The use of Educational Robotics for the teaching of Physics and its relation to self-esteem

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Abstract. The aim of this article is to use Educational Robotics(ER) in the discipline of Physics in order to investigate certain attitudes of Grade 10 students about Physics and to correlate these with certain cognitive structures and the learning performance. It is well known that the Computational experiment includes three phases, namely the modeling phase, the simulation phase and the computational phase. In this framework ER is a good candidate to implement the computational experiment since it uses the simulation phase not as a screen simulation but using a real device control. In our work ER was also used as an active learning theory tool in order to investigate the development of the algorithmic approach, a fundamental ingredient of the computational science. In our research we used the programming language Basic-Stamp and during the project students had the chance to explore-change the pseudo as well as the real code in order to make different measurements of various physical quantities and to deal with the algorithm of the application.

Key words: Educational Robotics, Didactic of Physics, Modelling, Simulation, Psychology

1 Introduction

Problem-Based Learning (PBL) is a total approach of education and involves a constructivist approach to learning [1]. The basic principle of PBL is that students learn through the process of solving so called 'real-world-authentic' problems. Additional features of PBL are learning in context, elaboration of knowledge through social interaction, emphasis on meta-cognitive reasoning and self-directed learning [2] and [3]. PBL can also be considered as an instructional system that simultaneously develops both problem solving strategies and learning by placing students in the active role of problem solvers confronted with practical problems in the workplace. The term Approach to Learning has been adopted (instead of term "level of processing" which had been derived from information processing theory [4] to describe differences in students' experiences contexts, and for explaining the variation

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in learning outcomes. What has been more difficult to establish is how teaching and learning environments can be designed to promote deep approaches to learning [5]. Three approaches to learning are identified in the research, namely: the conceptual approach, in which the intention is to understand concepts; an algorithmic approach, in which the focus is on calculation methods; and an information-based approach, in which the intention is to gather and remember information. The literature suggests that «approaches to learning» is a valuable tool to conceptualize the different ways in which students experience a learning context [6]. Approach to learning and the learning process is also related to cognitive styles of users [7]. Cognitive style deals with the 'form' of cognitive activity (i.e. thinking, perceiving, remembering), as opposed to its content. Cognitive style is usually described as a personality dimension, which has an impact on attitudes, values, and social interaction. It also refers to the preferred way individual processes information and is related to the approach of learning. Approach to learning and the learning process result is also influenced by many aspects of the human behavior such as the choice of activities, the effort exerted, the persistence on the accomplishment of a target and the skepticism about the final choice. These aspects of human behavior are related to psychological constructs such as self-esteem [8] and [9]. Self–esteem is the global perception that we develop in relation to our value as individuals, besides our self-descriptions and our self-evaluations on the various domains of our lives. Self-esteem is an intervening variable in the educational and professional decision-making process, since it relates to a group of psychological variables (self-perception of ability, accomplishment stress, values, educational attitudes, interests, personality, centre of control etc) which influence the students' decisions. Rosenberg [10] found support for a selectivity hypothesis in that an individual will be disposed to value those things at which one considers oneself to be good and to devalue those quantities at which one considers oneself poor. Students' beliefs were classified according to their approach to learning in Physics, using the following criteria: I am interested in explaining phenomena in a simplistic way without referring to the fundamental laws of Physics.(category 1). I am more interested in solving problems (category 2). I am interested in the various concepts in Physics in a coherent way, giving meaning to various observations in a holistic way (category 3).

2 The Computational Experiment

Computational science (which we have to distinguish from the computer science) focuses to a problem to be solved, with the components that constitute the solution separated according to the scientific problem-solving paradigm (Figure 1). Being able to transform a theory into an algorithm requires significant theoretical insight, detailed physical and mathematical understanding, algorithmic thinking and a mastery of the art of programming. The actual debugging, testing, and organization of scientific programs is analogous to experimentation, with the numerical simulations of nature being essentially virtual experiments [11].

The problem-solving method of computational physics is presented in Figure 1.

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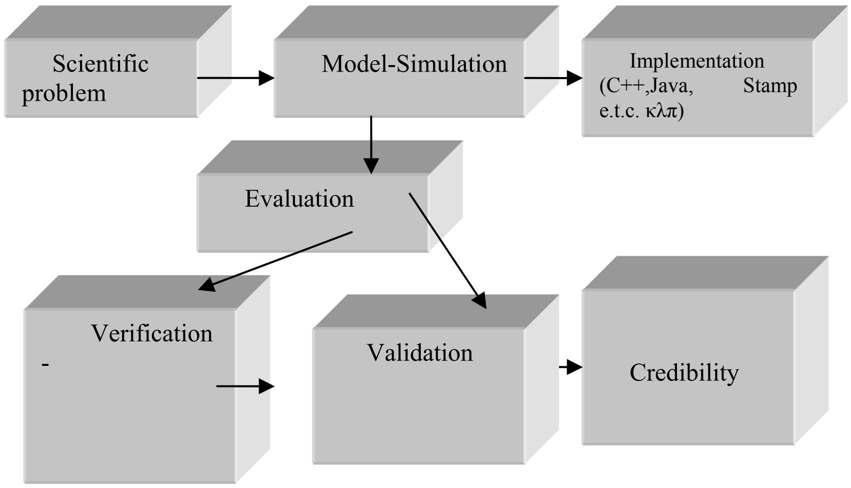

Fig. 1. The problem-solving method.

3 Talking to the Robot

A robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed techniques in order to implement various tasks. We need robots to do our jobs, communicate, and even entertain. Today's robots have also been an essential tool in a lot of fields of study. Teachers and schools use them to help students develop a better knowledge and understanding about the concepts in Physics. The aim of this project is to achieve making the robot walk and next to construct and compare two different methods of walking in order to compare their efficiency. The robot we used is called the Hex Crawler and was invented by the company "Parallax", which deals with the development of robotics.

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Fig. 2. “The Hex crawler” robot

The robot consists of the following parts:

1. Hi-tech HS-322HD Servos (six for vertical and six for horizontal movement). These servos are attached to the legs of the robot. Every leg has two servos, one helps to perform the vertical movements and the other one the horizontal movements, and therefore since there are 6 legs there are 12 servos (www.robotcombat.com).
2. Board of education programming board
3. The board of education includes a power switch and a servo jumper which provides voltage to power the 12 servos in order for the robot to work. The board of education also includes a DB9 connector for BS2-IC programming and serial communication during run-time and therefore is the tool that allows the robot to interface with the computer.
4. Parallax servo controller (www.parallax.com/detail.asp?product_id=28150). The parallax servo controller is the main motive machine of the robot which controls all of the 12 servos and gives the guidelines by which the legs of the robot will move.
5. The legs. The hex crawler can work both if it has its 6 legs in operation and when it has its 4 legs in operation. Furthermore, the computer was connected with the robot via a serial cable attached to the computer and the board of education at the main body of the robot because it has the capability to hold the problems written by the computer and then execute them (Fig. 3).

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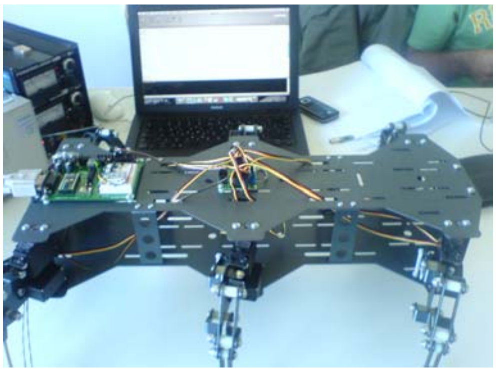

Fig. 3. Robot connected to the PC

The Basic stamp 2 module is a microcontroller (it has its own processor, memory, clock, and interface) and is used for the communication with the PC. Programming the robot lasted for four days. The CD –provided with the robot- contained a software and a compiler. The understanding of the code and the programming language was a very difficult task because it was designed only for the specific robot. This specific programming language is the BASIC stamp (http://www.phanderson.com/stamp/index.html). Every command written in the original software was studied independently in order to transform this to a new code suitable for the course under consideration. Robot could either walk with six legs (as initially designed), or with four legs. The program for the robot to walk with six legs was provided by the company an is called "Little step". From the documentation it was stated that the software could be used for changing certain parameters of the motion (stability, acceleration e.t.c.) and consisted of 8 modules. The first part of the code sets values to variables and commands for the motion of the robot and determines which servo is to be moved. Other parts of the code determine the velocity of the robot, and the time delays. An example of the source code is presented below.

```
servoAddr      VAR  Byte    'Servo addresses-declaration
of variables

ptrEEPROM      VAR  Word    'Gait select

servoPosition  VAR  Word    'to declare the position of
Servo

ramp           VAR  Byte    'Ramp used in SEROUT

rightRamp      VAR Byte     'Right side ramp values

leftRamp       VAR  Byte    'Left side ramp values
```

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```
This module corresponds to the declaration of
variables.

Calculations (part of the code)

Stride      CON   100

Delay       CON   Stride/2

Leg1Center  CON   Center1

Leg1Forward CON   Center1+Stride

Leg1Back    CON   Center1-Stride

Leg2Center  CON   Center2

Leg2Forward CON   Center2+Stride

Leg2Back    CON   Center2-Stride

Leg3Center  CON   Center3
```

After programming the robot for 6 legs we changed the code in order to have the robot running with 4 legs. The algorithm was implemented in order to give specific orders and the main changes concerned the motion of servo.

4 The Pedagogy of the Robotics

Educational Robotics deals with the concepts from different disciplines (Physics, Maths, etc) aiming to explore at all the levels of education in order to improve understanding of students of various conceptions, processes and phenomena. [12], [13] and [14].

We can consider that ER cuts the curriculum in such a way that implies a cross thematic approach to education.

ER is strongly connected to the computational experiment approach since it involves modeling, simulation and the computational phase by writing code and developing algorithms leading to the creation of cognitive structures.

In Figure 4 we present the pedagogical and computational approach of the use of ER.

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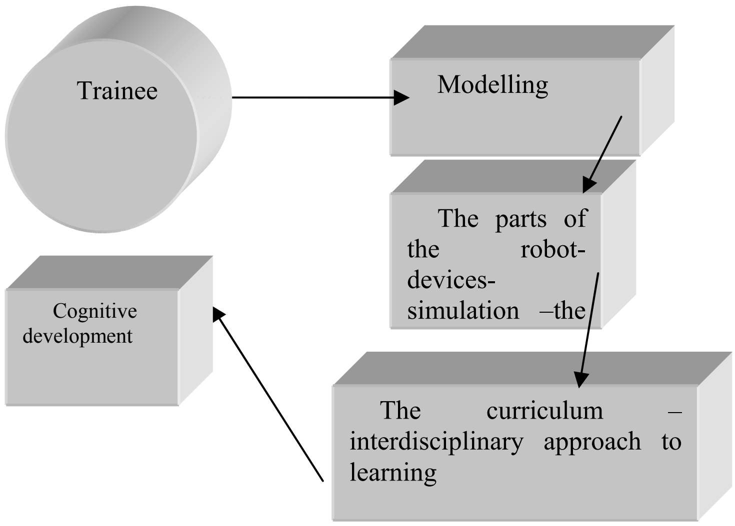

Fig. 4. The pedagogical-computational approach to the use of robot in class and its cycle

5 Research Methodology –Results

20 students of Grade 10 participated in the project which lasted for 3 months. During the research students worked with the teacher in order to explore the functioning of the robot in all aspects of its use, namely the way it operates, the algorithm of the code for the motion with 4 or 6 legs, to measure the velocity and make graphs of the displacement versus time. According to Tobochnik [15] types of manuscripts that would be appropriate for physics education fall generally into three categories.

The first of these categories consists of papers that describe a new algorithm or one that is not well known. There should be enough detail in such a manuscript so that readers could write their own program. The manuscript should not only explain the algorithm, but provide some significant examples of how it will help students learn some new physics. The algorithms might include methods of visualization, animation, numerical analysis, and simulation. In our project we wanted to combine the education in physics with ER and make students involved in the transformation of the algorithm or even the model under consideration. During the teaching-learning sequence students had to explore the parts of the robot and to relate their functioning with the modules of the software code and the algorithm. Controlling the software they could change for example the time interval for certain distance, or the acceleration, the coefficient of friction and to connect these values and measurements with the number of legs of the robot. They actually had to measure the distance and connect this concept with the time interval in order to make measurements and plot their results.

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5.1 Phase 1 – Before instruction with the use of ER

Students participated in Rosenberg's test for their classification according to their self-esteem. After that classification, a questionnaire was given to students in order to find out the approach to learning they preferred. In this questionnaire there were three possible outcomes:

A) I am interested in explaining phenomena in a simplistic way without referring to the fundamental laws of Physics (category 1). B) I am more interested in solving problems (category 2). C) I am interested in the various concepts in Physics in a coherent way, giving meaning to various observations in a holistic way (category 3). We scored the approach to learning with the scale: category 1 with score 1, category 2 with 2 and category 3 with grade 3. The total score of the Rosenberg questionnaire was in the scale 0-30. We have considered that scores ranging between 15-25 correspond to individuals with normal self-esteem (category 2), scores that are equal to or less than 15 correspond to low self-esteem (category 1) and the scores that are equal to or higher than 25 correspond to high self-esteem (category 3). Before instruction using ER, students had also to answer 20 questions for the duration of 2 hours about the issues of velocity, distance, displacement and friction. The performance scale for this diagnostic test (learning approach, learning performance) ranged from 1 to 4, with 1 being the score which corresponds to wrong answers without reasoning, 2 to correct answers with correct reasoning for less than 5 questions, 3 to correct answers with correct reasoning for more than five and less than 15questions and 4 to correct answers with correct reasoning for more than 15 questions. We should mention that students had a level of knowledge about the physical quantities of this course from previous classes.

5.2 Phase 2 – After instruction with the use of ER

After the instruction we measured the self esteem ,the perceptions about Physics as well as students' learning performance(learning approach ,diagnostic test). Students had to answer 20 questions for the duration of 2 hours .The performance scale for the test ranged from 1 to 4, with 1 being the score which corresponds to wrong answers without reasoning, 2 to correct answers with correct reasoning for less than 5 questions, 3 to correct answers with correct reasoning for more than five and less than 15 questions and 4 to correct answers with correct reasoning for more than 15 questions.

Table 1. Results for perceptions about Physics (1 stands for Phase 1, 2 for Phase 2).

	Mean	*N*	*Std. Deviation*	*Std. Error Mean*
PERCEPTION FOR PHYSICS 1	2,00	20	,725	,162
PERCEPTION FOR PHYSICS 2	2,75	20	,615	,145

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We observe a significant shift from category 1(I am interested in explaining phenomena in a simplistic way without referring to the fundamental laws of Physics to category 3 (I am interested in the various concepts in Physics in a coherent way, giving meaning to various observations in a holistic way).

5.3 X^2 test for SELF ESTEEM and LEARNING PERFORMANCE

Table 2. Results for the relation of self-esteem and the learning performance (diagnostics test) before the instruction(phase 1).

		Diagnostic test- phase 1				
		1	2	3	4	***Total***
Rosenberg	1	2	1			3
	2	2	5	2	1	10
	3			3	4	7
Total		4	6	5	5	20

5.4 X^2 test for SELF ESTEEM and LEARNING PERFORMANCE

Table 3. Results for the relation of self-esteem and the learning performance(diagnostic test) after the instruction

		Diagnostic test-phase 2				
		1	2	3	4	***Total***
Rosenberg	1	1		1		2
	2	0	4	3	3	10
	3			3	5	8
Total		1	4	7	8	20

6 Conclusions

The main goals of the project were:

1. to investigate the development of thinking skills about certain concepts of physics due to the involvement in the algorithmic approach,
2. to study the relation of the algorithmic approach with the cognitive structure of self-esteem and learning performance and

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3. to examine the change-if any-of students' perception about Physics.

The algorithmic approach is fundamental in any kind of process which involves teaching and learning. The algorithm entered in the teaching sequence through the involvement of students in the pseudo code provided by the software and they had to 1) understand this 2) alter this by proposing certain changes.

Most of the students for example considered that the robot with six legs had a bigger velocity that the robot with four legs. Also the concept of the gradient of the graph position vs time was clarified since students could measure instantaneously both the gradient and to control the velocity in order to identify that these quantities are equal.

Our results show also a big improvement concerning the self-esteem as well as the learning outcome after the teaching-learning sequence using ER. Despite the fact 10 students remained at the category 2 of the self esteem they optimized their learning performance. Also one student shifted from category 2 to category 3.

The average value for the learning performance has increased from 2,55 at phase 1 to 3,1 at phase 2.

Interviews with the students after the experiment revealed that students felt that "doing" during the experiment provided the impulse to consider themselves as active and they actually had the control of what they did. They also considered that dealing with the algorithm of the software enabled them to be fully conscious of the problem under consideration and handling of the parameters of the code increased their self esteem.

The learning outcome (students' performance) was also quite encouraging to continue our efforts for further developments in ER. One point worthwhile to mention is that students expressed their willingness to deal with the computational phase of the experiment. They considered that with the help of the teacher they should deal with _at least –with the pseudo-code, while others wanted to deal with the source code. ER can thus enhance students' understanding of software despite the constraints helping bring a sense of authenticity to the classroom [16].

In addition, this project could also serve as a proposal to shift from the view of computational – physics education, in which the dash indicates a union of computation and physics on pretty much equal footing as individual courses or formal programs, to the computational physics–-education, which views the computer as a tool to advance physics education [17] and ER can facilitate this transfer.

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