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Developing Educational Printable Robots to Motivate University Students Using Open Source Technologies

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Abstract TODO

Keywords 3d printers, creativity, educational robotics, innovation, motivational education, open source, printable robots.

1 Introduction

Since the insertion of the computer in schools, the desire to incorporate the teaching of robotics in the classroom always remained latent. Technical colleges, mainly those related to electronics, began its first robotics projects connected to the PC interfaces. But this work was enrolled in a small set of institutions, because a lot of knowledge both teachers and students was needed. Furthermore, the built robots were not any kind of autonomy and they were required to remain connected to the PC [1] [2].

In the late 90s, begin to appear on the market a set of educational robotics kits that solve these two problems do not require deep electronic knowledge and allow the construction of autonomous robots. The most popular of these kits is the Lego Mindstorms kit [11] that broke the boundaries of educational institutions and today, thanks to the Internet, has a huge community of educators, scientists and hobbyists develop software and hardware to extend its functionality.

Therefore Educational Robotics is conceived as the mode of adaptation and development of student activities, which is carried an understanding and improved attitudes based technologies. By implementing educational and handling robot controlled through computer systems, students can solve problems of different kinds.

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Some of the benefits offered by educational robotics are: allow the integration of different areas of knowledge. Development of systematic thinking. Allows different variables operate and control synchronously. Give the creation of learning environments. Recognized and classified. They are autonomous in decision making. Greater accuracy, without fatigue. Faster. Reduced costs.

On the contrary, one of the most important disadvantages to consider is that students need training especially in the construction and handling of devices and learn to program. Another important aspect is the need for adequate infrastructure such as laboratories and the cost of devices.

For these reasons, we want to change the methodology. We want that any student can learn-investigate-practise in the field of robotics. To do this, we have developed an educational robotics architecture based on the Open Source philosophy [9]. All aspects that influence the design and manufacturing process are based on Open Source technology (Hardware, Software, others tools). Thus, we obtain a mobile robot that has a very low cost and therefore it is accessible to everyone. The workshops are the other tool which we have used. These workshops are for beginner students. We teach the basic knowledge of programming, hardware, modeling, control, for students to create their own projects.

So, in this paper, we propose an educative robotic platform based on low cost Open Source technologies and lastly, we present the results of several experiments using educative modular robots, as showed in Figure 1. The experiments are focused on the effort and creativity of the students, mainly university students, who have no knowledge in robotics. And we can conclude that it is possible to program simple but useful programs for a robot doing easy tasks in a reduced time.

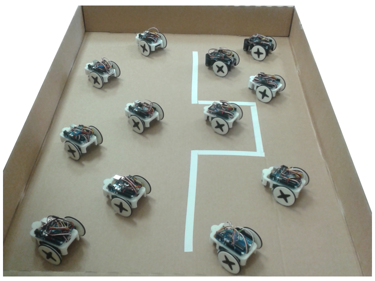


Fig. 1: Main mobile robot colony and parking space.

The rest of the paper is organized as follow. Next section (2) has the explanation of the motivations that we had for doing this project. Which the aims are and what we want to obtain. In section 3 the robotic platform is presented. There we describe the main parts. In this case, the design, the electronics and the software used. Section 4 contains all the experiments and results we have developed and obtained. We try to explain the aims of the experiences and how good the results have been. And lastly, section 5 shows the conclusions we are able to know from the experiments and future work or proposal we would like to do.

2 Motivation

This project was carried out through an initiative by the members of the UC3M Association of Robotics (ASROB) [4] to encourage the use of robotics technologies in a open and accessible way for all university students. Also, robotics is a very interesting field with potential for growth in the near future [6].

Great companies like Google, Apple or Facebook are joining every time more to the field of robotics. And, this will create the necessity of new jobs that universities will have to satisfy in a near future. Furthermore, traditional robotics is evolving toward agile methodologies for the improvement of robots. All these reasons are great motivations in order to the robotics field be imposed in the educational level.

There are every day more professionals in the robotic and education fields that it is focusing their work on educational robotics and human-robot interaction. Authors like Chiou [7], Bredenfeld [6] or Alimisis [1], they have focused their efforts on teaching robotics to kids and young students. That direction, of course, is very good for the future of those students who will arrive to the university with all base knowledge learned. Nevertheless, we feel that there is not a real effort yet for new university students, those who we direct our work in this continuous project.

Up to now, the majority of the projects in educational robotics like Dyne [8] or Bilota [5] projects, it is being realized with commercial kits of robots or software that it is very expensive. As it is well known, we live in hard times where universities are reducing the costs at maximum. By this reason, one of the main motivations was to create a modular robotic platform and accessible to any student who wants to learn about robotics.

But not only exist projects with commercial products. Also, there are projects which have taken the first step for doing more accessible robotics to students. Gonzalez and Valero [9] proposed a low-cost small modular robot which accomplish with some of the desired features by us. In this way, being this last project an Open Source project, we had tried to base in that work realizing modifications to other projects [10][11].

On the other hand, as several other projects like the Project Mindstorms [7], our work was initially carried out as an educational activity and not like a research activity. However, observing the high participation in the workshops we thought that robotics could be used for "recruiting" students [8]. ASROB have seen an increase in the number of members interested in the robotics field by more than a 50% of students. In this way the students can follow learning about robotics, computer science and new technologies while giving relevance to the work done.

Lastly, we have tried to promote this kind of activities to the students with no previous knowledge in the matter within the university. All activities carried out aim to encourage creativity and innovation among the students. By these reasons, the activities are planned with a competitive character which can motivate students for developing programs in the short time available.

Summarizing, the main motivations for teaching robotics in the university are mainly accessibility to the content, modularity of the robots, the use of Open Source technologies and low-cost.

3 The Educational Robotic Platform

Education is the process of transmitting a series of concepts or skills, based on different methods, with the support of a variety of materials. In our case, we propose a new robotic platform as supporting material which will allow us to develop our activities. The educational robotic platform is a mobile mini-robot based on a modification of the Protobot robot model [1] by A. Valero. The main features of this robot model are low cost and easiness of producing it. This is because the platform is totally based on Open Source technologies.

On the one hand, this platform has two versions. Both are based on the same Open Source principles, but the second version is an improvement of the first version. On the other hand, as in any manufacturing process of robotic architectures, the process of development is divided in three different parts. In our case and firstly, we have designed a mechanical model, which was developed with the OpenSCAD program. Secondly, we have selected an open hardware platform. In this case, Arduino UNO micro-controller is the platform used for the first version and Freaduino UNO micro-controller for the second version. Finally, the robot must be programmed. For this, Arduino IDE programming software has been used. Thereby, the philosophy of knowledge sharing and making available to other members of the robotic community is fostered. Figure 1 shows the fleet of mini-robot done.

3.1 Design

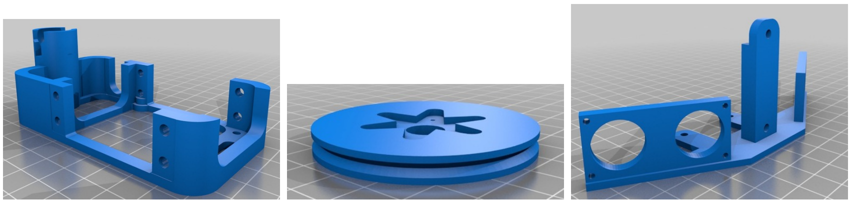
When a new robotic platform is designed, there are four aspects that must be considered in the manufacturing process. The four aspects are not equally important. First and most important, we must choose the intrinsic capabilities of our platform. The assigned qualities will impact on the other aspects of the design and manufacturing process. Second, we must consider the dimensions of the coupled devices (micro-controller, servo motors, batteries and ultrasound sensors). This is very important because it can happen that there are gaps or the pieces do not fit together properly. Third, we must decide what tools we will use to make prototypes or parts. The manufacturing process will impose certain limitations that we must consider in the designs. And finally we must choose what tools we will use to perform CAD designs (Computer Aided Design). The selected software will depend on the above three aspects.

In our case, we have decided that the design should be compact, small, easy to replicate, modular, economical, and of course printable. When we are designing the pieces, these qualities must be present at all times. Thus, we get that the robotic platform is robust.

Physically, our educational robotic platform is divided into three different parts. The chassis, the wheels and the support of sensors. The first two pieces have been created by other designers, so we encourage further Open Source principles. The chassis is the main piece of the mobile robot. This piece was designed by A. Valero and this frame takes care of loading with most devices (motors, batteries, micro-controller and the support of sensors). In addition it incorporates a

[1] `http://www.thingiverse.com/thing:18264`

third support based on an idler wheel. Figure 2a shows the CAD design of the chassis. The wheels are the mainstays of the robot and transform the torques generated by the motors in motion. The wheels are directly coupled to the engine without any gearbox. Figure 2b shows the CAD design of the wheel developed by Juan G. Finally, the support of sensors is designed by the authors of this publication and it is responsible for providing an attachment for the ultrasonic sensors. The orientation angle has been chosen is 30 degrees respect to the sagittal plane. Figure 2c shows the CAD design of the support of sensors.



(a) Chassis. (b) Wheel. (c) Support of sensors.

Fig. 2: Arduino Uno hardware platform with the integration board.

Moreover, the tool used to perform the CAD design has been an Open Source 3d modeling software. For this task, OpenSCAD is the software used. OpenSCAD is a free software application for creating solid 3D CAD objects, which is available for any OS (Operating System). In addition, we have developed a user manual. In this guide, we have explained the basic knowledge of this software. We have described the basic tools and added examples and exercises. In this way we have managed to have a self-taught manual. So anyone can learn to create simple pieces in little time. The Figure 3 shows the final design of the mobile robot with all the mounted devices. The global dimensions of our platform are 12cm x 12.5cm x 7cm (length, width and height).

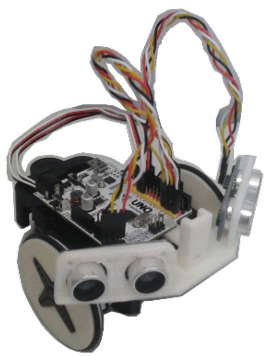


Fig. 3: Educational robotic platform.

Finally, the designed 3d models of the mobile mini-robot are printed with a 3d printer. So in this case, we have used a 3d printer as a tool to build the prototypes or pieces. Nowadays, 3d printers are becoming the most common tool to build prototypes. 3d printers are a recent technology with an exponential growth. The RepRap Project (replicating rapid prototyper) is an initiative that aims to create a self-replicating machine that can be used for rapid prototyping and manufacturing. A rapid prototyping machine is a 3d printer that is able to made three-dimensional objects based on a computer model. Due to the capacity to be self-replication and an open source machine, Josef Prusa revolutionized the mechanical design of this device when he dramatically simplified the construction of the RepRap Mendel. The result of his efforts, the Prusa has become a standard in RepRap building. Therefore, this Prusa model is an Open Source design. To build our fleet of mini-robot, we have used a 3D printer Prusa Air 2 model. This model is distinguished from the rest by his body of transparent acrylic, which makes it more elegant, robust and easy to calibrate. Table 1 shows the main characteristics of our 3d printer.

Table 1: Main features of the 3D printer Prusa Air 2 model.

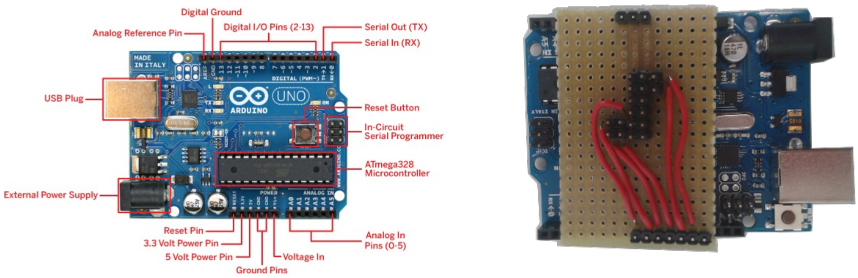
Features	
Total size	410mm x 405mm x 400mm
Print volume	3910cm3 (20x17x11,5)
Hotend type	J-Head MKV 3mm
Extruder	Jonaskuehling 3mm
Electronics	Sanguinololu 1.3b
Structure	Acrylic laser cut
Base hot	MK2

3.2 Hardware

3.2.1 Micro-controllers

As mentioned previously also the hardware architecture of our mobile robot is Open Source. In addition we have said that we have developed two versions. In any case, for both versions, we decided that a low cost and easy integration should be the main features of the micro-controller.

On the one hand the first version of the educational robot is based on the Arduino UNO. The Arduino Uno is an Open Source hardware platform. It consists of an Atmel 8-bit AVR micro-controller with complementary components to facilitate programming and incorporation into other circuits. An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as shields. Besides, The Arduino board exposes most of the micro-controller's I/O pins for use by other circuits. It provides 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs. For this first version, we have developed a small board of integration through a prototype board. Figure 4 shows the Arduino Uno micro-controller with the integration board coupled.



(a) Arduino UNO. (b) Developed integration board.

Fig. 4: Arduino Uno hardware platform with the integration board.

On the other hand, the second version is based on the Freaduino UNO (Figure 5). Also it is an Open Source hardware platform. Freaduino UNO is an improved and updated board based on Arduino UNO (ATmega328P), 100% compatible with all interfaces, shields and software designed for Arduino.

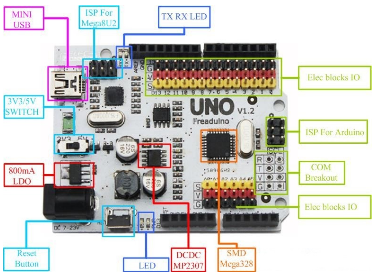


Fig. 5: Freaduino Uno hardware platform.

The reasons why we decided to change the micro-controller are three. The first is its new design. This allows attaching more easily any peripheral device. So we need not build any board integration and therefore, we have reduced costs. Another reason is the price of ONE Freaduino. This is cheaper than Arduino UNO. UNO Freaduino costs 17.73 €and other micro-controller costs 20 €+ VAT. The last reason is associated with the restart Arduino UNO micro-controller. When there are multiple peripheral devices connected to the board, the electronics is unable to supply power enough. Because of this, the supply current in the micro-controller decreases too much and consequently the micro-controller is reset. On the contrary, this does not happen with Freaduino, because developers took care of this problem. Apart from these reasons, Freaduino hardware has other features which are better than Arduino UNO. Table 2 shows these features.

Table 2: Comparison between the two hardware architectures used.

Feature	**Arduino UNO**	**Freaduino UNO**
USB socket	Type B Female USB connector	Mini USB connector
Operating Voltage	5V	3.3V or 5V selectable by swich
3,3V current	50mA	800mA
5V current	500mA	2A
Input voltage	7V-12V	7V-23V
Reset button location	Hard to press when plug in shield	Easy to press whenever
LED location	Invisible when plug in shield	Visible whenever
Micro controler	DIP Atmega168 or ATmega328	More reliable SMD ATmega328
BUS breakout	NO	YES (for SPI, COM, IIC)

3.2.2 Sensors and Actuators

The peripheral devices which we have chosen are two. The ultrasonic sensor and the servomotor. The first aims to perceive the environment, to receive information. The second is responsible for acting on the environment, generating a response action. We have chosen these devices because they have a low cost, are easy to use and integrate, have low power consumption and both need the same supply voltage (5 volts). Figure 6 shows the peripheral devices used.

(a) SM-S4303R servomotor.

(b) HC-SR04 ultrasonic sensor.

Fig. 6: Peripheral devices.

The sensor device is the HC-SR04 ultrasonic sensor. The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats or dolphins do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. Its function range is from 2cm to 400cm. It operation is not affected by sunlight or black material. The main feature for us is the measuring angle. The value of this is 30 degrees. For that reason, the orientation angle of the support of sensors is 30 degrees respect to the sagittal plane. Because the function angle is 60 degrees and it is maximized. In addition, at no time the ultrasonic sensors stop perceiving what is in front of them.

The actuator device is the SM-S4303R servomotor. The SM-S4303R is a standard-sized servo that has been built by SpringRC specifically for continuous rotation. At 6 V, it has a maximum rotation speed of 54 RPM (no-load) and can produce up to 5.1 kg-cm of torque. The servo can be controlled using a direct connection to a single micro-controller I/O line without any additional electronics, which makes it a great actuator for student robotic projects. Table 3 shows some characteristics of the devices.

Table 3: Main features of the peripheral devices.

Feature	**HC-SR04 ultrasonic sensor**	**SM-S4303R servomotor**
Power	5 V	5V
Current	15 mA	100 mA
Size current	45 x 20 x 15 mm	41.3 x 20.7 x 40.2 mm
Weight	8.5 g	41 g

3.3 Software

To program Arduino/Freaduino UNO micro-controllers, both use the software IDE with the same name Arduino programming IDE (we use version 1.0 or higher), which is Open Source and multiplatform.

Arduino programming is based on an extension of the C programming language. Furthermore, it is possible to use external libraries for receiving information from the most common sensors or controlling the actuators. Many of them are free on the Internet.

The program structure for Arduino is very simple and any inexperienced student can develop a simple program quickly. A common program in Arduino has at least three parts. First part is the library inclusion, in this case we only work with the **Servo** library. Second part is the *setup*, when serial is configured and pins are assigned. Third part is the *loop*, when the main program is being executed forever. This last part is the most crucial and difficult part to understand for the students because is different than other programming languages. Having a continuous loop executing makes students open their minds to program with another methodology.

To program the activities we proposed, students need the common library Servo, that it is included by default in Arduino, and the library for the ultrasonic sensors. To get last one, it is necessary to access to the Internet and download a zip file with the code[2]. That code has to be located in the "libraries" folder inside the skechbook of Arduino.

3.4 Cost

Table 4 shows the total unit cost of a single robot. In this, the prices of each component are disaggregated. As we can see, the electronics and actuators are more expensive devices. In contrast, the pieces printed with the 3d printer are the cheapest. This is due to the modularity of our platform. So this allows the student to modify the mobile robot to its shortcut, without changing the expensive devices. Also we can say that we have developed an educational robotic platform that has a lower price to 50 euros and has endless possibilities.

[2] `http://www.elecfreaks.com/store/download/product/Sensor/HC-SR04/HCSR04Ultrasonic_demo.zip`

Table 4: Breakdown of the costs of the mobile robot.

Quantity	Description	Unitary Price	Subtotal
1	Freaduino UNO	17,730 €	17,73 €
2	Servomotors SM-S4303R	13,190 €	26,38 €
2	Ultrasonic sensor HC-SR04	2,590 €	5,18 €
1	Printed Chasis	0,100 €	0,10 €
2	Printed Wheels	0,020 €	0,04 €
1	Printed Sensor plugin	0,020 €	0,02 €
2	O-ring	0,035 €	0,07 €
1	Marble	0,020 €	0,02 €
Total			49,54 €

4 Evaluation and Results

The evaluation and results which we have obtained from the experiences in the activities done are completely explained next. Briefly, we have done three experiments with success on participation and results. For each experiment, we show many statistics about gender, age, etc. which we think it is important and useful information to gather for future experiences.

Before to show each one of the experiments, there is to keep in mind that two of the experiments are focusing in one way, to educational robotics focusing on teaching the use of new technologies as 3d printers, Open Source technologies, and agile programming of mini-robots. And, on the other hand, last experiment is focusing on teaching Open Source techniques to realize modular designs for the mini-robots.

4.1 First experiment

Fig. 7: People from TechF3st workshop.

This experiment was the first of all. To this experiment we built a fleet of 10 complete mini-robots. It had a duration of one session of one hour and a half. The experiment was done with a group of 20 students. The initial idea was to have two students per robot because programming and test were not too much difficult.

As it is showed in Figure 7, the activity took place within the TechF3st[3] workshop at the University Carlos III of Madrid, Spain. And, the main goal consisted in programming parking movements in a semi-close space.

Next, we show the statistics we got for this experiment. Figure 8 shows the ratio between men and women in the experiment.

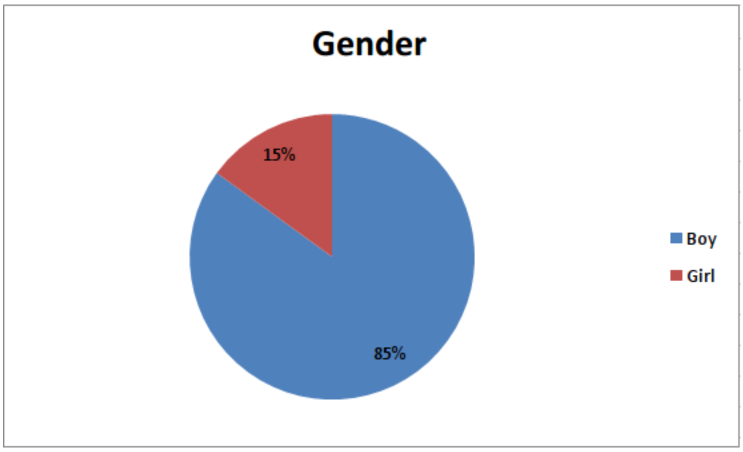


Fig. 8: Diagram of gender ratio in experiment 1.

About gender, we checked that there are more men than women. For that reason, we tried to promote to women next experiments.

In Figure 9, we show the ratio about the ages. We divided the students in three groups, ages between 10 and 17 - pre-university students, ages between 18 and 25 - university students, and ages between 25 and 50 - master and non-university students.

This group was mainly adults between 18 and 25 years old, which is our mainly audience. Also, we had a 10% of people in the third group who were pre-university teachers.

Lastly, Figure 10 shows the results from the experiment. Results are divided in three groups, students who complete the task; students who almost complete the task, this group did the program but its robot cannot complete the task completely; and students who do not complete the task.

All the students in this experiment succeeded in programming the task with the robots. These results show how the task to implement was not too hard to teach in a session because everyone complete the task. Also, this results were a motivation for us to keep trying to teach robotics to university students.

[3] Official website: `https://techfest.uc3m.es/2013/`

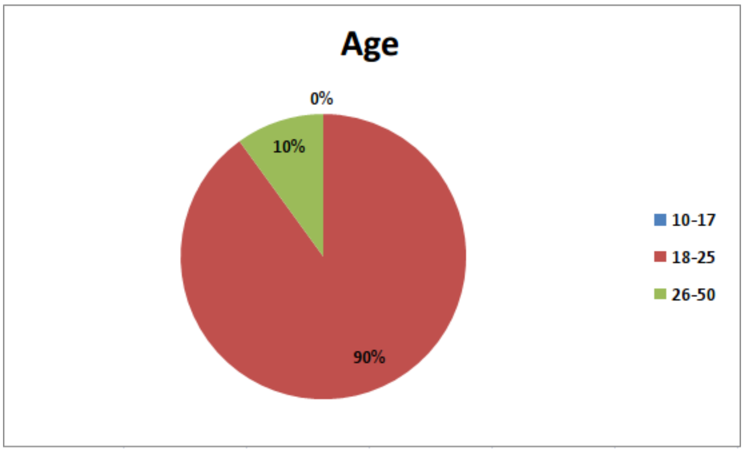


Fig. 9: Diagram of age ratio in experiment 1.

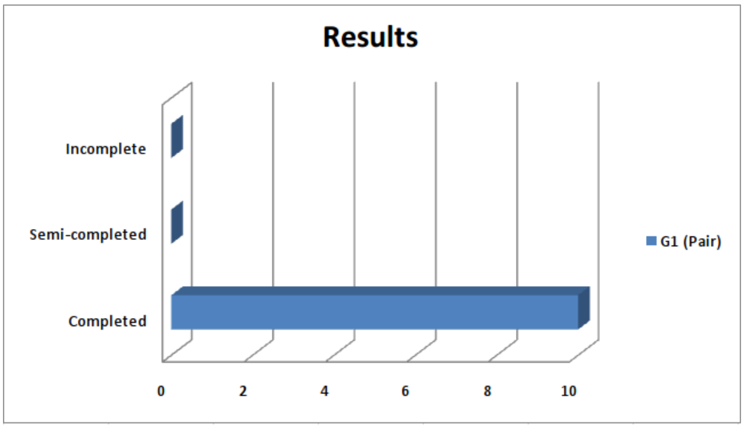


Fig. 10: Diagram with results of experiment 1.

4.2 Second experiment

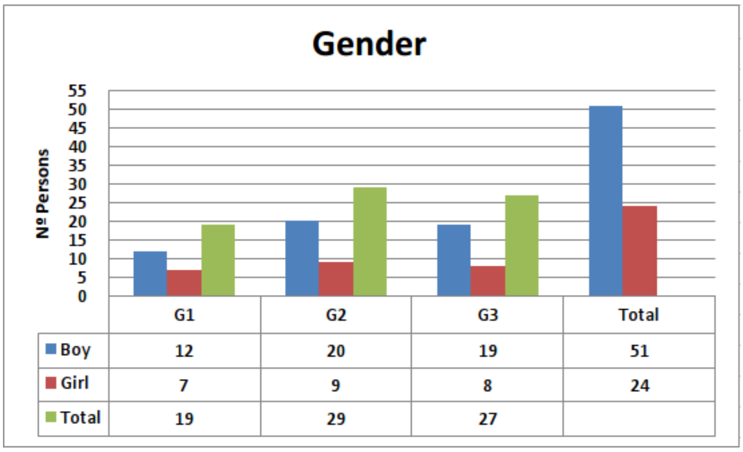
Second experiment tried to be a replica of the first one, checking if good results are repeated or it was an isolated result. We used the same fleet of robots as before experiment. It had a duration of only one session of one hour and a half per workshop. We did three workshops this time. In this experiment there were groups of around 30 students (2 or 3 students per robot).

The activity took place within the Robocity13[4] workshop at the University Carlos III of Madrid, Spain. Figure 11 shows the huge participation in these workshops. The goal of this experiment was the same of the first experiment.

[4] Official website: `http://roboticslab.uc3m.es/robocity13/`

Fig. 11: People from Robocity13 workshop.

Next, the statistics we get for the second experiment are showed. Figure 12 shows the number of men and women and the total amount of students by workshop.



	G1	G2	G3	Total
Boy	12	20	19	51
Girl	7	9	8	24
Total	19	29	27	

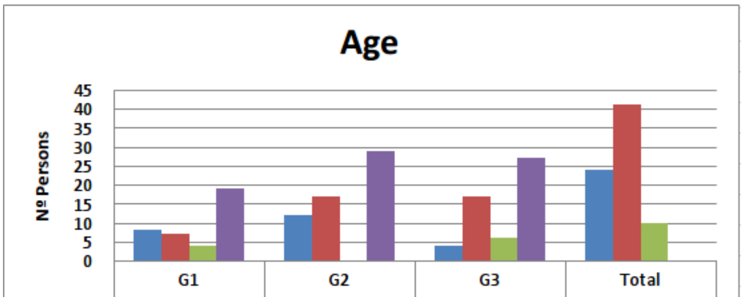
Fig. 12: Diagram and table of gender statistics in experiment 2.

From these partial results we can conclude that the number of men still follows being higher than women. Having approximate ratios of 60% of men and 40% of women in the first workshop, and 70% of men and 30% of women in the second and the third workshop. Then also, can be observed from the graph that assistance was to much higher than the first experiment, having groups of till 30 students instead of 20. Finally, we can conclude that even though still lower, the number of girls was plenty increased in comparison with last experiment.

The graph of Figure 13 shows the information about ages. Being the groups divide at same from before experiment.

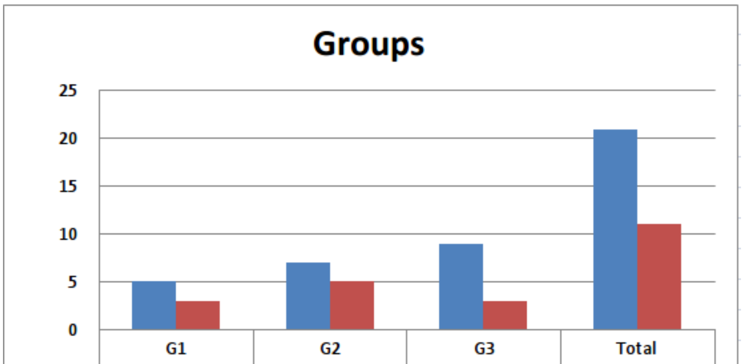
The slot with biggest number of participation was the second (university students) again. However, the workshops had a high participation of pre-university students due to workshops were open doors to all kind of public this time.

In this experiment, we have added a new graph, Figure 14, that show the ratio of students in groups, that is, if the task was realized in pairs or in groups of three students.



	G1	G2	G3	Total
10-17	8	12	4	24
18-25	7	17	17	41
26-50	4	0	6	10
Total	19	29	27	

Fig. 13: Diagram and table of age statistics in experiment 2.



	G1	G2	G3	Total
Pair	5	7	9	21
Trio	3	5	3	11

Fig. 14: Diagram and table of groups statistics in experiment 2.

This graph is useful as previous step to analyze the results. Results, Figure 15, show the number of groups (pairs or trios) who have completed or not the final task.

In this case, almost every group achieves to finish the task of programming the parking movement. As same as the first experiment results were positives, but this time having in mind that the number of participants had been incremented a lot.

4.3 Third experiment

Trying to change the goal and also the destination of the workshops we decided the third experiment would be different from the previous. The main goal of this experiment was to design a new and original prototype of a modular mobile mini-robot. The new design had to be based on our original model, taking present the

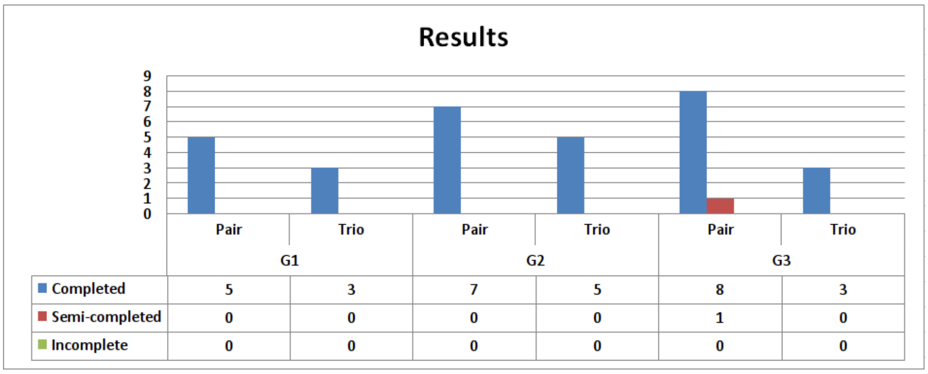


Fig. 15: Diagram and table of results statistics in experiment 2.

sensors and actuators used originally. Another goal we pursue was to teach how to use a 3d printer (Prusa Air 2) to print the models designed and to check if the prototypes work appropriately. This experiment was done with a group of 10 students and had a duration of 6 sessions of about 2 hours.

The activity took place as a seminar within the Master in Robotics and Automation program at the University Carlos III of Madrid[5], Spain.

To pass the seminar, every student had to publish their work under a free license (Creative Commons Attribution-NonCommertial-ShareAlike[6]) on the web page Thingiverse [14]. In this way, students learned how to publish the work accessible for all the community and with a correct license.

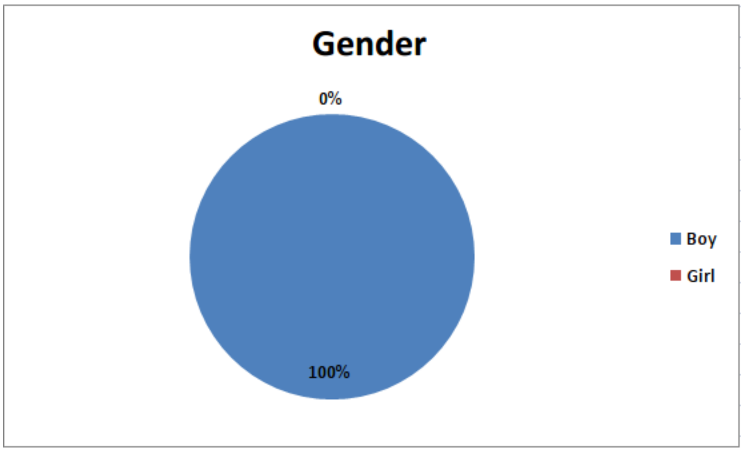


Fig. 16: Diagram of gender percentages in experiment 3.

[5] Official website: `http://portal.uc3m.es/portal/page/portal/postgrado_mast_doct/masters/robotica_automatizacion`

[6] More details in: `http://creativecommons.org/licenses/by-nc-sa/3.0/`

Although the results were evaluated in a different way, we tried to give the same relevance to age and gender as in the other experiments. The graphs in Figures 16 and 17 show the ratios between men and women, and the slots of ages evaluated respectively. As can be observed, in this experiment we had the disadvantage of having no women in the group.

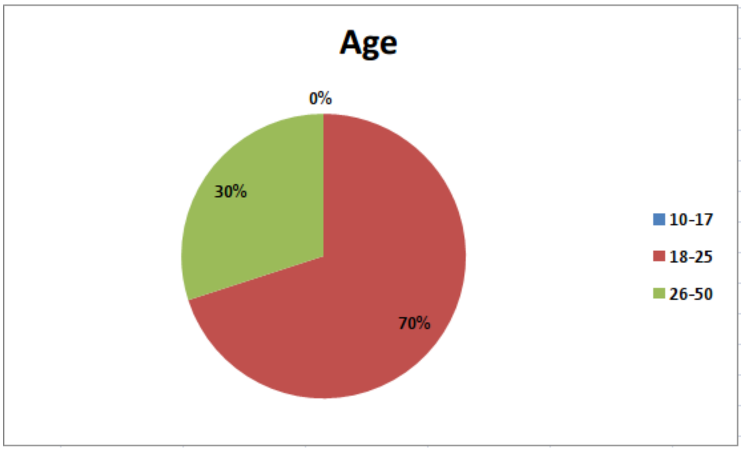


Fig. 17: Diagram of age percentages in experiment 3.

Nevertheless, we follow with the main goal of these experiments. To intent all efforts for teaching university students with no previous knowledge in the matter. By this reason, students in the second slot of ages still follow predominating.

Lastly, the final results of this experiment have been evaluated in a different manner of the rest because the complexity of the designs. In this case, the evaluation considers the efficiency, the creativity, and the functionality of the designs. And, on the other hand, if the student have done documentation and have published correctly the design on the Internet.

Conclusions obtained from this experiment were the following. Every student document and publish their design satisfactory. Students learned, in this way, the philosophy of the Open Access/Source. At least, 3 of the 10 designs reach to be totally functional, the rest of them had some difficulties easily rectified to become it. The creativity of the designs was very innovative in general, standing out 4 designs from the rest. And last but not least, the feature more harmed was the efficiency of designs, having in mind the sensors and actuators they start having. The reason of that happened was because the most of the modular accessories were attached to the main structures with no having in mind the connectors and wires.

Some of the final designs done by the students are showed in Figure 19. Observing very good results in general for all of them.

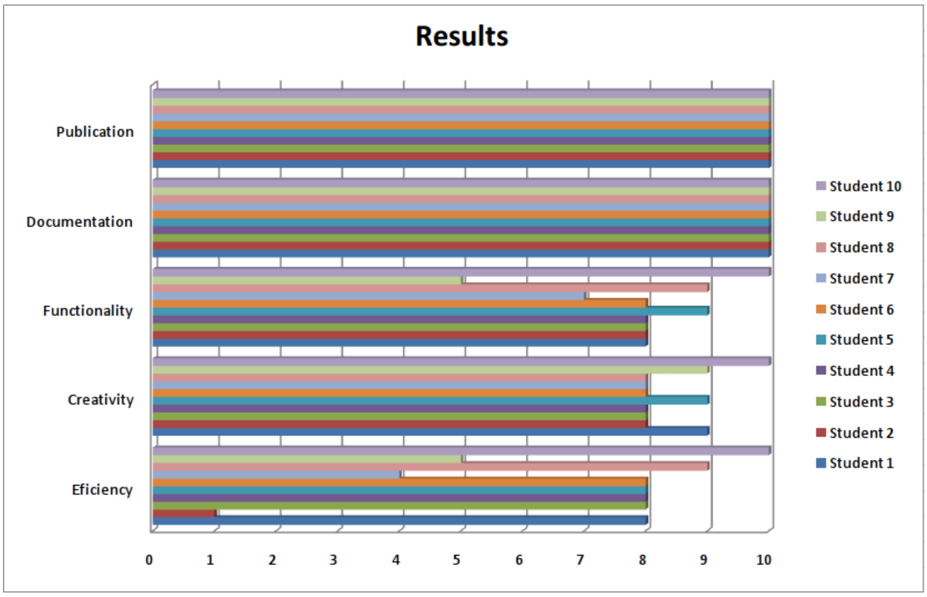


Fig. 18: Diagram with results of experiment 3.

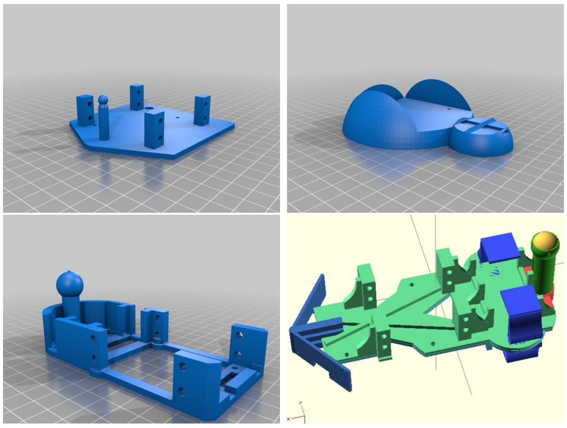


Fig. 19: Main structure from four different designs.

5 Conclusions and Future Work

In this paper we have kept present for all experiments our main goals. To encourage the use of Open Source technologies and to teach robotics promoting the creativity for the students with no previous knowledge in the matter.

We have also collaborated in the extension and construction of an educational robotic platform which is low-cost and open to replicate it. Furthermore, it is developed to be totally modular. And it can offer the possibility to show to the students the essential capacities about sensors and actuators, basic movements with a robot, and easy programming of a micro-controller. We have reached very good results having little time for each experiment and that show us educational robotics it is not the future, it is the present.

In other way, we have achieved, with a low-cost, to offer for university students the opportunity to learn about basic knowledge on robotics, 3d modeling techniques and the Open Source philosophy. Also, having a great adaptation and reaching very good results with the master students - students more specialized in the matter.

Lastly, not being our main goal at first, we have presented a pedagogy model to teach robotics, and unified statistics to control and demonstrate that the teaching is valid. This model is neither fixed nor closed, but it will do that we learn about the necessities of the students in next experiments.

For a near future, we have in mind to follow our experiments in two possible ways. The first one will focus on improving our educational robotic platform, adding new sensors or actuators or even new modular accessories. And, the second one will focus on teaching new students in other basic technology-related matters like software versioning (SVN, Git), 3d printers (build, materials), etc. among others.

On the other hand, we do not want to leave any student, inexperienced or with some experience, without the opportunity of learning robotics. For that reason, we are proposing new workshops with a higher level of difficulty, taking advantage of all capabilities of our educational robotic platform. Using the sensors of the robots we have the possibility to teach signal processing, control techniques, mapping and localization, etc.

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References

1. D. Alimisis, "Educational robotics: Open questions and new challenges", Themes in Science and Technology Education, Vol. 6, Issue 1, pp. 63-71, 2013.
2. D. Alimisis, "Integrating robotics in science and technology teacher training curriculum", Proceedings of 3rd International Workshop Teaching Robotics, Teaching with Robotics Integrating Robotics in School Curriculum, pp. 170-179, 2012.
3. Arduino, last visit: 2014-03, url: `http://www.arduino.cc/`.
4. Association of Robotics and IEEE Student Branch of the UC3M, last visit: 2014-03, url: `http://asrob.uc3m.es`.
5. E. Bilotta, L. Gabriele, R. Servidio, and A. Tavernise, "Edutainment robotics as learning tool", Transactions on Edutainment III, pp. 25-35, 2009.
6. A. Bredenfeld, A. Hofmann, and G. Steinbauer, "Robotics in education initiatives in europe-status, shortcomings and open questions", Proceedings of SIMPAR 2010 Workshops Intl. Conf. on Simulation, Modeling and Programming for Autonomous Robots, pp. 568-574, 2010.
7. A. Chiou, "Teaching technology using educational robotics", Proceedings of The Australian Conference on Science and Mathematics Education, pp. 9-14, 2012.
8. M. Dyne and J. Fjermestad, "Robotics in education: a tool for recruiting, engaging, retaining and educating students", Proceedings of the 12th WSEAS International Conference on Robotics, Control and Manufacturing Technology (ROCOM12), pp. 196-201, 2012.

9. J. Gonzalez-Gomez, A. Valero-Gomez et al., "A new open source 3d-printable mobile robotic platform for education", Advances in Autonomous Mini Robots, pp. 49-62, 2012.
10. R. Pérula-Martínez, J. M. García-Haro and A. Al-Kaff, "Modelado e implementación de un robot de entretenimiento para competición", 11 workshop Robocity 2030. Robots Sociales, pp. 39-57, 2013.
11. R. Pérula-Martínez, A. Al-Kaff, and J. M. García-Haro, "Diseño de un robot móvil como mascota robótica de entretenimiento para personas con dependencias", in 11 workshop Robocity 2030. Robots Sociales, pp. 21-37, 2013.
12. R. Pérula-Martínez and J. M. García-Haro, "OpenSCAD User Guide", Educatech, last visit: 2014-03, url: http://educatech.sytes.net/wiki/OpenSCAD, 2013.
13. M. Saleiro, B. Carmo, J. Rodrigues, and J. du Buf, "A low-cost classroom-oriented educational robotics system", Social Robotics, pp. 74-83, 2013.
14. Thingiverse, last visit: 2014-03, url: http://www.thingiverse.com/.
15. A. Valero-Gómez, J. González-Gómez, V. González-Pacheco, and M. A. Salichs, "Printable Creativity in Plastic Valley UC3M", in IEEE Educon 2012, pp. 1-9, 2012.