Project-based learning using robots with open-source hardware and software

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***Abstract*—One of the main issues of the current education system is the lack of student motivation. This aspect together with the permanent change that the Information and Communications Technologies involve represents a major challenge for the teacher: to continuously update contents and to keep awake the student's interest. A tremendously useful tool in classrooms consists on the integration of projects with participative and collaborative dynamics, where the teacher acts mainly as a guidance to the student activity instead of being a mere knowledge and evaluation transmitter. As a specific example of project based learning, the EDUROVs project consists on building an economic underwater robot using low cost materials, but allowing the integration and programming of many accessories and sensors with minimum budget using open-source hardware and software.**

***Index Terms*—project-based learning, open-source, robotics**

I. Introduction

THE education system as we know it, organized by subjects, was developed 120 years ago. Although it has undergone some modifications, it has not essentially changed. It is based on knowledge blocks, often not taught together in an integrated and transversal way. These blocks of information and knowledge are organizational mechanisms, non-educational. Considering a high technological world, as the current one, the aforementioned blocks do not correspond to the real educational needs or to the training needs of a growing employment market [1, 2].

There are many experts stating that this education system, exclusively based on subjects, without interconnected content blocks divided into compartmentalized information, represents an obsolete and incomplete tool for the student learning, especially in cases in which the student receives the knowledge passively [3, 4]. Students learn much more building and understanding the concepts with their own experience, based on previous knowledge or on information acquired for this purpose [5].

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A. Project-based learning

An appropriate complement to the current education system is the project-based learning [6, 7]. This is based on the dynamic view of the experience concept, proposed by John Dewey, which presented that the experience is an exchange between the human being and his physical and social environment, not only related to knowledge [8]. Nowadays knowledge is available in free and open format in the Internet. Therefore, learning based solely on the transfer of information from teacher to student is obsolete, and learning organized by skills should be encouraged.

This idea does not exclude the teaching by subjects as knowledge base, but it complements it with educational experiences [9]. Project-based learning is an opportunity to promote active student learning in a transversal and multidisciplinary way, improving the integration of this knowledge with the use and development applied to them [10]. Students are much more involved in their own learning and they collaborate together exploiting the individual capabilities of each student. This involves a positive learning factor in terms of plurality and diversity and an enhancement of the group as a whole.

To work organized by projects strengthens the learning of educational competences [11] and allows a convenient way to integrate values such as cooperation, teamwork or organization that are not easy to teach in a theoretical way. This does not eliminate the traditional system of teaching / learning, but tries to find the right combination of the traditional teacher with the collaborative work done in the classroom considering a practical view to develop a specific project. Furthermore, it is intended to solve on the major issues of the current education system: the student's lack of motivation.

Student's creativity, motivation and active attitude are some of the main shortcomings of the current education system. For students, to initiate and complete a project is something novel and allows the interdisciplinary integration of knowledge in a collaborative, active, fun and motivating way for students, enabling young people to learn to face challenges together. This disruptive learning model, using the experiences against the formal curriculum, is in line with the availability and access to information today, where learning is ubiquitous and informal, with the Internet as the main source of documentation. Disruptive learning strengthens soft skills, replacing command and control with cooperation and respect with an inclusive student-focus teaching [12].

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Fig. 1. Makespace Madrid. *Internet of Things Day*, 2013

B. *Educational robotics*

Many actions are being organized following a project-based learning strategy, especially in the fields of technology and robotics, as these are quite attractive for young people [13-15].

The development of robots as an educational tool has been developed with the hardware-software ideology of open-source hardware-software, internationally supported by the rise of the *Maker Movement* and the *Do It Yourself* (DIY) [16]. With this philosophy and often in response to highly technological activities for productive or recreational purposes, many *MakeSpaces* are opening internationally. These are spaces and workshops open to the public to develop and generate prototypes using the ideology of open-source hardware-software, with possibilities to create in several fields such as medical applications, engineering, design or home automation, among others [17, 18]. These centers of technological development are having a major boom in the job market, as they can be a turning point in the development of prototypes, especially with the launch of 3D printers (also based on this philosophy). Fig. 1 shows the center Makespace Madrid, during the organization of the *Internet of Things Day*, in 2013 [19].

Students must be ready for the new market model and the skills which will be required over the next 10 years, among which are adaptive thinking and the ability to meet new challenges, multicultural and multidisciplinary skills, computational thinking and virtual cooperation [20]. All these skills are aligned with the implementation of projects such as collaborative learning, particularly with the implementation of Educational Robotics in the classroom. However, this training based on experiences and projects cannot rely on high cost commercial packages or expandability, and creativity limited solutions.

II. METHODOLOGY

In the development of projects in the classroom based on the *Maker Movement*, of open-source hardware and software, direct actions and proposals from teachers cannot be expected. Therefore, specific low-cost proposals, which could be implemented on a general level, easy to use, friendly and accessible for teachers, are required. Accordingly, educational projects consisting on directly "usable" products in the centers (and likely to stay in them) should be encouraged, not dependent on external funding.

A. *EDUROVs project*

The EDUROVs project consists on the creation and installation of an underwater robot with educational purposes, built from simple off-the-shelf materials, not dependent on any specific trademark. The construction is done taking wood as basic material, cable for the console control and PVC pipes for underwater robot chassis. It also requires specific material including two push buttons and a joystick for the console, as well as small motors and propellers, which allow the motion of ROVs (Remotely Operated Vehicles). For these specific pieces, different options on the market can be used without requiring any particular trademark.

The project covers three levels, ranging from compulsory secondary education to early university courses. At the university level new sensors based on Arduino or an equivalent technology are integrated in the vehicle, so students can learn skills in electronics, communications and programming in a practical, tangible and motivating way. A picture of students working in the classroom in an ROV integration is shown in Fig.2.

An instruction manual is provided to facilitate the first steps of a basic model, which can serve as a reference for the development of new ideas [21, 22].

The cost per ROV including all the required materials is less than 100 € including a basic sensor system and the Arduino board, as well as the power supply. All the items are reusable and attachable to different robots, thus it is easily affordable by the budgets of many schools.

Fig. 2. Students working in the classroom in a ROV integration

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III. RESULTS

Project-based learning using robots with Arduino technology (or a similar technology) allow working specific issues within the Information and Communication Technologies area, since the possibilities based on open source hardware and software are diverse. Topics to consider could be wireless communication systems, innovative sensors and accessories programming or 3D printing designs. A success case has been demonstrated within the EDUROVs project, in which an ROV (Remotely Operated Vehicle) is created by students at different levels. This approach allows considering a multidisciplinary perspective, or a specific standpoint in a specific subject.

The project-based learning approach has been integrated into educational projects in one or more subjects with an increased interest of students in over 92% of the considered cases, according to surveys completed by more than 200 students and 40 teachers.

Most of the surveyed teachers consider that an experimental educational project as EDUROVs increases student motivation in the subject. Accordingly, students acquire the required skills in a much more enjoyable way, based on project learning and experience with the practical application of the theoretical contents previously taught.

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BIOGRAPHIES

Daura Vega Moreno is PhD Assistant professor and PhD in Marine Science by the University of Las Palmas de Gran Canaria (ULPGC). She is a member of the Research Group “Environment technologies, management and biogeochemistry” at the ULPGC. She was responsible in the Dissemination & Training unit at the Oceanic Platform of the Canary Islands (PLOCAN) until early 2015 and co-responsible of the Underwater Robotics project (EDUROVs) since 2013. She is specialized in scientific dissemination in the marine environment.

Eduardo Quevedo (M’13) obtained the Telecommunication Engineer degree in 2007, the Electronics Engineering degree in 2009 and the PhD in 2015, all by the University of Las Palmas de Gran Canaria (ULPGC) and all with honors. In 2008, the Telecommunication Engineers Spanish Association awarded him the best Master Thesis prize in Interactive Services over the Internet Protocol. He has written more than 35 publications in national and international journals and conferences and has participated in 5 research projects funded by the European Commission, the Spanish Government and international private industries. He is currently working at the private company Anova IT Consulting leading a project to dynamize an ICT Marine & Maritime Demonstration Center at the Oceanic Platform of the

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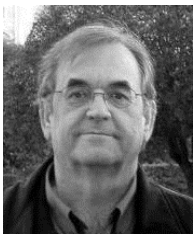

Octavio Llinás holds a Ph. D. in Chemistry (1975) by the University of La Laguna, and he is an Associated lecture at the Faculty of Marine Sciences of the University of Las Palmas de Gran Canaria since 1994. He has been a marine science researcher, supervisor for several thesis, national and international oceanographic cruises and responsible for over 30 national and international projects in the field of Marine research. He lead a research group founded in 1985 and nowadays it is constituted by ICCM (Instituto Canario de Ciencias Marinas, Canary Marine Sciences Institute) from the Oceanography department and teachers from several departments of the University of Las Palmas de G.C. with the continuous collaboration of associate researchers from other countries (Germany and USA). He has held several management positions of relevance managing research institutions such as the University of Las Palmas de Gran Canaria (President of the University during the period 1989-1993), director of the Spanish Oceanographic Institution (2003- 2004) and the ICCM (Canary Marine Sciences Institute), from 1991- 2002 and 2004-2008. Since 2009, he is the Director of the ICTS (Unique Scientific and Technological Infrastructure), PLOCAN (Oceanic Platform of the Canary Islands) where he is in charge of developing infrastructures, services and projects.

Joaquín Hernández-Brito holds a Ph. D. in Chemistry (1986) by the University of La Laguna and has been a marine science researcher, supervisor for several thesis, and responsible for over twenty national and international projects. He has held several R & D management positions at the University of Las Palmas de Gran Canaria, such as Dean of the Faculty of Marine Science, Director of the Research Results Transfer Office (TTO), Director of the Scientific and Technological Park, and Research Vice-Rector. He has also held the position of Director of the Canary Institute of Marine Science. Since 2009, Dr. Hernández-Brito is the Manager of the ICTS (Science and Technological Singular Infrastructure) PLOCAN (Oceanic Platform of the Canary Islands) where he is in charge of developing infrastructures, services and projects. He is responsible for meeting objectives for PLOCAN's operational, environmental, financial and commercial performance under the supervision of the Director. Moreover, he is coordinator of European projects within PLOCAN such as LEANWIND or OCEANERA-NET, associated with sustainable energies new developments and innovations. He also coordinates the project FIXO3, which is on the multidisciplinary observatory side of science. His main motivation is to bring out new knowledge, skills, marine and maritime resources, linking administration, training and business.

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