Integrating Modular Strategies into an Embedded System Design Laboratory: An Outcome-Based Educational Approach

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Abstract

Teaching embedded systems design and enhancing student skills in this area is an important task in computer engineering programs to provide an up to date education. This work focuses on the development of a teaching methodology based on a modular design, aided by an Outcome-Based educational framework. To achieve this objective, the content, pedagogical, and assessments activities for an embedded system design laboratory were aligned to ensure proper student learning. The pedagogical methods were designed based on modular strategies through progressive lab experiences. The proposed methodology is currently in the process of validation through a performance comparison between students who took the course in previous semesters (control) and those currently taking it (experimental). At the moment, the data for the control group have been collected and analyzed while the data for the experimental group is being collected.

Keywords

Modular design, outcome-based education, embedded system education.

Introduction

The average American interacts with as many as one hundred embedded systems per day[1]. This number continues to grow as integration technologies continue to develop. This growth denotes the relevance of embedded systems in our daily lives and highlights the importance to provide a solid and up to date education in this area to future computer engineers (CE).

Due to the relevance of embedded systems (ES) in CE education, courses in this area are considered core knowledge in most computer engineering programs. Different methodologies have been developed and implemented to teach the fundamental ES concepts and at the same time enhance student's practical skills in this area. Some of these methodologies use problems[2-4], projects[5-7], video games[8,9] or virtual labs[10,11], among others, to attract and motivate students in their learning. Furthermore, well-designed courses need to cover not only aspect related to embedded systems architecture and interfacing but also on the design process. This paper proposes a strategy based on modular design technologies and an Outcome-Based educational (OBE) approach to teach embedded systems design concepts in an applied laboratory.

The rest of this paper is organized as follows. The OBE framework implementation is briefly explained and the modular design approach is introduced in the next section. Subsequently, the results collected for the control and experimental groups are discussed. Finally, a summary of the continuing work is presented in the last section.

Laboratory Structure Redesign

An OBE framework proposed by Streveler et. al.[12] was implemented in the Embedded System Design laboratory at the University of Puerto Rico, Mayagüez campus to provide for a structured student learning process. This framework attempts to align content, pedagogical, and assessment methods in order to obtain a well-structured laboratory experience.

The proposed laboratory content was revised based on a desired student profile for a computer engineering graduate. This profile took into consideration the current Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering[13], an analysis of social and industrial expectations, and the current departmental focus for the computer engineering academic program. At the end of this review process, the proposed content was summarized in a series of learning objectives that students need to meet at the end of the class.

Once the content was designed, the pedagogical methods were implemented using a modular design approach in which students worked with a progressive series of lab experiments and a set of functional circuits modules (educational modules). The progression of experiments was structured to use, in each new unit, the abilities learned in previous experiments. A total of eight experiments were designed where each unit was organized in four dedicated sections: objectives, lecture, basic exercises, and a complementary task.

A total of six different modules were developed to fulfill the technical objectives of each experiment (See Figure 1). These modules were constructed based on the topics and circuits stablished for the eight experiments, where each module could be used in one or more experiments. Each module provides students with an example of how electronics modules are structured including functional diagrams, schematics, board design, and software usage guidelines, allowing for their combined use with a target controller to develop target applications.

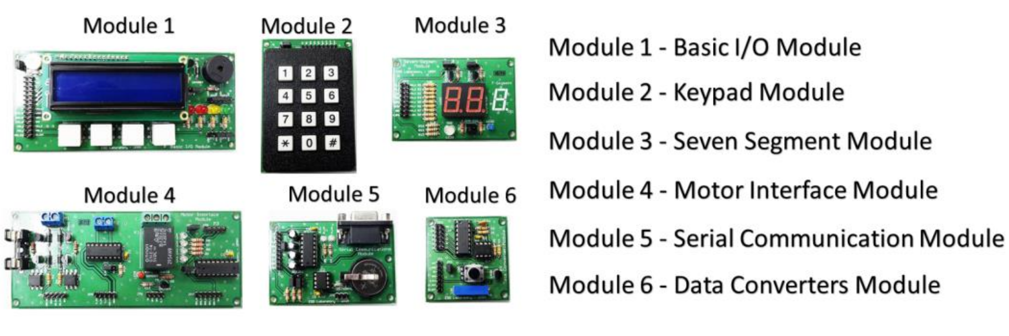

Figure 1: Educational modules developed

The OBE included assessment methods to validate the methodology and to assess how well each student met the learning objectives defined in the content phase. The assessment methods included a series of pre- and post-tests given to students in each experiment to quantify the prior and gained knowledge. Each test was subjected to a validation process to determine its item difficulty, discrimination, and reliability index. Also, learning gain factors were computed for each test and student, in order to conduct a performance comparison between both student groups. The first of the groups corresponds to students who took the class with the previous methodology (control group) and the second group is formed by students who are taking the class with the proposed methodology (experimental group).

Preliminary Tendencies

Currently, the data collection process for the control group was completed. These data correspond to six different experiments where a total of sixteen students were evaluated. Figure 2 shows the current grades for the pre- and post-tests in a normalized scale while Figure 3 shows the learning gain factors for the tests.

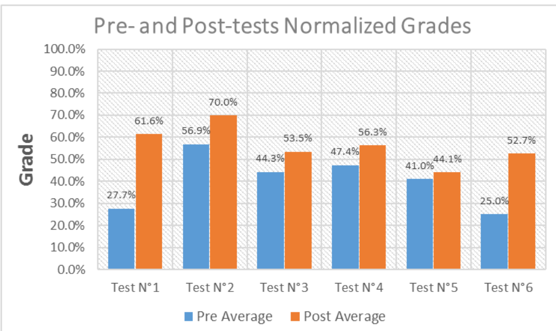

Figure 2: Control group tests grades

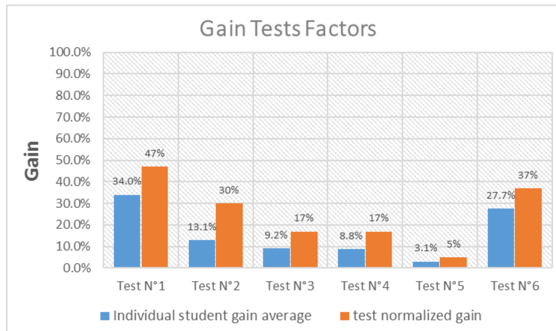

Figure 3: Control group tests gain factors

From Figure 2, we can observe that the pre-test grades were lower than those in the post-tests, meaning that students improved their knowledge after experiencing the laboratory practice. Although they had an increase in knowledge, the post-test average (56.3%) was under the threshold defined by the Computer Engineering department to define if a student passes a course (70.0%). Figure 3 shows the learning gain trend for the tests. From this Figure, we notice that tests (N°1, N°2, and N°6) can be considered effective by getting learning gain factors above 30%[14].

Summary and Ongoing Work

A new teaching methodology based on modular design and OBE framework for an embedded system design laboratory was presented. The OBE framework implementation was conducted making emphasis on how: (1) the content was established, (2) the methodology was selected, and (3) the assessment methods were designed. Also, the implementation of modular design concepts through the use of progressive experiments and modules design was explained. Currently, the results for the control group have been obtained and analyzed, showing that there is an opportunity for improvement in the laboratory pedagogy and the way in which students learn concepts about embedded systems. For this reason, once the results for the experimental group are obtained, we expect to see an increment in the post-tests grades and an increment in the student learning gain factors. This shall provide the evidence to support the proposed methodology. Our expectation is that if our hypothesis were confirmed, the proposed methodology could be implemented in other courses.

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