Robots as learning tools in a vocational school

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Abstract:. Many researchers have commented on the use of technological resources in education, in particular in the robotic field, but consistent data that assess how robots affect motivation and learning in the vocational education programs are missing from the literature. We present an educational experience over one year in a vocational high school class forming electronic technicians. Motivation and pressure are considered two factors impacting vocational high school student learning. The introduction of educational robot project and then of the robot competition showed to be effective in improving learning efficiency in different fields as a consequence of enhancing intrinsic and extrinsic motivation. Results are encouraging, and should affirm the idea that the didactic project "educational robot" is a well facilitated learning environment of different disciplines, where the motivation to learn increases, the achievements of both individual and class are positive.

Key-Words: Educational Robots, Intrinsic and extrinsic motivation, Parallax Boe-Bot, Vocational School, Robocup Junior Competition, Learning Motivation

1 Introduction

In Italy the high school education is organized mainly in three different groups: lyceum schools, technical and vocational institutes. All of them take five years before arriving to the final exam to get diploma and to have free access to university courses. Among them only vocational institute have an intermediate step, an exam for obtaining a qualification after the third year of schooling, making it less long and challenging.

Generally students enrolled in a vocational school are those who did not perform very well in their past scholastic history, often they have problems of learning due to lack of concentration. They usually come from a problematic family context and a low social level. The first classes are composed by almost fifty percent of foreign student, without good knowledge of the Italian language. They are expected to master certain skills to an extent good enough to earn their own livings in a relatively short time range.

Unlike students enrolled in other types of schools, almost none of them will go to university; they have more pressure from future expectation to find a job. However, in spite of aspired by future expectation, vocational high school students in Italy were reported less motivated in studying and not confident enough of their capabilities due to their past history of frequent school failures [25]. The first major reason contributing to their academic frustration and failure was lack of learning motivation. The proof of this is the big problem of non-school attendance and the high dropout rate.

Learning takes place through interplays among cognitive and motivational variables and these two aspects are found inseparable [20], [23],[22] , [14].

2 Learning motivation

Motivation in education can have several effects on how students learn and how they behave towards subject matter [18] like the following : direct behaviour toward particular goals; lead to increased effort and energy; increase initiation of, and persistence in, activities; enhance cognitive processing;

determine what consequences are reinforcing; lead to improved performance.
The motivation is a component very complex involving many psycho-social models from the Maslow pyramid [13] to the attribution theory. For our purpose we can sketch motivation within 2 dimensions.
First, motivation can be intrinsic or extrinsic. Intrinsic motivation comes from the pleasure one gets from the task itself or from the sense of satisfaction in completing or even working on a task. An intrinsically motivated person will work on a math equation, for example, because it is enjoyable.
Extrinsic motivation refers to motivation that comes from outside an individual (such as money or grades). In the case of a student, the reward would be a good grade on an assignment or in the class.
Secondly, there is the motivation 'toward a goal' or 'away from something'. This dimension takes also into account of the reaction of students to reward/ punishment politics. The motivation away from something is always badly formulated because it doesn't consider the choice of the goal, and as soon as the thing from which I try to escape disappear, the motivation disappear.
Combining these two dimensions, we can find out the picture of fig. 1.
The extrinsic motivation alone has some serious drawbacks:

- It's not sustainable - As soon as you withdraw the punishment or reward, the motivation disappears.
- You get diminishing returns - If the punishment or rewards stay at the same levels, motivation slowly drops off. To get the same motivation next time requires a bigger reward.
- It hurts intrinsic motivation - Punishing or rewarding people for doing something removes their own innate desire to do it on their own. From now on you must punish/reward every time to get them to do it.

A student, for example, may want to get a good rating on a test, but if the task does not interest that student, the possibility of a good rating can be not enough to maintain that student's motivation to put any effort into the exercise.

As figure 1 shows, only intrinsic motivation really consistently works, and it can be helped by the extrinsic motivation (i.e. rewards etc). This is of course the main motivational logic of peer production.

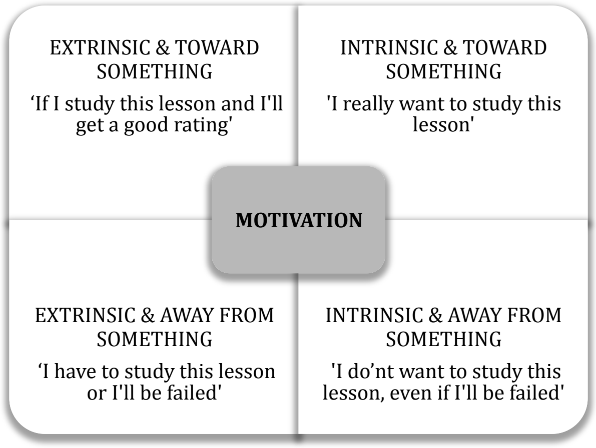

Fig.1: Learning motivation dimensions

Although both influence learning outcome positively, intrinsic motivation was found associated with a lower dropout rate, higher-quality learning, better learning strategies, and more enjoyment of schooling [3], [5], [10],[6].
Rather than being the source of motivation, the teacher must help students to find their own intrinsic motivation. Extrinsic motivation can be very useful to reinforce intrinsic motivation.
What enhances intrinsic motivation?

- Challenge: Being able to challenge yourself and accomplish new tasks.
- Control: Having choice over what you do.
- Cooperation: Being able to work with and help others.
- Recognition: Getting meaningful, positive recognition for your work.

To improve the intrinsic and the extrinsic motivation to learning in our Vocational School students, we decided to introduce robotics in the electronic curricula.

3 The Robot Didactic Experiment.

Today, often teenagers love ICT world and some provocative ideas for projects on robots can be an effective way to get their interest [2].
School projects based on robots can be exciting ways for students to learn and get creative.
Teenagers usually love being social: if the

whole class is working on the robots together students can compete, cooperate and help each other on tasks [16] .
Also, the class can move through the curriculum together.
Furthermore, by using ICT tools and, as in particular, robots and PCs in the class, learning about scientific, mathematical, computer science and technological topics is facilitated [1], [7], [24]. Robots are complex machines and require knowledge of many different academic disciplines. Algebra's ratios and proportions are covered by many different aspects of robots including most obviously gear ratios, Ohm's Law (E=IR), work force problems (W=F x D) and Newton' laws (F=ma). These are also physics in the form of simple machines, electricity, work and force. Finding connections to other math disciplines like geometry and pre-calculus is not hard. Even connecting robots to Chemistry, with batteries and biology, with any variety of sensors, is relatively trivial. So we can think that educational robotic can enhance motivation to study among students of socially deprived areas and can help students with difficulties in learning [15], [8].
After a year long project we tested whether these hypothesis where correct, i.e. if the educational robotic in our class has brought benefits regarding an increased knowledge in the technical and scientific disciplines and in a possible improvement in logic capabilities and of finding solutions to general problems.
We can say that our project was successful if the following 4 questions get positive answer:

- Have students acquired basic physical, mathematical and geometrical principles that underline the robot activities?
- Has awareness increased by students on the operation of various sensors in terms of electronic enhanced?
- Has their ability to problem solving and logical reasoning in the face of concrete situations increased?
- Did their intrinsic motivation to learning increased?

4 The Robot Lab

The School laboratory hosts 10 workstations inter-connected via LAN. Each workstation consists of a PC, a data acquisition board and other equipments.
The basic setup for the laboratory experiments conducted is made up of a simple physical plant, a controller and a computer.
The physical plant consists of a Parallax Boe-Bot robot and a Parallax Basic Stamp II Board of Education. The controller is implemented in the Basic Stamp II microcontroller mounted on the Board of Education. The software for the management of the sensors was developed in Parallax PBASIC language, which was installed in the PC.
This set up was chosen because is cheaper than Lego Mindstorm Kit, Parallax PBASIC language is very powerful, user-friendly and Basic Stamp II microcontrollers are easy to learn and have considerable I/O functionality. Similar experiments can be conducted using different platforms like Java or lab view, but the learning curve of Java is relatively steep and Labview was more expensive. The PBASIC language has easy-to-use commands for basic I/O, such as turning devices on or off, interfacing with sensors, etc.
The students could choose, within a finite budget and of all provided by Parallax, such as sensors to equip the robot. Their choice fell on the following sensors: four infrared sensors (QTI Sensor) to follow a black line, three ultrasonic sensors (Ping Sensors) for recognizing walls and barriers, and a camera (TCS3200) for recognition of colours.
The QTI sensor is an infrared emitter/receiver that differentiate between dark surface (with low IR reflectivity) and light surface (with high IR reflectivity). These small sensors can be very handy for line following. Wiring options allow it to be digitally used for fast black/white line following, or as an analogue sensor to detect different levels of gray. A daylight filter is built into the sensor.
The Parallax's ultrasonic sensor (Ping Sensor) is a low-cost and easy tool for measuring distance. It is useful for many applications requiring measurements on either moving or stationary objects. The Ping sensor measures distance using sonar; an ultrasonic (well above human hearing) pulse is transmitted from the unit and the distance-to-target is determined by measuring the time required from the echo to

return. Output from the PING sensor is a variable-width pulse that corresponds to the distance from the target.

TCS3200 Colour Sensor Daughterboard is colour detector, including a TAOS TCS3200 RGB sensor chip, white LEDs, collimator lens, and standoffs to set the optimum sensing distance. It plugs directly into the BASIC Stamp-2pe Motherboard or Propeller Backpack and will also interface to any other BASIC Stamp module or Propeller board using the optional DB-Expander SIP Converter. The TCS3200-DB can detect and measure a nearly limitless range of visible colours. The TCS3200 has an array of photo detectors, each with either a red, green, or blue filter, or no filter (clear). The filters of each colour are distributed evenly throughout the array to eliminate location bias among the colours. Internal to the device is an oscillator, which produces a square-wave output whose frequency is proportional to the intensity of the chosen colour. Students have developed the SW for the extraction of information from the data from these sensors and algorithms for decision-making. Teachers used a variety of techniques in the classroom, most notably laboratory exercises and projects, to ensure that each student has the opportunity to meet the learning objectives.

5 The robot competition

Recent studies in literature [4], demonstrated that a competition provides additional extrinsic motivation for the students. The goals of a competition often have a surface intersection with the topics addressed by education. However, competitions focus on winning (although some define winning in terms of design rather than performance), whereas education concentrates on teaching the methods that ultimately lead to success. Pavelic et al. in [19] suggest that a competition can aid the intellectual maturity of students who are beginning to accept that there might be more than one correct answer to a problem. The competition goals are to have fun and meanwhile to encourage undergraduate students to get more experience with mobile robotics, thereby improving both the quality of students going into the work force and the number of students willing to make a career in robotics or in technological field.

Competitions offer a more immediate payoff to the general educational development of the individual student.

It provides additional extrinsic motivation for the students to mature [4].

A competition involves a clearly defined, but open ended, problem to which there are many possible solutions. The students must be largely self-reliant to understand the problem and apply their knowledge and problem-solving methods. Working voluntarily with other students encourages them to identify and evaluate a variety of opinions stemming from the text books, internet, teachers, and their colleagues which should move them to cope with different possible solutions.

The typical team organization of an adviser plus student members lends itself to a realization of relativism, whereby the teacher serves as a consultant instead of an arbiter. The goals of the competition, as opposed to other potential applications of robotics, serve to stress the contextual aspect of applying knowledge. In addition to the general intellectual maturation of the student, a competition provides a forum in which to acquire and exercise specific job-related skills. Mobile robot competitions, in particular, require software, interdisciplinary interactions, and teamwork. It is difficult for the students to make progress without applying good testing and debugging strategies. A competition offers the potential for an educational experience, but it doesn’t guarantee it. As with other team projects, negative events can reinforce a student’s tendency to shun teamwork (“I could have done it better by myself.”) or transfer responsibility to another agent (“It was my partner’s/the hardware’s/the software’s/the competition sponsor’s fault”). The relatively low level of intellectual maturity of undergraduates favours the teacher providing the overall architecture and design so that the students work on personalized portions that are both relevant to the project and have a high potential for being completed. For these reasons, and to test learning efficiency we enrolled the vocational class to the national robot competition "Italian

Robocup Junior 2009", performed in Torino at May 2009. 57 High Schools from different towns have been involved. Among all, only two Vocational Institutes were participating. The winner would have had access to the International Robocup Junior [12].
The competition chosen by students among "soccer, dance and rescue" was the last one. The robot was supposed to cope with a rescue situation, performing different tasks like to follow a black line, to find it after some interruptions, to overcome obstacle of different types, to recognize the victims of different colours through a camera.

6 The Project Development Plan

The target group for the robotic didactic experience was the fourth class of the Vocational Electronic Course, composed by 17 students during one school year (about 9 month). Our data set compare results coming from tests on both robotic and non robotic-based didactic classes of the same Electronic Course.
The robotic didactic project was introduced for a number of 6 hours per week in the course for electronic technicians and performed in the laboratory of computer science. At the end of the project, three sets of test, consisting of 20-35 multiple choice questions were administered to assess knowledge acquired.
After taking some introduction to basic programming rules, students were supposed to possess basic skills in using computers and were asked to write simple programs for guiding the movement of the robot. The latter, made with a commercially available robotic kit, consists of a cart with three wheels, two of which are controlled by two stepper motors. The robot "sees" the world through different sensors that guide the movement through the programming of a microcontroller (Fig. 2).
Once students had acquired these skills, a few lectures have been provided on scientific, technology and instrumentation materials.
Our experience indicates that students could pick up simple routines quickly by doing a number of selected simple practical experiments, although they had been considered little inclined to study and unable to bear the weight of a major training project.

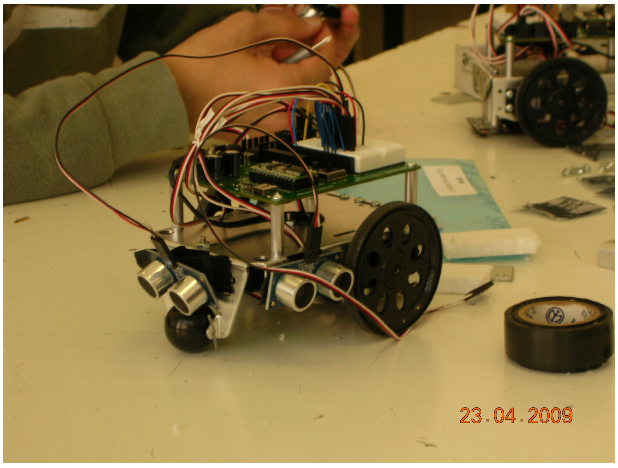

Fig. 2: structure of the robot and sensor assembly.

6.1 Laboratory activities

The proposed didactic activity has been effectively conducted with two integrated components: classroom lecturing and hands-on practice.
Most successful classrooms have robots for student groups of four. A teacher can usually break up building, programming, wiring, and leadership tasks easily among the four students in a group for each task. Our project provided young people with an good opportunity to get hands-on, real-world science and engineering experience in a way that brings true excitement to learning.
First some basic knowledge on informatics and technology have been thought in classroom lessons, then students have been organized in up to 4 people group, having available 5 identical prototypes of the robot. Students were required to implement a series of exercises of increasing difficulty, starting from basic routines such as 'go back and forth', 'follow a line ', follow a square' etc. Each group has been asked to mount the robot, to make the necessary mechanical modifications to overcome some adversity such as overcoming climb and passing through doors. The next step was to mount sensors (Fig. 3) and electronic circuitry necessary for their optimal functioning The students, guided by teachers, have developed step by step the algorithms required for navigation of the robot within the grounds of race “rescue” and realized the flow

chart. The latter was translated by the guys in P-Basic language and uploaded to the microcontroller via USB. As the difficulty of the robot implementation grew, it becomes necessary to solve problems of electronic (as does the sensor, how do you connect it), mechanics (where it should put it), physics (what do the data come from it?), geometry (as I prepared for my purposes? E.g.: walk tot cm with wheels involves knowing the geometry of the circle).

Fig. 3: Students in a laboratory dedicated to assembly of the robot.

All this work was interspersed with frequent checks on the field and any correction and immediate reassessment of operation. Then subjects or topics that had previously been rejected as unnecessary taxation became an object of curiosity and study because they were designed to achieve better performance in a game competition.

6.2 Evaluation

We evaluated the work done by students in the pipeline, through the use of oral and written tests (structured and unstructured tests) aimed at verifying the achievement of specific knowledge and skills, that was associated with development (software and hardware) and its proper functioning the robot. At the end of the year we administered questionnaires aimed at providing answers to our questions about overall goals, educational curriculum objectives, which were due to be acquired independently of the teaching method adopted, therefore independent from the speech "robot". For this reason it was possible to administer questionnaires to an equivalent class (for number of students and level of instruction) belonging to the same address, to which the same didactic contents were presented with traditional teaching methods.

The questionnaires were 3 with 4 possible answers per item: one on general knowledge of basic mathematics and sciences (35 items, e.g.: what is an ultrasound, what are the infrared rays, how is calculated the circumference of a circle, how many times is a small length in a larger etc....); the second covering the electronics of sensors (20 items), subject of the studies plan of the electronic course and the third aimed to investigate the logic capabilities to solve simple practical generic problems (32 items).

7 Results

In fig. 4 the histogram represents the percentage of correct answers over the total (the wrong answer has been evaluated with 0 score) in the questionnaire deals with electronics, in particular the electronics of the sensors.

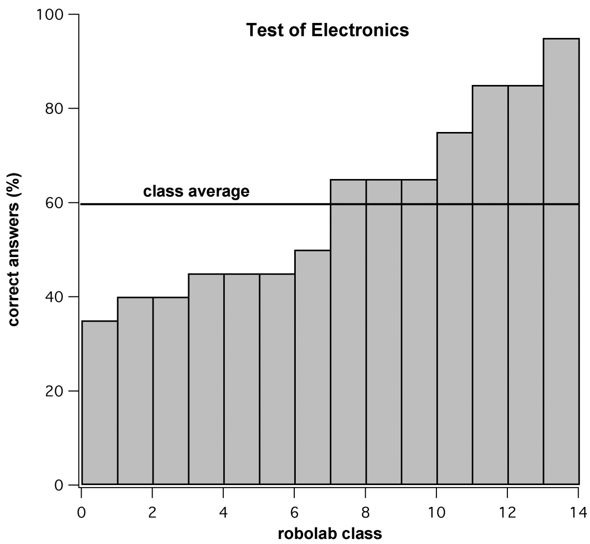

Fig. 4: Percentage of correct answer in test of Electronics for students that token part to the Robo-didactic Project. The horizontal line indicates the average value.

The horizontal line, around 60%, indicates the average value of the correct answers normalized over the whole class. None of the students fell below the value of 36% of correct answers.

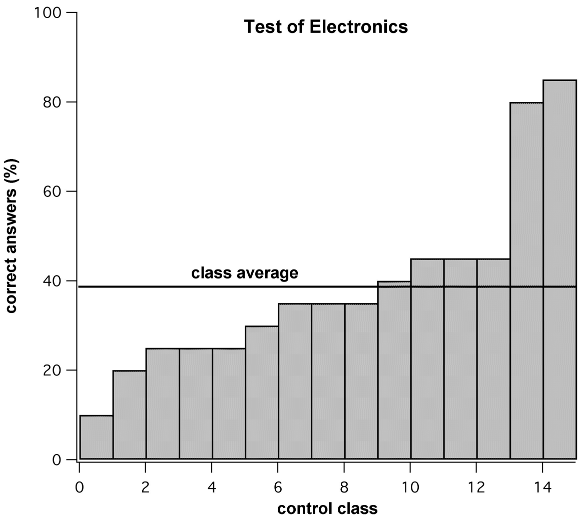

Fig. 5: Percentage of correct answer in test of Electronics for students of the control class. The horizontal line indicates the average value.

Fig.5 shows the results of the same test for a class that followed the same program of the subject but with an ordinary didactic method. The average value does not reach the 40%, while many students didn't reach the 30% of the correct answers.

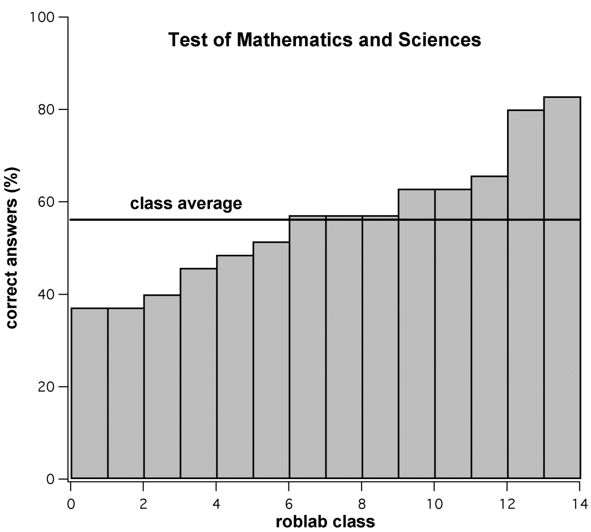

Fig. 6: Percentage of correct answer in test of Mathematics and Sciences for students that token part to the Robo-didactic Project. The horizontal line indicates the average value.

The results that indicate the level of acquisition of some fundamental knowledge in science and maths are displayed in fig. 6 and 7.

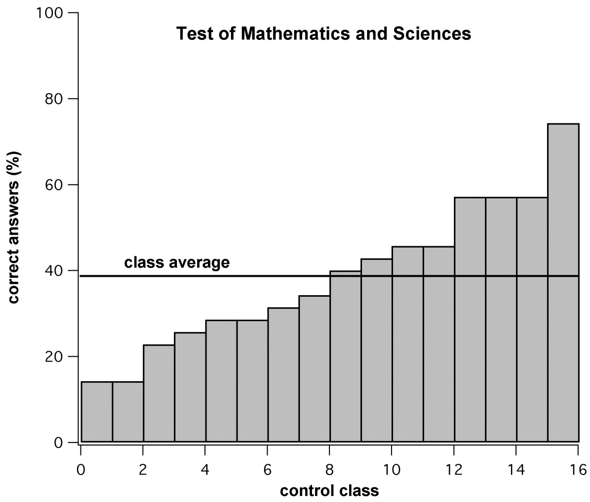

Fig. 7: Percentage of correct answer in test of Mathematics and Sciences for the control class students. The horizontal line indicates the average value.

Again the robolab students show a better average performance respect to the control class (57% against 39%).

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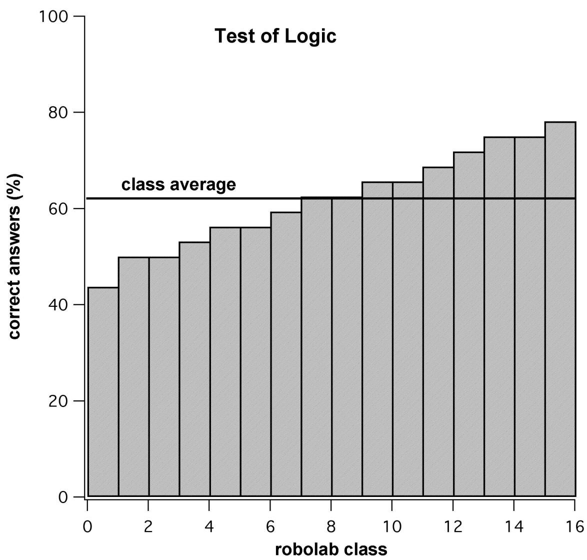

Fig. 8: Percentage of correct answer in test of Logic for students that token part to the Robo-didactic Project. The horizontal line indicates the average value.

Moreover in the control class the standard deviation is larger; this means that there is large

difference among the student level of learning within the same class: only few of them performed pretty well.
The highest level of performances in both tests of electronics and maths, for students participating to the robolab project, suggests that the motivation of learning on topics connected to robot world and in particular to robot competition, has increased.
The Robocup J competition provided motivating examples of how abstract concepts can be transferred to practice and meaningful assignments and this increased the learning rate of the whole class.
Fig. 8 and 9 show the results for the test on logic. Here the robolab class students performed, in average, a little bit worst than the control class students.

Fig. 9: Percentage of correct answer in test of Logic for the control class students. The horizontal line indicates the average value.

These results suggest that the logic abilities have not been influenced by the one year robodidatic project, maybe they are more connected to personal skills and perhaps they could be improved by longer time experiences.
Again the dispersion around the average value is smaller for the participant to the project, showing a better homogeneity within the class maybe connected to the teamwork experience. Mutual support and a great team work was seen abundantly during the robolab sessions, especially when discussions and explanations occurred. In fact, before accepting the final problem solution, it was common to see students demanding for explanations from their teammates regarding that which they did not understand. Because the competition perspective forced the whole group to come to a consensus, the other teammates explained the misunderstood concepts or subject matters until every member of the group understood. It was common to see all members involved in discussions and explanations. The motivation was based on the activity's newness and by the competition against other schools team.
Regarding the resolution process, positive interdependence was seen since the students not only had to fulfil their own tasks, but also needed to complete them in coordination with their other teammates.
Probably, the added stimulus of the competition has encouraged students to put forth their best effort in working in a group, and applying knowledge. Students in the race have pledged more: they left a sense of revenge against teams coming from schools in which they failed. Their enthusiasm was increasing day by day until the final qualifier. We arrived at the seventh place of the final list and this place looks great.

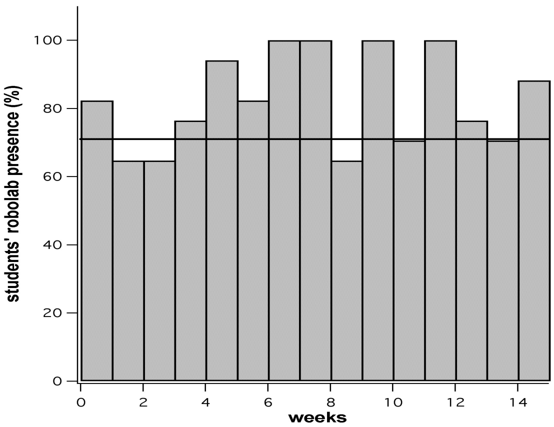

Fig. 10: Percentage of student presences at the robolab. The horizontal line indicates the average value of student presences.

Finally in fig. 10 the percentage of student presences at the robolab. The horizontal line indicates the average value of student presences at school. This graph shows that the student participation to the activities involving the robots was pretty good, because during these activities students were not just spectators, but became relevant actors, developing a great commitment to their team and towards the activity resolution.

8 Conclusion

The introduction of the robots in the classroom and the participation to a competition can provide both motivating examples of how abstract concepts can be transferred in practices to meaningful assignments and projects.

The results, though preliminary are encouraging, and should affirm the idea that the didactic "educational robot" project is a well facilitated learning environment of different disciplines, where the motivation to learn increases, the achievements of both individual and class are positive and consequently we can suggest that the self-esteem in students increases .

These early promising results lead us to continue the experiment of teaching with the use of robots, expanding the number of targets to be monitored and the number of participating student.

Acknowledgment

We gratefully acknowledge the support of, and collaboration with Scuola di Robotica of Genova

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