RiE 2015

6th International Conference on Robotics in Education

Yverdon-les-Bains, Switzerland, 20 - 23 May 2015

Jean-Daniel Dessimoz, Richard Balogh, David Obdržálek, editors

ISBN: re proceedings

Teaching Robotics in Primary Education: Applying a Constructivist Educational Methodology for the Creation of a Space vehicle with LEGO NXT

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***Abstract*—This paper presents the methodology applied on a project that took place in the academic year 2013-2014, in the Robotics Club of Ralleia Model Experimental Primary Schools in Greece, within the framework of the Hellenic contest for World Robotics Olympiad in Open Category, the theme of which was "Robots and Space". The presented workflow was chosen in order to inspire pupils to work on a common goal as well as to stimulate their interest in Robots, Astronomy and Space, fields that are out of the Primary School educational program. The results extracted through external evaluation of the outcome of the applied methodology, as well as the mostly positive evaluation remarks that were extracted by the pupils through the completion of a questionnaire were very promising as this project won the second place in the contest. In addition, the pupils that were voted to be members of the contest team were so excited about the whole process that they were eager to participate again.**

Keywords—Constructivism, robotics, primary education

I. INTRODUCTION

During the last two decades robotics has been the new challenge through all levels of education. Either as a S.T.E.M. or as an interdisciplinary project based learning activity like the World Robotic Olympiad's (WRO) 2014 Open Category challenge was, robotics are gaining continuously more supporters. This is not a coincidence, as it offers to the pupils involved the joy of creation through discovery, learning and knowledge of how things work.(ref) This paper presents a brief description of the theoretical context, which is mostly based on constructivist principles, as well as the steps followed for the preparation and the choice by the pupils themselves of the three-member team that was to participate in the "WRO 2014 Robotics Competition". The evaluation took place into two directions; first comes the presentation of the comments of the pupils as they were recorded on the teacher's diary during meetings and second, the final outcome of the contest.

II. THEORETICAL CONTEXT OF SCIENCE IN EDUCATION

To the question "Why robotics?", none could actually answer better than J. Piaget, who claimed that our aim should be "An education with scientific spirit and a Science teaching which insists on research and discovery rather than repetition" [1].

According to J. Solomon [2] there are two distinct areas for young pupils, Science domain and real life/world domain. Their thought spontaneously arises from the second and can hardly be moved to the first. According to Solomon, the language used by the teacher is of particular importance for the transition from one domain to the other. The teacher should make use of scientific terminology. Robotics as an educational tool assists in the transition to the science domain and the scientific way of thinking by naturally following the procedure:

1. Observation/ Hypothesis
2. Application (Building/Programming)
3. Experiment (Observation/Measurement)
4. Conclusion/Feedback (When feedback is necessary).

At this point, the teacher should use the appropriate scientific terminology as well as the appropriate expressive means to lead students from the specific to the general, the science behind their work.

Due to the nature of the subject -Astronomy, and robots in space are far from the primary school subjects- there was an urgent need that the teacher should take into consideration apart from her own dynamic, the other two dynamics which function along. These dynamics- Folklore, Internal and Teacher's dynamic- are described by Osborne in [3] and they are all functional at the same time. Thus, the teacher provided them with appropriate tasks and material in order to modify and rebuild Folklore dynamics and create new internal dynamics through experiential activities.

III. *CONSTRUCTIVIST EDUCATIONAL METHODOLOGY FOR INTEGRATED INTERDISCIPLINARY ROBOTICS PROJECTS (C.E.M.-4-I.I.R.P.)*

Working on an Integrated and Interdisciplinary Robotics Project with a class, demands a very well scheduled and organized plan of activities, especially if the number of pupils exceeds the provided resources. The particular project was goal-oriented as its aim was to create an integrated Robotic application model along with a scenario as a proposal to the challenge set by WRO2014 for Open Category: "Design and create robots which will assist humankind in solving different tasks in Space. "

This was a totally interdisciplinary project as pupils in order to work both effectively and creatively had to take a glance at Astronomy, climate conditions in planets and their satellites and the difficulties and obstacles that humans have assigned to robots to deal with. The project plan was set based on the principles of learning by design [4], [5],[6]. Learning

tasks were organized as a sequence structure though young learners were encouraged to express themselves and unleash their imagination. The pupils were organized into teams of three so they could share experiences and exchange opinions and ideas on the tasks they had to fulfill. This process produced a bit of noise but created also a pleasant and constructivist learning environment for the pupils as they experienced the feeling of being creative while having multiple degrees of freedom.

Their tutor mainly acted as facilitator and mentor mostly rather than a source of knowledge. The introduction to the new and unexplored field of Astronomy and Space was approached in different ways such as through visiting the exhibition "Return to the Moon", watching a movie, attending a presentation in the classroom. Material from multiple sources was uploaded on the Robotics Club blog (http://ralleiarobotics.blogspot.gr/) in order to modify Folklore dynamics and possible diversions. A source that pupils found very interesting was the one where they could access and explore our solar system with simulation software (http://www.solarsystemscope.com/) Furthermore an Astrophysicist from the University of Athens was invited to present the Greek mission of Cassini to Titan, the satellite of Saturn. This was an inspirational moment for the pupils as they were inspired to create their project-mission to Titan. The pupils chose themselves the theme of their project after brainstorming and supporting their ideas into a plenary session in class and, after discussing about it, they ended up with the idea of a mission to Titan.

IV. Implementation of the Methodology

The Robotics club began its meetings at the end of October of the academic year 2013-2014. The theme announcement took place in January 2014. Until then, the students had become familiar with the use of Lego Mindstorms NXT programming as well as the operation and the function of the sensors through the implementation of short projects. Twenty three pupils of 5th and 6th grade expressed their interest in participating in the school's robotics Club. Their statement which was confirmed by the teacher's observation mentioned no previous knowledge and/or experience with Lego NXT.

A. Project Plan

1. The theme of WRO 2014 was announced to the pupils who were excited at the idea of taking part in a National contest.

2. Multiple sources of information and extra material were given to the pupils and were uploaded to the Robotics Club blog online, as mentioned above.

3. A presentation by an expert took place and real scientific problems were introduced to the pupils. A very interesting discussion followed where questions were answered.

4. The pupils visited the exhibition "The conquest of space -Mission to the future" and watched the movie "Back to the moon...for good". They had the opportunity to see simulations of robotic vehicles and space equipment.

5. The members of the club had to choose one topic related to the contest issue. The previous steps 2-4 provided them with the information, knowledge and inspiration that they needed. The adoption of a single topic for all the members of the club was a necessity due to the fact that only one Lego NXT kit was available and this was achieved through brainstorming. They drew their scenario- proposals and presented -supported them into a plenary session in class. Then, after observations on the feasibility of implementing the scenario that was made by the class, some of them were amended to become possible. They designed their ideas on paper and they built models of their designs with simple everyday material, increasing in this way the creativity and Imagination. They created their vehicles with Lego bricks and they presented their construction into a plenary session in class. The pupils voted for the best scenario in order to build it with Lego NXT.

6. Pupils also voted for the team that would represent them at the contest. Three basic members and three runners-up were chosen.

7.

a. Construction and programming of the robotic vehicle.

b. Construction of the model by the rest of the members of the club.

8. Video and poster creation.

9. Presentation to the plenary of the school.

10. Presentation to the 6th National WRO contest 2014 Scientific Committee where the project and the team totally gathered 515 points for the presentation, the construction, the program and a set of predefined scoring criteria on the rules of WRO 2014 (http://www.unitbv.ro/Portals/9/Lego/Rules-Open-Category.pdf).

V. Evaluation of the Methodology

The evaluation of this work was done using three different tools. The calendar of the Robotics Club for the period of the project, the questionnaire with open-ended questions which was given to the students after the completion of the project and finally the evaluation of the result /score that the team managed to achieve by participating in the nationwide educational robotics competition WRO 2014.

A. Teacher's evaluation

The teacher's evaluation of the project took place after studying the diary of the project. This diary was kept by the teacher along with photos of pupils' work during the project. Other than a means of reflection and an assessment tool, the collection of this material enabled students to monitor their work and its evolution through time after the completion of the project.

Furthermore, as occured from the observation of the remarks from each day, pupils very often complained when they had to write or read an assignment and they were excited each time they had to build their models and propose/share

ideas with other members of the club. Many times there were complaints about not having enough time for all to test and play with Lego NXT, something which was a fair complaint as the number of pupils in the club exceeded the provided resources.

B. Pupils' evaluation

A questionnaire with four questions and space for their own suggestions and ideas was given to pupils.

As the competition took place after schools had closed (June 2014), the questionnaire was given to the pupils in September. As a result, only 12 out of the 22 returned it, as the rest members of Robotics Club had graduated from primary school.

1. What was the best thing you can recall from this project?

2. What was the worst thing you can recall from the preparation of this project?

3. Are there any points you believe that we should insist more on? If so describe them.

4. Are there any points we should insist less? If so describe them.

5. Make your suggestions to improve our lesson.

The pupils replied according to their personal experience about their best and worst moments during this project. The majority of the pupils' statements on what their best moments were, had to do with their work as team. "My best experience was when we all had very good ideas", "my best experience was the time that models of all teams were exposed and we observed and played with each other's model like an interactive museum". The rest of the pupils mention building the robot as their best experience: "My best experience was the time when we put the logo "SPACE" and the ejector on the robot"

TABLE I.

My Best Experience		
Category	***Example Statement***	***N***
Teamwork	My best experience was the time that models of all teams were exposed and we observed and played with each other's model like an interactive museum	8
Building/ programming the robot	My best experience was the time when we put the logo "SPACE" and the ejector on the robot	4

The fact that almost the 1/3 of the pupils recall as the best thing happened to them the activity of building and programming the robot, is reasonably expected. The young pupils expressed their enthusiasm whenever they were working with NXT Lego Mindstorms. A rather surprising point of view came from the other 2/3 of the answers given to the questionnaire. It seems that pupils enjoyed the process of the teamwork wherever it took place and they expressed their disappointment if they had disagreements. During the project, the trainer's effort was also focused on creating a harmonious team culture which helps the personal improvement and evolution of each of the members and the team as a whole. The pupils observed themselves that they may reach a better result whenever they exchanged their ideas without fighting and they understood the importance of teamwork.

As for their worst experience, the pupils' opinions were equally divided into four quarters. The first, named the quarrels between members of their team as their worst experience. Their statements were like "I wish we had fewer quarrels». The second, complained about the fact that none of their ideas for building the robot was adopted "None of my proposals was adopted even when I had been told that it was quite good…" The third stated that they could not recall any bad experience at all, whereas the fourth, stated that their worst moment was when they could not the team of the Club the day of the contest due to other commitments.

Half of the pupils had either no worst experience or their worst experience had to do with their unavailability to participate to the activities of their team, which is a very encouraging result. The rest of the pupils are underlying the fact that they all have understood that teamwork is a prerequisite for a good result. The rest of pupils' worst moments had to do with their estimation about their contribution to the team. As the ratio of equipment regarding the pupils was very low, many good ideas of the pupils could not be applied and that was a point of disappointment for them.

On the third question, almost all pupils stated that they would like to have more time to spend on building and programming the robot. Whereas in the fourth question, 11/12 mention they had not spotted any activity that the team should have spent less time on.

Finally, all their suggestions about the activities of the robotics Club and the points that they thought that needed improvement had to do with the equipment requirements and the need to improve the ratio of MINDSTORMS kits to suit the number of the students. "We should have more robots and better computers."

Almost all of the pupils mentioned that would like to spend more time on building and programming the robot. This need is totally justified due to the above ratio. The fact that 11/12 pupils stated that there was no activity that should have spent less time on, highlights that pupils understood the necessity of each of the activities they had to cope with.

TABLE II. TABLE STYLES

My Worst Experience		
Category	***Example Statement***	***N***
Quarrels between team members	I wish we had fewer arguments	3
Personal disappointment: none of their ideas was adopted	None of my proposals was adopted even when I‘ve been told that it was quite good…”	3
Could not follow to support the their team	I was so sad that I could not follow and support our team to the contest	3
Could not recall a bad experience at all	I didn’t have any bad experience at all	3

VI. DISCUSSION AND CONCLUSIONS

Through the whole project, it was observed that pupils were very enthusiastic and worked hard for the final result. According to pupils’ responses to the questionnaires, this seems to be related with the fact that more than just a new interesting activity, robotics seemed to inspire their team spirit and to actually involve them to decision making and solution finding throughout this project.

This statement is enhanced by the fact that the choice of the project theme was based on pupils’ ideas which, of course, were triggered by the pluralism of information provided by experts and sources. Their achievements were mainly based on their active involvement and their commitment to the successful completion of the project.

An important improvement would be the enrichment of the project with further evaluation methodologies. To this direction the idea of pupils keeping a diary of their meetings as in [7] and [8] would be a good practice.

Obviously, it is clear that the presented methodology should be re-applied under better conditions on the field of equipment in order to draw more reliable conclusions for robotics in primary education.

ACKNOWLEDGMENT

I would like to thank Dr. D. Alimisis for his valuable remarks on this paper as well as Dr. Ermioni Deli for her ethical support and her inspiring comments during this project.

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