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Starting Robotics in secondary school: Assembling i-SIS an autonomous vehicle

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Abstract—The project aims to develop, balance and enhance the theoretical knowledge, skills and attitudes of students focusing on Science, Technology, Engineering and Mathematics (STEM) disciplines applied at secondary school level. The work, carried out by K-12 students, is differentiated into two blocks, coding and robotics. In the first block, programming in Scratch becomes one of the main goals, in which the students make code intuitively but supervised by the teacher, enhancing and developing the computational thinking and the digital competence. The programming tools used are Code, Scratch, Arduino and Scratch4Arduino. In the second block, an autonomous vehicle named i-SIS is assembled. Here, they will implement their knowledge to make it work. In teams, the students will apply their knowledge of mechatronics. Controlling emotions, interpersonal motivation and collaborative work will be essential for success. Moreover, the student’s autonomy self-esteem and entrepreneurship are boosted.

Keywords—digital competence; starting robotics; autonomous vehicle; mechatronics; computational thinking

I. INTRODUCTION

Mobile robots and robotics are an educational tool that provides a complete solution to promote technology for secondary school students. The purpose of this project is designing, building, programming and testing robots during the first years of secondary school. The global task combines physics, mathematics, technology and computing. During the sessions, students are actively engaged with all these disciplines. Another key factor of this project is that it introduces students to technology, giving them a different point of view for learning robotics, in an attractive and fun way. It was inspired by the programming pioneers and other robotics projects made before, and it aims to avoid commercial brands using open source hardware and software. However, what makes the i-SIS project successful and motivating is its low-cost nature [1].

Over the last decade, in our country there has been no economic investment in technology in the state schools, to the point that for economic reasons, it may disappear. The cost of i-SIS is very accessible to schools due to its modest budget. This allows our project to expand to many of these institutions easily. Moreover, i-SIS provides a great introduction to do-it-yourself robotics in secondary school, it provides open hardware in technology classes, a reusability of the materials, and it gives a framework for high school students to conduct experiments that will give them experience in addressing global engineering challenges.

I-SIS was inspired by professor Michael Resnick [2]’s quote:

I believe that the best way to help people understand the world is to provide them with opportunities to actively explore, experiment and express themselves.

This project has emerged from the intense debates of regional Artificial Intelligence and Educational Robotics (IARO) conferences held in the Institut Font del Ferro [3] which have been adapted every year since its origins in 2013. The aim of these events are to spread the technological and computational thinking [4, 5] into the local educational community of the Institut Font del Ferro of Palafolls, Barcelona.

II. METHODOLOGY

The purpose of both secondary education and digital competence is to educate people with knowledge of the world. With the project, students will acquire the tools to understand it, to inhabit it and improve it. We will apply a methodology that seeks mainstreaming, which is understood as the criterion for the selection of content and focus on interdisciplinary learning areas. An example would be the close link with communicative competence through the connection with the subject in English as a foreign language, where students are introduced to new technical vocabulary. Our methodology is based on functionality, and prioritizing strategies oriented towards the application of learning in different contexts and real situations. It also aims to encourage the students’ autonomy, to promote learning strategies based on self-regulation, to make students more independent, and to take responsibility in the evaluation period.
Therefore, this methodology is not based on storing and reproducing information, but on teaching how to search, select, organize and interpret it using reason and knowledge. In this way students can make their own interpretations, to communicate these one to another, in different situations and contexts of the project.

In summary, the project model uses the computational thinking and the digital competence detailed below, and it is training-based problem solving. This is the philosophy that facilitates technology education through the practice of the process.

A. The computational thinking and the digital competence in secondary school.

The computational thinking (CT) can be achieved in many different ways. Therefore, we need to view the model of CT as a way of defining the problems of the real world by digital representation. In this way it is interesting that we can classify the thinking into two types, according to the interests of the CT. On one hand, we mention algorithmic thinking that structures a sequence of actions according to a result that leads us to solve the problem. On the other hand, the heuristic thinking is made by informal or intuitive rules that point to "mental shortcuts." This thinking is used when it is not possible to use algorithms, either because they are not available or because the application is impossible in practical terms. All this will provide students with a clear understanding of computers and their daily applications.

The digital competence applied in our project is described in 4 dimensions which allow the students to develop the abilities mentioned below:

- Instruments and applications: includes the necessary skills to understand concepts related to information and communication technologies (ICT). Also, it includes the ability to solve technical problems and use the more extended applications, such as word processor, spreadsheet editor presentations, among others.
- Information: includes skills related to searching, selecting, evaluating and organizing digital information. The student must be able to transform and adapt to a new product or develop a new idea.
- Communication and collaboration: groups the skills that are related to transmitting, exchanging ideas and working with others using the technology.
- Digital coexistence: includes skills which help students to evaluate ethics, learn how to use ICT responsibly understand the risks and opportunities of the Internet and be able to decide the limits of sharing information.

B. Applying the curriculum in secondary school: linking robotics with technology

Initiating the students in robotics in secondary school is a task that requires a correct and coherent application of all the concepts, definitions and procedures from the technology area. The teachers implied in the project were then encouraged to adapt this to of the national educational technology standards [6]:

- The basic operations and concepts where students demonstrate a sound understanding of the nature and operation of technology systems, and a proficiency in the use of technology.
- Technology productivity tools: students use technology tools to enhance learning, increase productivity, and promote creativity.
- Technology research tools: students use technology to locate, evaluate, and collect information from a variety of sources.
- Technology problem-solving and decision-making: students use technology resources for solving problems and making informed decisions. They also employ technology in the development of strategies for solving problems in the real world.

C. Students level and timing in i-SIS project

The students are between 12 and 16 years old. In order to increase project effectiveness, the group was distributed initially into two small groups: D1 and D2. In the final phase of the project, four teams were created. The work sessions are taught once a week.

D. Materials

All the materials used for carrying out the activities listed below:

- Workbenches for assembly, disassembly and handling of the vehicle.
- Projectors for presentations.
- Shelves and cabinets to store written procedures and instructions.
- Boxes to store portable machines and delicate tools.
- Panels for common tools.
- Panels for placing technical information.
- i-SIS material (See Table I and Fig.8).

### TABLE I. i-SIS MATERIAL

<table>
<thead>
<tr>
<th>Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATTERIES CONNECTOR</td>
<td>1</td>
</tr>
<tr>
<td>SCREWS M3</td>
<td>8</td>
</tr>
<tr>
<td>MOTOR DC</td>
<td>2</td>
</tr>
<tr>
<td>WHEEL</td>
<td>2</td>
</tr>
<tr>
<td>BATTERIES HOLDER</td>
<td>1</td>
</tr>
<tr>
<td>UNIVERSAL WHEEL</td>
<td>1</td>
</tr>
<tr>
<td>WIRES DUPONT</td>
<td>10</td>
</tr>
<tr>
<td>MOTOR CONTROLLER L293D</td>
<td>1</td>
</tr>
<tr>
<td>PROTO BOARD</td>
<td>1</td>
</tr>
<tr>
<td>INFRARED SENSOR</td>
<td>2</td>
</tr>
<tr>
<td>ARDUINO BOARD</td>
<td>1</td>
</tr>
<tr>
<td>CHASSIS</td>
<td>1</td>
</tr>
</tbody>
</table>


E. Structure of the project

According to the work plan, the project is structured in two main blocks: robot programming and i-SIS assembling. Table II, shows the stages, the timing and the student grouping in every session described here below. Also, the last column of the table shows two abbreviations: Ti means student individual work and Gt means student teamwork.

CODE [7]: Individually, students learn to program intuitively while playing at the same time, upgrading their abilities step by step and creating the movement of the objects. Also, they improve in blocks design and the equivalent written code in Java Script (See Fig.1).

<table>
<thead>
<tr>
<th>Working plan</th>
<th>Blocks</th>
<th>Sessions</th>
<th>Description</th>
<th>Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Robot</td>
<td>4 h</td>
<td>CODE</td>
<td>Ti</td>
<td></td>
</tr>
<tr>
<td>I programming</td>
<td>6 h</td>
<td>SCRATCH</td>
<td>Ti</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 h</td>
<td>SCRATCH 4 ARDUINO</td>
<td>Ti</td>
<td></td>
</tr>
<tr>
<td>II i-SIS</td>
<td>2 h</td>
<td>FRITZING</td>
<td>Gt</td>
<td></td>
</tr>
<tr>
<td>II assembling</td>
<td>4 h</td>
<td>UNBOXING ASSEMBLING</td>
<td>Gt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 h</td>
<td>ENVIRONMENT</td>
<td>Gt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 h</td>
<td>TESTING</td>
<td>Gt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 h</td>
<td>COMPETITION</td>
<td>Gt</td>
<td></td>
</tr>
</tbody>
</table>

SCRATCH [8] [12]: Individually, students make simple games by means of a didactical guide and then they create their own games (See Fig. 2).

SCRATCH 4 ARDUINO (S4A) [9]: In teams, students use the code once the robot is assembled. Initially, the primary code is given to every group and they will modify it according to their own building in order to improve the robot’s effectiveness.

FRITZING [10]: In teams, students will design the electronic circuit. They will draw with the PC the Arduino connections in which are included the sensors and the servos. This activity will take place under the careful supervision of the teacher. (See Fig. 3)

UNBOXING AND ASSEMBLING: students will build their own robot, observing and comparing with a sample vehicle and interpreting the Fritzing design (See Fig. 4).

ENVIRONMENT: students will design the path to testing i-SIS and prepare the future competition (See Fig. 5).
TESTING: Once the robot is assembled with the Arduino board, students will introduce the code Scratch4Arduino so they can test i-SIS and adjust the parameters if necessary. Fig. 6 shows the materials distribution over the selected chassis between two types available in the kit.

COMPETITION: Students will compete between the different teams of the class.

Fig. 7 shows the whole project duration as well as the distribution of the students according to the session requirements.

III. INITIATING ROBOTICS WITH I-SIS

A. i-SIS simple mechanical concepts

Robots use a variety of mechanisms. The mechanisms of i-SIS need to be analyzed in detail by the students so they can adjust some physical parameters in the assembling process. Then, they have to deal with common definitions such as force, mass, weight, acceleration, speed and distance.

B. Practicing some geometry

While students tested the robot and before the creation of the environment, they took measurements of the robot: the rotation angle introduced in the code of the wheels, the length of the planned path and the wheel diameter. Then, while they adjusted the parameters, they applied basic maths calculations.
like perimeter and area of the robot wheel, expressed in equations (1) and (2) respectively.

\[
\text{Perimeter} = 2 \pi \text{ ratio} \\
\text{Area} = \pi \text{ ratio}^2
\]  

(1)  
(2)

C. Measuring and playing

Students also made measurements about speed, distance and time reached by i-SIS. The results where recorded by each team on sheets and they compared the final results, as well as the speed average of each assembled robot.

D. Extra work for advanced students

In general, all the students reached the goal of assembling and programming the robots. However, some students needed to go further and to program basic Arduino commands in the Arduino board, with the aim to give independence to i-SIS, which has the connection cable from the personal computer to the robot.

IV. Evaluation Process

The evaluation process started at the time the teacher guided the activity, put forward a challenge and the objectives. The first reactions from students are adequate indicators of the success or failure of the project. Further, the trial and error testing is an important factor in student motivation because they can observe in real time if what they are doing is giving the expected results. If they don’t get the expected results, they can modify and prevent future changes in both the assembling and the code. Evaluation also requires the observation of the teacher, as well as the presentation of the student results in a clear and transparent way for the corresponding level.

Thus, the quantitative evaluation is applied individually or in groups. The score is given in percentages and the maximum reached is the 100%:

- 10% i-SIS assembling
- 5% ability to correctly distribute the pieces over the chassis.
- 5% capacity to debate, expose and make decisions.
- 5% correct calculations and testing.
- 5% correct i-SIS code.
- 5% correct design with Fritzing.
- 5% Participation in the design and building of the environment.
- 15% correct use of Scratch code.
- 10% Scratch guided exercises.
- 20% Scratch videogame creation.
- 5% correct material identification in the workbook.
- 10% good attitude.

Fig. 9 shows the summary results for student’s evaluation and Fig. 10 shows a collection of i-SIS of each team. Finally, the involvement in the assigned tasks, the collaboration, and teamwork and the suggestions for improvement and/or expansion of activities is evaluated.

V. Valoration and conclusion

The experience acquired with this project was very positive and gave us some learning tools adapted from the secondary school curriculum and arising from the STEM disciplines integration. We consider that the project is very helpful, very easy to apply and quite adaptable, depending of the diversity in the classroom and the previous student knowledge. In conclusion, students learned in an active way, according to their level, technological knowledge and algorithmic thinking.

VI. Future work in i-SIS

Robotics has been advancing over the years and has been implemented into the life of the human being. It will not take long for it to become a necessity rather than a tool, and lately its presence has become essential for the optimal development of businesses and industries. The future work of this project is to integrate it into the educational initiative of the local Department of Education entitled "Mobilize Coding" [13], which is a festival held in the context of the mSchools (Mobilize schools) program, and sponsored by the International Association of mobile companies and the Barcelona Mobile World Capital Foundation. In that sense, we will implement the curriculum in which students will design and develop an application for mobile devices that
communicate via Bluetooth with our autonomous vehicle i-SIS, combining robotics and mobile applications.

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