A Framework to Guide Undergraduate Engineering Students in a Design-Based Learning Module

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Abstract

Design-based learning is drawn from concepts relating to problem-based and project-based learning. Design-based learning is used in this paper to refer to the design and construction of an electronic hardware project by undergraduate engineering students. Students often experience difficulty with design principles regardless of the methods used to teach them. Many factors contribute to this struggle, including the selection of an appropriate project, the choice of and availability of components, the design platform used and financial constraints. The following research question therefore arises "What framework may be used to help guide undergraduate engineering students to successfully complete a design-based learning module"? The purpose of this paper is to present a framework that engineering students may consult regarding selecting an appropriate project and components for their electronic project that will lead to higher academic success. Data obtained from completed student projects in 2015 form the basis for this framework that focuses on the number and type of components used together with the final grade awarded to the project. A quantitative research methodology is used as the relationship between the number and type of components used in the electronic projects are quantified and correlated to the final grade awarded to the project. A total of 42 student projects were analyzed, and a correlation was drawn between 54 different criteria and their final grade. Results indicate that students who spent more money on their projects were more likely to achieve a higher final grade. Furthermore, students who used an alternating power supply and a more powerful microcontroller were also more likely to achieve higher academic success. The developed framework has the potential of guiding future undergraduate engineering students in selecting more appropriate components for their electronic projects that will enhance its performance and lead to higher academic success.

1. Introduction

"Give people enough guidance to make the decisions you want them to make. Don't tell them what to do, but encourage them to do what is best" [1]. These words, by an American coach Jimmy Johnson, certainly relates to teaching design principles to undergraduate engineering students in design based modules (DBL). These students need to be guided and encouraged to do their best by reflecting on the quality of their work. The value of reflective practice is widely accepted in education [2] and is a mechanism to turn experience into learning [3]. However, encouraging

students to reflect on their work by considering the work of others prior to them has the potential to further enhance their work and academic success [4]. This reflection may be encouraged by providing specific theoretical frameworks to students. A theoretical framework is a structure that supports the theory of a research project [5], and may be used by individuals to reflect on what has been accomplished within a specified field. It also contains the seed for research problems that is related to a particular field that may be used to guide, develop and shape specific research [6]. In the same way that a theoretical framework guides a researcher in the identification and understanding of a problem, it is envisaged that the proposed framework of this study will guide undergraduate students in the design and development of their electronic projects.

The purpose of this paper is to present a framework that engineering students may consult regarding the selection of an electronic project and appropriate components in a DBL module. Principles relating to learning are discussed and the context of the study is presented. The design of the framework is then explained, followed by the results, discussions and conclusions.

2. Principles Relating to Learning

A. Framework

Researchers are aware of the importance of theoretical frameworks in teaching, learning and research [7]. Clarkson pointed out that "models and frameworks are helpful for clarifying theories and abstract concepts or constructs. However, to be useful in practice, a model or framework must apply to the conditions that it is attempting to describe, analyse or predict" [8]. Theoretical frameworks form the basis for many research projects and are, among others, used to develop questionnaires [9] and design protocols [10]. They may also be used to explain principles [11], such as design principles used in DBL modules as described in this paper.

B. Reflective learning

Reflective learning is a process for reflecting on experiences that enable learning [12]. It is not only limited to student learning, but is also a well-used technique by academics and teachers [13]. Reflective learning is very important in academic studies [14] and is a method that encourages students to reflect or meditate on all available sources of knowledge. It's main aim is furthering understanding of complex situations, developing personal abilities and enhancing experience [15]. Reflective learning has been fostered in the current digital world where a wealth of data on almost every topic exists. In the context of this paper, students will be requested to reflect on a theoretical framework based on the analysis of previous student projects. This has the potential to enhance their experience and understanding of complex principles within DBL modules.

C. Design-based learning

DBL is an effective approach to learning that is centred on problem-solving in combination with project based learning [16]. In the context of this paper, DBL is used in two modules which involve the conceptual aspect of learning (this requires knowledge seeking and idea formation) and the material aspect of learning (this requires the creation of prototypes and products) [17]. DBL is a trend in Engineering and Architecture that increases the objectivity of the learning process, while stimulating team and interdisciplinary work [18]. The advantages of DBL include providing a relevant opportunity for student learning, increasing student motivation and engagement [16], developing higher- order cognitive skills [19], promoting active learning [20], stimulating collaboration and cooperative learning and also fostering

personal and interpersonal traits and creativity [21, 22].

3. Context of The Study

The Department of Electrical, Electronic and Computer Engineering at CUT offers courses in electronic engineering, power engineering, and computer systems engineering. These courses deal with the study and application of electricity, electronics, electrostatics and electromagnetism which covers a range of sub-studies including power electronics, control systems, signal processing and telecommunications [23].

Engineering students may complete Higher Certificates, National Diplomas or B.Tech degrees in electrical engineering, depending on their previous qualification. The National Diploma requires engineering students to complete a total of 360 credits (3600 national hours), which equates to around 20 modules, each with a credit value of 12. In addition, there is a compulsory Work Integrated Learning module that has a credit value of 120. The National Diploma programs include both theoretical and practical instruction where students can demonstrate vital graduate attributes [24], including problem-solving using DBL. Two of the modules in the National Diploma involve DBL, called Projects II and Design Project III, where engineering students need to design and develop a working electronic project [25].

The learning outcomes for the practical part include compiling a project proposal, writing progress reports, doing a project presentation, drafting the final report and presenting the final completed electronic project. Pedagogical methods used include personal one-on-one sessions, class presentations, videos and a learning management system (LMS called Blackboard) where the progress reports are submitted. Constructive alignment exists between the learning outcomes and assessment methods, while the course content is drawn from journal articles, conference papers, e-books and the Internet.

A. *Projects II and Design Project III assessment*

Continuous assessment is used in both modules which are usually completed within a 14 week period. The project proposal is the first submission that contributes towards the final grade of the students. This proposal, that outlines the proposed project, must be approved by the lecturer before the student can continue with the project.

There are also two opportunities for students to hand in a progress report on the LMS. The progress report consists of a section where the student submits a PDF file as proof of the progress of his/her project. This proof includes photographs that indicate the progress made, which is usually obtained by using student cell phones. Screenshots of their schematics, their PCB designs and any other relevant information about the progress of their project is included. A theory test is also written as there is a small theory section in the syllabus of Projects II.

The oral presentation is a critical evaluation which requires students to present their projects to the rest of the class. Students are expected to explain the design by using a block diagram for the chosen hardware and a flow chart for the software. Finally, students submit a completed project and report for evaluation.

4. Method of Framework Design

The designed framework is derived from quantitative data obtained from analysing the electronic projects and results for students registered for Projects II and Design Project III during 2015 (n=42). The projects were analysed in terms of 53 components or variables that were used and are correlated to the final grade that was awarded. This correlation value is obtained by correlating each component (represented by a 1 or 0, depending on whether the student used it or not) to the final grades awarded to the students.

Due to the fact that the final grade is continues and the project related variable is a dichotomous variable, a point-biserial correlation was used. A point-biserial correlation is used to measure the strength and direction of the association that exists between one continuous variable and one dichotomous variable [26]. It is a special case of the Pearson's product-moment correlation, which is applied when you have two continuous variables, whereas in this case one of the variables is measured on a dichotomous scale [27]. The correlation was done between the different variables and the final grade awarded to the student at the end of the semester. The results are presented in the following section.

5. Results

Fig. 1 highlights the correlation between 26 different project variables and the final grade awarded to the student for the project at the end of the semester. Variables that were present in more than 10 of the 42 projects were taken into account. The variables are ranked from the lowest correlation to the highest correlation with the final grade. For instance, projects with less than ten wires being used had the lowest correlation coefficient (-0.08) while projects that cost more to construct had the highest correlation coefficient (0.34) to the final grade. This would imply that student who used less than ten wires in their project had a lower chance of academic success. On the other hand, projects that cost more had a better chance of success.
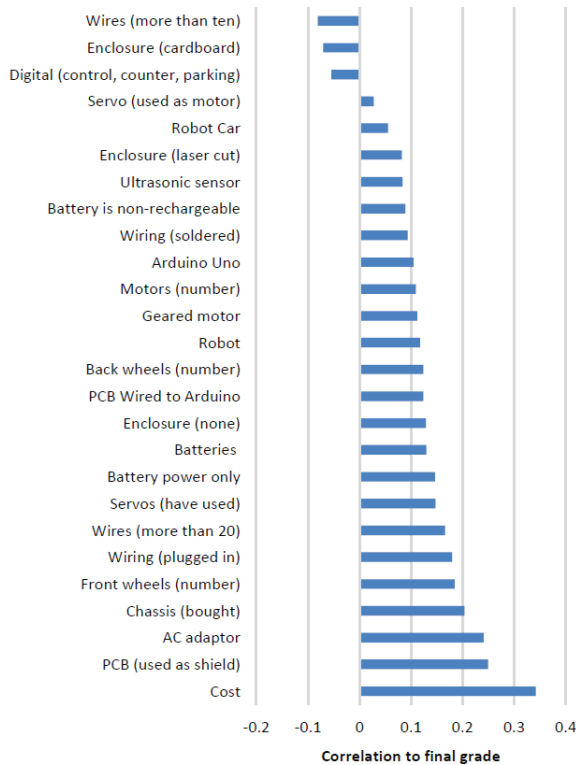

Figure 1. Correlation between project variables and final grades.

6. Discussion

The aim of the designed framework is to help future students make informed choices regarding the selection of projects and components for the DBL module Design Project III and Projects II. Fig. 1 indicates the top four most relevant variables or components (correlation more than 0.2) which include the cost, the use of a PCB as a shield, the use of an AC adaptor and the use of a commercially available chassis to mount the various components. The cost of the project is related to the components and the complexity. A key recommendation to students would, therefore, be at the proposal stage, to carefully select a project that is at the correct complexity level for the module that they are enrolled. The use of the PCB as a shield is well correlated with the final grade. A recommendation in this regard would be for students to spend more time on the design of their PCB and to consider designing it to fit as a shield. The power supply used is also a contributing factor and can be an indication of a more complex project. Concerning the power supply, it can thus be recommended that students take care in selecting an appropriate supply for their project. For the robot car type of projects, using a commercially available chassis resulted in higher grades being awarded to the student. It is therefore recommended that students, with limited time and mechanical background, rather use such a chassis in order to improve their chances of academic success in this DBL module.

7. Conclusion

The purpose of this paper was to present a framework that engineering students may consult in regard to selecting an appropriate project and components that will lead to higher academic success. The framework was developed by analysing 42 student projects from 2015 and correlating 53 components or variables to the final grades awarded to the students. Collecting data over a longer period of time with more projects can verify the results and strengthen the study.

Students who spent more money on their project, while using a PCB as a shield, an AC adaptor as the power source and a commercially available chassis to mount all the components attained a higher grade than students who did not use them. This developed framework may provide guidance to undergraduate engineering students in DBL modules to make informed decisions regarding the choice of their project and components. This guidance may encourage students to put forth their best, resulting in academic success.

8. Reference

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