develop interactions and the social skills of students with Autism Spectrum Disorder (ASD) [14] which will be later mentioned.

In this paper we show the results obtained in two teachers training workshops entitled "Robots & SNE: The educational robotics in inclusive context", developed in the virtual learning environment Moodle, in the academic year of 2014/2015, with Portuguese and Brazilian teachers, that explored the educational robotics with 26 students with different special needs – such as ASD, Cerebral Palsy (CP), Mental Retardation (MR), Attention-Deficit / Hyperactivity Disorder (ADHD), Learning Disabilities (LD) and deafness.

Students could work the motor skills and mathematics by assembling the prototype (especially in fitting parts and the separation of the pieces by colour and size), decoding of the instruction manual and using the manual 2D images to build the real prototype in 3D.

Through robotics students worked different curricular areas, namely: i) Portuguese as mother tongue in the construction of the exercises scripts or in the story scripts to be represented/dramatized by the students and by the prototype; ii) mathematics and programming, acquiring new knowledge and consolidated pre-existing knowledge, through trial and error playing, during construction, assembly and interaction with the robot prototype.

The obtained results allowed us to verify the educational and inclusive potential of educational robotics when providing challenging and motivating activities supported in learning to play and learning through projects while in both recreational and educational settings, which is the reason why we consider relevant replicating our approach in similar projects.

II. EASE OF USE

A. Learning by playing

In 1951 Piaget emphasized the importance of games in the cognitive, social and physical development of children [6]. Since then learning to play can be defined as a method [7] or educational strategy for devising fun activities for children in which the teacher explores the characteristics and the potential of toys and games to promote exploration; to stimulate thinking and help students building mindsets; to manage time and space; to promote citizenship and work the emotional, social, motor and cognitive aspects [8] spontaneously and sometimes unconscious by the student.

Through recreational activities the student has a wider view of the world, finding his own voice to "express, analyse, criticize and transform reality" [7].

Also for Vygotsky [9], the game enhances problem solving and promotes development, because when the child acquires certain knowledge while playing hardly loses this knowledge and that capacity.

And Negrine pointed out that playful activities promote the full and inclusive development in which affectivity generated by the game produces the energy required for intellectual, psychological, motor and moral progression of the participants [10].

Taken altogether this is why we consider that playful and interesting activities have an important role in the development of children with SNE.

B. *Special Needs Education*

It is well established that the students with SNE feel higher difficulties than usual thus needing support, guidance and specific teaching strategies..

The student special educational needs may be permanent or temporary, an this student can also be cognitively gifted or being at educational risk, which is why:

- the student in educational risk has difficulty in at least one period of his journey, and should therefore be met in order not to compromise their academic performance,
- the talented student has skills above the average of its peers, so the curriculum of the student should promote and harness his potential;
- permanent SNE occur when the student has adapted his curriculum and should receive specific educational support and targeted for much or all of their academic record;
- temporary SNE only require curricular adaptation for a specific range of time by which the objectives of the student are equal to those of their peers without SNE [11].

C. *Inclusive potential of Educational Robotics (ER)*

The ER has been identified as one of the tools with great educational potential [12], given its practical and experimental project-based [13] and problem solving [12] approaches that allows students to test the validity of their ideas [13] and develop critical thinking and reasoning in an active and interesting way for students, exploring different areas of knowledge such as mathematics, physics, expressions, technology education [12] and languages.

When applied with pupils with SNE, ER has been shown to enhance social inclusion, interaction, motor skills and increase self-esteem of students [3].

There are several studies that assess ER inclusive and recreational potential worthing emphasis:

- project UARPI acronym for Using Assistive Robots to Promote Inclusive Educations [4] whose activities carried out under the project promote inclusion, active participation of students, and the motor augmentative and alternative communication through an augmentative communication software and an alternative that lets you control a prototype of the Lego® Mindstorms®;

- the IROMEC project provided ten scenarios tested games with children with mental retardation, Motor Impairment (MI) and autism spectrum disorder and expose the educational objectives explored in five key areas of development, namely sensory; communication and interaction; cognitive; engine; social and emotional development [5];

- the ROBOSKIN project evaluates the sequence of human-machine interactions, more precisely the interaction between children with ASD and a humanoid robot called KASPAR to promote other interactions in order to develop the social skills of the participants and the actual robot face to stimulus [14].

- Vanderborght et al. used a humanoid robot, called Probo, to help assisted therapy in children with ASD, since the studies indicate that children insides of the spectrum frequently connected to machines better than with humans. The robot has the function of telling short social stories in order to improve the reaction of children in social contexts. The results indicate that the Probo is an added value in therapeutic context with children with ASD [15].

Also Howard reviews the literature on the therapeutic and recreational potential of robotics in paediatric physical therapy, concluding that ER and the game increase motor skills of children with developmental disorders, particularly when the robot interacts with the child [1].

III. METHODS

This work was based on learning through playing and doing projects, with the support of robotics sets available in the schools of participating teachers.

The participating teachers were selected according to predetermined criteria, namely:

- teaching in Portugal in 2014/2015 in the regular education or special education;
- have students with SNE;
- they must have access to one or more sets of educational robotics.

Participating students on the other hand had to:

- be enrolled in an regular education school;
- being diagnosed with a SNE;
- be between 6 and 18 years of age;
- have permission from the parents to participate in the activities.

Eight teachers used the Lego® Mindstorms® NXT® educational set, one teacher used the Lego® Mindstorms® EV3® set and two teachers used the Lego® WeDo® set.

According to http://www.lego.com/en-us/mindstorms/history, the Lego® Mindstorms® was launched in 1998 by the Lego® company in partnership with a group of MIT researchers led by Seymour Papert. The NXT® is the second generation of the Lego® Mindstorms® and was initially released in 2006. The first version entitled Robotics Invention System or RIS® was launched in 1998 and the third and final version, EV3®, was launched in 2013.

The set used in NXT® was the educational set and was selected by most of the workshop participants following the suggestion by the teacher trainer: it has detailed assembly instructions, real size coloured illustrations of the pieces and can therefore be easily used by students from eight years (recommended age by Lego®). Nonetheless the workshop teacher trainer has used the set with students as young as six years old and one of the participating teachers in the workshop used successfully the set with his class where the average student were seven years old.

One of the teachers used the educational Lego® Mindstorms® EV3® set with a group of students of the 4th grade (9 years old). Although this set is newer than the NXT® the EV3® programming environment is slightly more complex than the environment of its predecessor, which is why the set is recommended for children older than 10 years old.

The Lego® WeDo® Construction Set is recommended for children as young as seven years and allows for building 12 simple models that are accompanied by learning scenarios tested for a formal educational environment.

Although used kits have a higher price than alternative sets, such as GoGo Board, they have the advantage of being intuitive and include both manuals and support software for educational environments.

The methodology used was mixed in nature, resulting in both qualitative and quantitative data, including:

- photographs and audio-visual footage registered by teachers during the assembly of the robots;
- audio-visual recordings made by teachers enrolled in the training workshop during programming and interaction with the robot;
- the reports on the activities, written and published in Moodle by the teachers;
- weekly workshop assessment on the inclusive potential of educational robotics;
- two questionnaires administered to the workshop participant teachers: the first was applied at the beginning of the workshop and the second at the end of the workshop.

The workshops were in accordance with a Design-based Research model, which focuses on the integration of educational practice with the investigation in order to bring theory into the classroom through a flexible methodology, which is systematic, multidisciplinary and collaborative [17].

This model was chosen for favouring the design and the redesign of the workshops according to the results and feedback from the participating teachers.

Some of the teachers worked together in the same school, allowing them to developed the activities in group. Teachers who have not had the opportunity to work with other colleagues developed the activities themselves. Nevertheless they could always count on the support of the teacher trainer and other workshop participants via the virtual learning environment.

During the activities various support materials were provided, including literature on educational robotics and special educational needs, assembly plans, programming guides and video tutorials in which the trainer teaches the students the basics of assembly and of programming with Lego® Mindstorms®.

The workshops results enabled enhancing the workshop model and collect usage and inclusion indicators on the use of the educational robotics sets, in order to check the:

- learning acquired by students and teachers;
- difficulties encountered during the project;
- educational and inclusive potential of educational robotics with students with different SNE.

IV. RESULTS

The survey conducted to the teachers in the first week of training workshops allowed knowing the age, the number and type of SNE students who participated in the workshops.

From the 11 participating teachers, only the teacher's number 5, 6, 7, 8 and 11 had a robotics project in their schools, but none of them used the ER in inclusive context.

The remaining teachers created the robotic project within the teacher training workshop in their school and the teachers 1, 2 and 3 bought a robotics set from the Lego® Mindstorms® NXT® and teachers number 4, 9, 10 used a borrowed set.

TABLE I. TYPE OF SNE AND NUMBER OF STUDENTS PER TEACHER

	Teachers ID	Type of SNE and number of students					
		CP	ASD	MR	LD	AD HD	Deaf-ness
1st workshop	1, 2 and 3			7			
	4			2		1	
	5	1					
2nd workshop	6 and 7		1		4		
	8			2			
	9 and 10		1	1			3
	11				1		

Teachers 1 to 5 participated in the 1st workshop, having worked with 11 students with three different SNE. Teachers 6 to 11 participated in the 2nd workshop, during which they developed the activity with 15 students aged 7 to 16 years with a total of 4 different SNE. 13 students were male and 13 female, and they all were attending public education.

Teachers 5, 9, 10 and 11 were Brazilian, while the rest were Portuguese. Of the 26 participating students, 15 were Portuguese.

Students from teachers 1, 2 and 3 were five girls and two boys with intellectual deficit and aged between 13 and 16 years. They set up the robot easily after the teachers showed them how to assembly. The students were the authors of their own script programming, having the robot walk five steps forward, two turns to the right, six steps back and saying "good morning" at the beginning and "good job" at the end of the activity after the students put pressure on the touch sensor. This script was the beginning of other work, and teachers and students scheduled more activities for the next few weeks, since the school started a robotics club during the training workshop.

Students from teacher 4 were 7 years old and were in the 1st grade. Two girls have intellectual deficit and a child has ADHD. One of the girls was not enrolled in school when they started the activities and participated only in the robot programming but she was the student who was more enthusiastic during the programming. Students live in an underprivileged neighbourhood and have never had contact with a robot so they were particularly excited and jumped when they saw that the robot moved and executed the commands they ordered them through programming. The teacher intended to continue to explore robotics with students, writing a story with them for the robot to perform, but given the fact that the workshop only lasted five weeks the teacher simply introduced programming asking students to select a simple script that made the robot move seven steps, turn right and step back two steps.

Teacher 5 has a 10 years old student with CP who uses a wheelchair and carried out activities with his class. Students of the 4th grade reconstructed the child's story of the "Three little pigs", having assembled and programmed robots to be the characters of the story. The teacher had experience with robotics in mid-school, but intends to continue with the activities in the primary school with students with SNE while building awareness on the use of ER near other teachers.

Teachers 6 and 7 explored the Lego® WeDo® with 9th graders in which were included a boy with Asperger's/High Functioning Autism and 3 girls and a boy with learning disabilities, all aged 16. Students built a crocodile as a robotics club activity and performed the schedule suggested in the activity plans that came with the set, which consisted mainly on having the crocodile open and close its mouth. Although these teachers have experience with educational robotics it was the first time they worked with students with SNE so the teachers having been as excited as the students with the experience and with other scheduled activities subsequent to the workshop.

Teacher 8 already had a robotics workshop at his school, but the workshop was disabled until the teacher met the teacher trainer in a lecture he attended on the inclusive potential of ER with pupils with SNE. On that day the teacher told to the teacher trainer that he intended to resume activities in the workshop with his classes with students in educational risk. Two years later the teacher trainer invited the teacher to participate in the workshop, an invitation that was immediately accepted. During the activities carried out within that workshop the teacher followed 2 boys aged 13 with mental retardation and asked students to assemble the prototype whose assembly instructions are included in the Lego® Mindstorms® NXT® set. The programming script was adapted from a script created by the teacher trainer [16] that made the robot perform a route in the shape of a square, moving 5 steps forward and making a 90 degrees left turn. After that it was expected that students would use the loop to repeat the previous two steps, which they did. Students loved the activity, explored the math and decided to continue with robotics activities.

Teachers 9 and10 teach in Brazil, in a school that does not have a robotics set, so they borrowed a Lego® Mindstorms® NXT® set. Teachers had never worked with ER, so they were very excited about the activities, the potential of the ER and the workshop they attended that they convinced the school to buy their own set when the school receive funds. Five students participated in the activity: one of the students was 16 years old, with autism spectrum disorder and mild cognitive deficit; another student was 12 years old and was diagnosed with mental retardation; the remaining three students were two girls of 13 and 14 and a boy aged 14. In addition to assemble the robot, the students built their own story and programmed the prototype to be the main character, having in the end lively played and interacted with the prototype. Through these activities the students learned programming and consolidated math and Portuguese language while doing an interesting, different and fun activity [18].

Teacher 11 explored ER with a 14 years old girl and two boys both with 15 years old and with learning disabilities in mathematics. This school is located in a very poor neighbourhood known for drug trafficking and robbery, which is why the teacher three years ago had tried to create a robotics club, open to all interested students. After being asked directly under the Robots & SNE training workshop, the students actively participated in robotics activities, telling the teacher they had loved the experience of assembling, programming and playing with the robot and would like to continue to explore robotics. The teacher said that despite his experience with ER, the workshop "provided fresh approaches, new experiences and opportunities" to test ER with students who until then had not been included in the activities. Both students and teachers were very enthusiastic about the activities. All the second workshop teachers asked the teacher trainer to let them know if there are new workshops, because they "liked it a lot" and learned from the experience and the sharing of knowledge.

V. DISCUSSION AND CONCLUSION

Although there were 24 teachers enrolled in two training workshops, only 11 teachers have successfully completed all activities. The results we present here are of teachers who have completed the workshops.

The high dropout rate in e-learning courses is documented in several studies prowling values equal to or greater than 50% in Europe and Asia [19], so the teacher trainer tried to prevent participants/students giving up on the activities by being flexible in the course length and seeking to be close to participants. However the lack of time was the main reason given by teachers who have given up, which is in line with the major reasons cited by other authors [20] [21].

Teachers, who have completed the activities, were unanimous in considering that ER promotes inclusion, both in the final questionnaires [21] and in the weekly ratings. Also that ER has more inclusive potential when compared to other activities, as seen on what teacher 1 wrote in the evaluation of the 4th week of the 1st workshop: "these activities are exciting for all students, create dynamic of mutual aid, in which students with SNE can participate actively, collaborating in seeking solutions, feeling useful and successful in the learning process, thus proving that the educational robot provides a true inclusion environment".

Another teacher of the 1st workshop considered that ER "being a very motivating activity captures the attention of these students and allows them to put into action other type of skills that other subject disciplines do not".

Teacher number 7 states that "the assembly of robots has allowed students to be free, fun and committed" and that "all areas that enable experimentation lead to inclusion, because it allows the collaboration of all and the exchange/sharing of experiences". This teacher adds at the fifth week of the workshop that the assembling promotes inclusion when compared to other educational activities "because it allows the students to discuss solutions, ways to get the resolution of the intended problem (...). As teachers know it is easier for students to understand when they explain each other than it is to understand when they are trying to "decode" the teacher language".

Teacher 10 also values the highest score (20 points on a scale of 0 to 20) to the inclusive educational potential of robotics and said that it was "interesting as the development of the activity provides opportunities to teachers and students to identify the potential of students" and "that robotics promotes inclusion in a pleasant and dynamic way".

Teacher 8 states that "programming is considered an activity difficult to implement, so when students with SNE apply a programme to a model it causes other students to have some admiration for them". This statement of the teacher confirms previous work that argues ER increases the self-esteem of students [2] [3] [16] and raises a thought regarding the ER perception of teachers.

The teacher trainer and first author of this work has noticed in several lectures and workshops, that try to raise awareness about the potential of ER, that teachers before testing ER consider it too complex for them and their students; however after assemble and program their robot and upon ascertaining its simplicity and that it is not “rocket science” nor an exclusive tool of big "technological minds”.

The ER can be easily used by children with and without special needs in activities that can be pre-structured and planned by the teacher or even in free activities, where children can create a scenario (two-dimensional or three-dimensional, resorting to other objects and/or other Lego® sets), a story, and an exercise script; or even a robot built with no script, in which the student plays building and interacting with peers, with teachers and with the robot while learning new concepts or consolidate previously acquired ones, in real meaning of the concepts of learning through projects and learning by playing.

It would be interesting that other teachers and researchers devise more teacher training workshops, allowing collecting additional data and helping other teachers on the inclusive use of ER.

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