# Work-in-Progress: Engineering and Project-Based Learning as the focus of technology education in Colombian high schools

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*Abstract*—In the recent years technology education has gained importance worldwide. Colombian government has included it in the basic and secondary schools curriculum, but the current teaching-learning strategies and the resources used for technology class have proven to be insufficient. This paper presents a case study for implementing Project-Based learning in a Colombian high school, using Open source Hardware and Software. First, a set of technological competencies are defined for technology class, based on the suggestions of the Ministry of National Education. Then, a project for designing an irrigation system for the school orchard is presented, which will engage students to develop the selected technological competencies. Subsequently, a set of didactic tools for the project are presented, including an electronic platform for the control of the water flux in the irrigation system. The project will be implemented during the following months, and through diagnostic and summative assessment it is expected to measure the improvement of the technological competencies in students.

*Keywords—automation; electronics platform;high school; irrigation system; project-based learning; technology education*

## I. INTRODUCTION

Technology education has become an important part of the curriculum in schools worldwide. Many countries have incorporated technology education in basic and secondary education to help students to become technologically literate. In the curricula of these countries, the study of the effects of technology on society is emphasized, as well as the importance of developing abilities in the students related to plan, produce and evaluate technological artifacts, processes and systems [1]. As a result of this emphasis, it is possible to notice the strong relationship between technology education and engineering. Furthermore, using Engineering for addressing technology education provides a solid basis for curriculum designing and an easy way for integrating mathematics, science and technology [2].

The use of inductive teaching and learning methods for science and engineering education has increased. Project-Based Learning (PBL) is one of the most well known inductive methods in engineering education, and has been used universally [3]. In PBL, the learning activities are based on a real problem that derives on the creation of an end product which is the center of the curriculum [4]. Due to the relationship between engineering and technology education, inductive teaching methods have been used in high schools [5] and pre-colleges [6] in order to engage students to develop technologic competences.

In Colombia, technology education for primary and secondary school became mandatory since 1994, and in 2008 a set of competences suggestions for technology class for basic and secondary school was published by the Ministry of National Education (MNE) under the title "Be competent in technology: a need for development" [7]. According to the MNE suggestions, technology education can be addressed by four categories or components: "nature and evolution of technology", "appropriation and use of technology", "problem solving using technology" and "technology and society". Each teacher considers which one and how many of these components are useful for the class.

The authors of this paper have conducted a study in technology class in ten schools from different cities in Colombia. The study reveals that the didactic resources used in technology class are severely limited. Most of the schools have computers, but most of them do not have Internet connection. Additionally, it was found that technology class frequently deals with the use of office automation software. Furthermore, inductive teaching methods such as PBL are not used by the teachers. As a consequence, the current teaching-learning strategies promote technology just as the use of computers.

The approach of this Work-in-progress paper is to establish a relationship between technology education and engineering design topics by using inductive teaching-learning methods, mainly PBL. In such a way, the students will be able to internalize a wide definition of technology and will be able to put in practice the class topics with real life problems, with the main objective of contributing to improve the current situation of the Colombian students. The selected core of the project to be implemented is Control and Automation.

This work-in-progress paper presents a case study of a 10th grade technology class project, which aims to develop engineering competences through PBL. Four phases are needed

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for designing and implementing the project. First, the technological competencies proposed by the MNE are adapted to the local context. Subsequently, the project and the activities for the class sessions are defined according to the selected competencies. Then, a set of didactic tools for active learning are designed. Finally, the project is implemented an evaluated in the classroom. At the moment, the first three phases are completed, and the last one is being planned and executed.

## II. TECHNOLOGICAL COMPETENCIES ADJUSTMENT

MNE proposal structure consists of 4 four components, each of them with a technologic competence. A set of competencies are defined, in order to assess the performance level of each competence in the students. From this proposal, the components "Problem solving using technology" and "Appropriation and use of technology" were selected from the MNE competencies proposal, since the competencies associated to these components can be easily developed through PBL and are more related to engineering skills. Nevertheless, given the importance of the remaining two components, some of their associated competencies were added to the selected components, in order to be used horizontally.

After a revision process, eight competencies were selected for the first component, while seven competencies were selected for the second. These fifteen competencies were divided in five groups as shown in Table I, according to a set of skills: "Safety and Operation", "Technology's impact", "Communication", "Teamwork" and "Critical thinking". According to Williams [8], "Safety and Operation" and "Technology's impact" are competencies related to craft skills, while "Communication", "Teamwork" and "Critical thinking" are related to key competencies.

As part of the technological competencies adjustment, it is necessary to determine the interests of the community and prioritize the competencies according to it. The community preferences were determined using interviews and surveys. The results show that the community gives special preference to the groups "Teamwork" and "Critical thinking".

## III. SCHOOL ORCHARD IRRIGATION SYSTEM DESIGN AS A 10TH GRADE PROJECT

According to the community preferences, the selected project to be developed in technology class is an irrigation system for the school orchard. The project topics have been selected because they can be easily addressed by an engineering design process. Therefore, the project develops and enhances specific skills such as tools appropriation, as well as transversal skills such as oral and written expression, teamwork and critical thinking.

As shown in Table II, the project is split in five stages: Problem identification, solution design and planning, solution implementation, solution assessment and improvement, and results presentation. During these stages, the students are engaged to develop a different set of competencies.

Throughout the problem identification stage the students get an introduction about irrigation systems. Global affairs around irrigation are presented in order to show the importance of irrigation systems in agriculture, economy and society.

Later, students must define the limitations, constraints and

TABLE I.    COMPETENCIES REGROUPING FOR 10TH AND 11TH GRADE.

| Group Name | Competencies |
|---|---|
| Technology impact | Comparing processes, artifacts or technological systems, taking into account their effect to the environment and the community. |
|  | Identifying and formulating problems in my environment which can be solved using technology. |
|  | Evaluating design aspects such as safety, environmental, cultural and socio-economic impact when solving problems using technology. |
| Safety and Operation | Identifying and explaining the relationship between concepts and knowledge from other disciplines involved in the operation of some artifacts. |
|  | Using personal protective equipment in work and production environments, taking into account industrial safety rules. |
|  | Employing tools and equipment for the construction of models and prototypes, applying safety rules. |
|  | Performing maintenance to common technological artifacts |
| Communication | Using common informatics tools for searching, processing information and ideas communication. |
|  | Interpreting and using manuals, instructions, diagrams or schemes for assembling some technological artifacts, devices and systems. |
|  | Interpreting and representing ideas about designs, innovations or experiment protocols through the use of texts, diagrams, figures, blueprints, models or prototypes, using ICTs whenever is possible. |
| Teamwork | Using teamwork as a strategy for developing technological projects. |
|  | Proposing, analyzing and comparing different solutions for a problem within a team, explaining their origins, advantages and disadvantages |
| Critical thinking | Comparing design conditions, specifications and restrictions defined in a technological solution, and argue the selection of the most relevant. |
|  | Evaluating uncertainty conditions during the search of solutions for technological problems |
|  | Proposing improvements for technological solutions, arguing the selection criteria and the selected restrictions |

TABLE II.    PROJECT STAGES AND ENGAGED COMPETENCIES.

| 10th grade project for technology class | |
|---|---|
| *Stages of the project* | *Engaged competencies group* |
| Problem identification | Technology impact Communication Critical thinking |
| Solution design and planning | Safety and operation Communication |
| Solution implementation | Safety and operation Communication Critical thinking |
| Solution assessment and improvement | |
| Results presentation | Communication Critical thinking |

specifications of an appropriate irrigation system for the school orchard, such as the size of the orchard, the type of plants, the

weather and the resources. Next, they search for different solutions for similar problems around the world, and then they define which solution is the best for their context. Performing those activities, students are engaged to develop competencies related to Technology impact, Communication and Critical thinking.

During the solution design and planning stage the students give a detailed description of the selected solution. Thus, they must use software tools for designing diagrams, models and blueprints. After the detailed description, students plan a budget and then define a schedule for implementing and evaluating the proposed solution. At the end of this stage, students present models and blueprints of the final solution, and a detailed schedule for its implementation and evaluation. Through those activities, students are engaged to develop competencies related to Safety and operation and Communication.

In the solution implementation, assessment and improvement stages the students build and test their solutions, according to the defined schedule. For the mechanic part, students are given freedom in the materials used to construct the irrigation pipes and connect them to the water source. For the electric part, students implement a power and control system for irrigation. When both parts are assembled, students perform tests to determine the functionality of the irrigation system according to the limitations, constraints and specifications. Performing those activities, students are engaged to develop competencies related to Safety and operation, Communication and Critical thinking.

During the results presentation stage students show the conclusions of their projects. They must present results such as the possible problems or uses of the solution, budgets, blueprints and the documentation required to replicate their solutions. These results are presented to the community (teachers, students and parents). Through those activities, students are engaged to develop competencies related to Communication and Critical thinking.

Students are divided into teams during all the stages of the project, so they have different roles: design leader, technical leader, concept leader, resources leader and communications leader. In such a way, the students are engaged to reach a common task through collaborative learning and competencies related to teamwork are developed during the whole project.

IV.  SOFTWARE AND HARDWARE DIDACTIC TOOLS

The third phase for the design and implementation of the project in the classroom consists on proposing some software and hardware tools in order to perform some of the activities during the project. These tools will also allow assessing the performance level of the competencies in different moments of the project.

For the sessions which concepts and processes are taught, a set of virtual learning objects (VLOs) are being designed. These VLOs will support the instruction of some knowledge needed for the project, such as specific Software (e.g. modeling, planning and information processing applications). They will be used in the problem identification stage, as well as

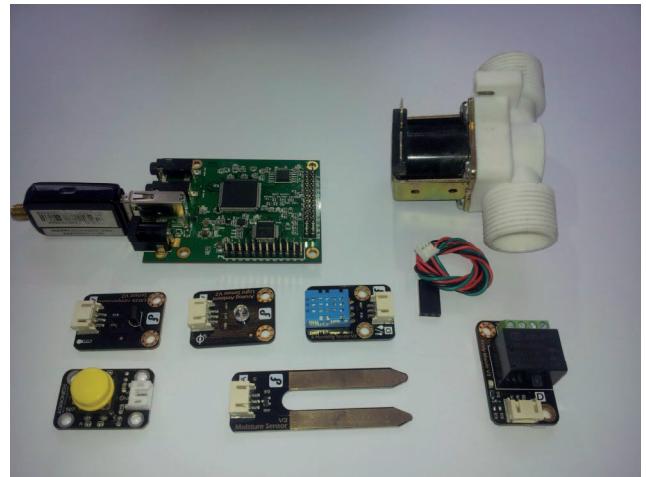in the solution design and planning and results presentation stages.



Fig. 1.  Stamp Mini Board, sensors and actuators. a) Stamp Mini Board. b) Temperature sensor. c) Ambient light sensor. d) Temperature and humidity sensor. e) Push botton. f) Moisture sensor. g) Solenoid valve. h) Relay module.

For the practical sessions, an electronic board called "Stamp Mini" has being designed, so the students can implement their control designs for the irrigation system. This microcontroller-based board has a set of sensors[1] (e.g. temperature, light, humidity, moisture and buttons) as well as a set of actuators (e.g. relay[1], motors, solenoid valve and LEDs), most of them from DFRobot, as shown in Fig. 1. It can be programmed using its own Blockly based graphic interface (Fig. 2). The entire hardware-software architecture was designed for reducing the computational load on the board, and for using the programming interface on any platform regardless of the operative system. Furthermore, the board is licensed under Creative Commons Attribution-ShareAlike (CC-by-SA) and the repository is available for any user.
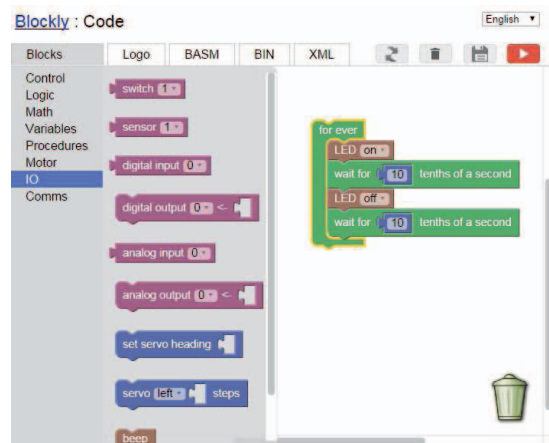


Fig. 2.  Blockly® based programming interface. Example for LED blinking.

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[1] www.dfrobot.com

The Stamp Mini board will be used during the design and planning sessions, as well as in the implementation stage. It is expected that students develop skills related to Safety and operation and to Critical thinking.

## V. FUTURE WORK

The school orchard irrigation system will be implemented during the following months in a Colombian high school. Two groups of students must be defined: a test group and a control group. Then, a diagnostic assessment will be performed in order to evaluate student's performance in each competency. Subsequently, the school orchard irrigation system design project will be implemented in the test group, while traditional teaching methods will be used with the control group. Hence, the impact level of the proposal can be measured as the difference between the improvement in the test group and the improvement in the control group.

## ACKNOWLEDGMENT

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