Integrating Robotics as an Interdisciplinary-Educational Tool in Primary Education

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Abstract: The current study examines the integration of robotics as an interdisciplinary-educational tool in the teaching and learning process. Study's sample was twelve, 6th graders that attended eight lessons, in November 2011, through which robotics was integrated as educational tool. To achieve the above the educational robotics package Lego Mindstorms NXT was used. Case study methodology was employed and 3 data collection methods were used: pre- and post-questionnaires, classroom observations and an evaluation assignment. The results showed that students found the lessons interesting and enjoyable. They managed to easily build the robots and relatively easily program the robots. The study highlights robotics' effectiveness as a tool to develop students' knowledge and skills, thus its interdisciplinary character was not highly revealed.

Introduction

The idea of robotics integration in education has been around for longer than someone might think of. It has been more than 20 years that the literature refers to the use of robots and programming in education (Miglino, Lund, & Cardaci, 1999; Papert, 1980). However, the great revolution in the field of educational robotics has been achieved throughout the last decade, where robotics escaped the laboratory and made efforts to connect to education (Chambers, & Carbonaro, 2003). The robotics materials (building blogs/ bricks, sensors and motors) which are perceived as toys by the children, and the educational activities designed using the aforementioned materials; bring the students closer to technology as well as challenge and their relationship with it (Chambers & Carbonaro, 2003; Hendler, 2000; Williams and Prejean, 2010). Numerous research studies suggest that robotics integration for educational purposes is an effective teaching method; however more research needs to be conducted in order to provide the foundation for implementing the appropriate teaching practices and strategies for the design of such learning environments (Williams, & Prejean, 2010). Finally, researchers argue that if robotics activities are appropriately designed and implemented have great potential to significantly improve and enhance the teaching and learning process (Bauerle, & Gallagher, 2003; Papert, 1993).

Theoretical Framework

Robotics can be integrated in various educational levels (from pre-primary to higher education) (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Eguchi, 2007) and within various disciplines such Mathematics, Science, Physics, Biology, Design and Technology (Williams, & Prejean, 2010). Additionally, researchers suggest that robotics is possible to enhance our understanding regarding the reality of various living organisms of our planet and thus become an integral part of disciplines such as Science, Biology, Technology, and Psychology (Miglino, Lund, & Cardaci, 1999). It could also be used in the course of Linguistics and Literature (Ma, Williams, Prejean, & Ford, 2008). Finally, robotics is possible to be integrated in formal, informal and non-formal educational settings

(Williams & Prejean, 2010). Robotics courses are also part of higher education curricula. Specifically, in order for elementary and secondary school teachers to integrate robotics as educational tools in their classroom activities they need to be trained accordingly within their university programs of study (Chambers & Carbonaro, 2003; Sullivan & Moriarty, 2009).

Jonassen (2000) was the first to provide the stimulus and motive for developing the appropriate theoretical background for the integration of robotics (technology) as an educational tool. He argued that technology and the various technological means can be considered as cognitive tools or "Mindtools", which enhance and enrich the educational process (Jonassen, 2000; Chambers & Carbonaro, 2003).

Research has shown that robotics integration in education promotes the development of student higher-order thinking skills such as application, synthesis, and evaluation, as well as teamwork, problem solving, decision making, and scientific investigation. Additionally, robotics provide students the opportunity to design and develop various objects, develop and test programming, experience the concepts of physics and movement; within a creative and enjoyable environment (Bers et al. 2002; Chambers & Carbonaro, 2003; Resnick, Berg, & Eisenberg, 2000).

Robotics has been connected to constructivism (Bauerle & Gallagher, 2003; Williams, Ma & Prejean, 2010). The teaching and learning theory that supports constructivism; highlights the educational value of such exercises as the ones the integration of robotics in the educational practice can provide. Such exercises are based on the philosophy of "learning by constructing", giving students the opportunity to develop interactive “thinking objects” (Kafai & Resnick, 1996; Papert, 1993 ; Harel, & Papert, 1991; Papert, 1986). Finally, students get to into the process of evaluating, changing, differentiating, re-designing, re-constructing and re-programming their objects, using materials from the world of engineering such as motors and sensors (Puntambekar & Kolodner, 2005).

Within a constructivistic learning environment, students have the opportunity to manage their learning; they are free to discover, and decide on how to proceed. Also, students get in touch with the multifaceted problem solving process and at the same time cultivate mathematical and scientific skills. Similarly, the construction of such objects helps students to represent reality. It is in this context, where students have an active role, that they understand the connection between theory and practice, relating the abstract to the concrete, as well as link what they learn within the classroom to reality and nature (Miglino, Lund, & Cardaci, 1999; Sullivan & Moriarty, 2009).

Teachers can design activities through the use of robotics that help students to explore new concepts and new ways of thinking (Chambers, & Carbonaro, 2003).Through these activities students further develop their technological literacy and engineering skills (Bers et al., 2002). Finally, recent studies (Talaiver & Bowen, 2010; Williams, & Prejean, 2010) argue that robotics employed as educational tool help students develop the knowledge and skills required in order to survive in the ever-changing, interconnected Information society era of the 21st century.

Main Aim

The purpose of this research is to examine the integration of robotics as an interdisciplinary-educational tool within the teaching and learning process. More specifically, it aims to examine if robotics used within classroom activity enhance students’ ability to apply the knowledge and skills gained across different subject matters, in other contexts and make connections to real life. It also investigates the effectiveness of integrating robotics as a tool to develop students’ knowledge and skills in relation to the achievement of instructional objectives. Finally, it explores students’ initial experiences, attitudes and opinions towards the integration of robotics as an educational tool.

Research Methodology

Case study methodology was employed for the purposes of the current study (Bell, 2001; Cohen & Manion, 1994). The study’s population was 25, 6th grade students in a rural public elementary school. However, 12 students participated in the experimental series of robotics lessons. Specifically, 6 boys and 6 girls was the sample of the study, aged 10-12 years old. The students participated on a voluntarily basis. The robotics lessons took place within the Design and Technology and students attended 8 lessons, 40 minutes each. The interdisciplinary approach was employed and numerous concepts of the following subject matters were integrated within the eight lessons: Physical

Science, Mathematics, English and Language. Students were asked to conduct 18 robotics activities having different levels of difficulty in robot construction and programming; addressing at the same time various concepts from the aforementioned subject matters, such as: movement, power, energy, geometric shapes, sensors, and human. The educational package Lego Mindstorms NXT was used.

Three data collection methods were used: questionnaires, classroom observations and an evaluation assignment. Specifically, 2 questionnaires were given to students: the pre- and post questionnaire (before and by the completion of the eight lessons). The two questionnaires had the same structure but somewhat different content. The pre-questionnaire contained 11 open-ended and 5 closed questions. The post-questionnaire contained 15 open-ended questions and 5 closed questions. Some of the questions were the same in both questionnaires aiming to investigate changes in students' knowledge, attitudes and opinions regarding robotics.

Classroom observations took place throughout the eight lessons and were guided by the following parameters: students' behavior and interest, discipline, difficulties encountered regarding robots' construction and programming, understanding and application of the various concepts examined. By the completion of the course, students were given an assignment aiming to evaluate the various concepts covered during the lessons. Five exercises were included in evaluation assignment, which has been developed based on the interdisciplinary approach employed throughout the 8 lessons.

The lessons and the data collection process were conducted in November 2011. Quantitative data was collected through the questionnaires and the evaluation assignment. Qualitative data was collected through the questionnaires and classroom observations. The statistical package SPSS (version 19) was used for the quantitative analysis, which includes: frequencies, percentages, means and standard deviations of some questionnaire variables and the evaluation assignment grades. The qualitative data was analyzed implementing the continuous comparison of data (Maykut & Morehouse, 1994).

Findings

It was the first time for all students to use robotics within classroom activities; however the vast majority of them (10 students) reported using Lego before in order to build various objects. Overall, the students expressed great enthusiasm about the robotics lessons and the majority of them (9 students) were anxious for the next robotics lesson (they were sacrificing their break in order to finalize their exercises or even to further experiment with robots construction and programming). Eight students requested for more lessons related to robotics. The results from the pre- and post-questionnaires revealed robotics lessons' influence and specifically, changes in students' knowledge, and differentiations in their attitudes, thoughts and opinions regarding robotics. Overall, students developed knowledge and skills regarding robotics, and realized its usefulness and necessity in our daily life activities.

The activities performed in class and the evaluation assignment revealed the effectiveness of robotics as an educational tool since the interdisciplinary-instructional goals were achieved on a satisfactory level. Additionally, students developed programming skills and at the same time enhanced their digital literacy skills. Higher-order skills development was revealed such as application, implementation and synthesis of knowledge and skills in different scenarios and activities. For example, they managed to apply and put together (synthesis) the knowledge and skills gained in order to successfully address the last two exercises in programming (that were most complicated ones). Students appeared to perform better in practice that is in building and programming the robot and highly performed on the exercises related to Design and Technology and English. Unfortunately, students did not perform that well to the exercises related to the other 3 subject matters (Physical Science, Mathematics, and Language). Additionally, a little bit disappointing was the fact that some students (4) did not manage to apply their knowledge and skills in other subject matters and three of them did not understood very well the use of sensors in our daily life activities (they did not make the connection to real life). For example, they did not manage to make the connection between the circular or rectangular robot programmed movements to Mathematics. Given the above results, the interdisciplinary character of educational robotics was not highly revealed.

There were 2 students that in both questionnaires expressed skepticisms and concerns regarding robots in our lives and the necessity of integrating robotics in education, showing that there were no changes in their attitudes and opinions. Nevertheless, these two students enhanced their knowledge and skills in robotics.

In general, students did not face any major difficulties in constructing the Castor Bot, thus they reported that the process was really interesting and they totally enjoyed it. The same experiences were recorded regarding the programming process: it was easy at the most part and enjoyable. Three students found some difficulties in programming specific robot movements. Finally, some minor problems and disagreements revealed within the teams, and in some cases their collaboration did not run smoothly.

Conclusions

The paper has important educational and theoretical significance. Through this study the possibility of integrating robotics as an educational tool has been shown, even though its interdisciplinary character has not been highly revealed. Consequently, it adds to the relatively new body of literature related to robotics integration as educational tools. Additionally, it provides the foundation to further examine robotics' role in enhancing the teaching and learning process and promoting the development of students' higher-order thinking skills as well as the relationship between the interdisciplinary approach and educational robotics. Future research also aims in further examining and defining the appropriate learning pedagogies and teaching approaches to be employed when robotics is integrated within classroom activities.

Additionally, the results of the study hold important implications for pre- and in-service educators. It is a great necessity for university programs of study and professional development trainings to appropriately prepare educators, since gaining such knowledge and skills, increases their ability to meet the modern educational requirements. Finally, educators are charged with significant responsibilities with equipping students with the necessary knowledge and skills needed in order to survive to the demanding information society.

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