A framework to encourage the use of reflective practices by undergraduate engineering students in a design-based 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 proposed 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 proposed 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 and 2016 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 74 student projects were analysed, and a correlation was drawn between 53 different criteria and their final grade. Students who used battery power, plug-in wires, and DC motors attained a higher grade than students who did not. The proposed 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.

Index Terms—Practical work, student perceptions, entry level, theory, freshman

I. INTRODUCTION

“Is there anyone so wise as to learn by the experience of others?” These words, by the French writer Voltaire, certainly relates to teaching design principles to undergraduate engineering students in design-based modules (DBL). These students need to be guided and encouraged to reflect on the quality of their work and also work done by preceding students. The value of reflective practice is broadly accepted in education [1] and is a mechanism to turn experience into learning [2]. However, encouraging students to reflect on their work by considering the work of previous students has the potential to further enhance their work and academic achievement [3]. This reflection may be encouraged by providing detailed theoretical frameworks to students.

A theoretical framework is a structure that supports the theory of a research project [4], 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 connected to a particular field that may be used to guide, develop and shape specific research [5]. In the same way that a theoretical framework guides a researcher in the identification and understanding of a problem, it is envisaged that a proposed framework will guide undergraduate engineering students in the selection of an appropriate project along with its associated components. The proposed framework is based on the assessment of previous student projects in a DBL module. It further presents the correlation between the components used and the final grade that was assigned to the students.

The purpose of this paper is thus to present a proposed framework that engineering students may consult regarding the selection of an appropriate project along with its associated components in order to achieve academic success. Firstly, some principles relating to learning are discussed where after the context of the study is presented. The design of the proposed framework is then explained, followed by the results, discussions, and conclusions.

II. PRINCIPLES RELATING TO LEARNING

A. Framework

Researchers are aware of the importance of theoretical frameworks in education, learning, and research [6]. Clarkson pointed out that “models and frameworks are helpful for clarifying theories and abstract ideas or constructs [7]. However, to be useful in practice, a model or framework must apply to the conditions that it is trying to describe, analyse or predict” [8]. Theoretical frameworks form the foundation 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 [13]. Reflective learning is imperative in academic studies [14] and is a method that encourages students to reflect on or meditate on all available sources of knowledge [15]. Its main aim is furthering understanding of complex situations, developing personal abilities and enhancing experience [16]. Reflective learning has been fostered in the current digital world where a wealth of data on almost every topic exists [17]. In the context of this paper, students will be requested to reflect on a proposed 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 centered on problem-solving in combination with project-based learning [18]. 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) [19]. DBL is a trend in Engineering and Architecture that increases the objectivity of the learning process, while stimulating team and interdisciplinary work [20]. The advantages of DBL include providing a relevant opportunity for student learning, increasing student motivation and engagement [18], developing higher-order cognitive skills [21], promoting active learning [22], stimulating collaboration and cooperative learning and also fostering personal and interpersonal traits and creativity [23, 24].

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>Assessment tools</th>
<th>Pedagogical methods</th>
<th>Syllabus</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compile and write a proposal for selected project</td>
<td>Evaluation on Blackboard using a rubric</td>
<td>Project consultations</td>
<td>Project Proposal</td>
<td>Journal articles</td>
</tr>
<tr>
<td>Compile and write a progress report for project</td>
<td>Evaluation on Blackboard using a rubric</td>
<td>Demonstration of Arduino hardware and software (computer-based learning)</td>
<td>Progress report</td>
<td>Conference papers</td>
</tr>
<tr>
<td>Prepare and give presentation on project</td>
<td>Evaluation of an oral presentation by the student using a rubric</td>
<td>Lectures</td>
<td>Presentation</td>
<td>E-Books</td>
</tr>
<tr>
<td>Compile and write the final report</td>
<td>Evaluation of a hard copy of the project documentation using a rubric</td>
<td>Videos</td>
<td>Documentation</td>
<td>Web pages</td>
</tr>
<tr>
<td>Design and construction of Arduino-based project</td>
<td>Evaluation of completed project using a guideline</td>
<td>Oral presentation</td>
<td>Complete electronic project</td>
<td></td>
</tr>
</tbody>
</table>
A. Projects II and Design Project III assessment

Continuous assessment is used in both modules which are usually completed within a 14-week period. Both formative and summative assessments are used to cover the syllabus, as listed in Table I.

The project proposal contributes 10% to the final grade of the students. The project proposal is submitted via the institutional LMS approximately three weeks after the start of the semester. In the project proposal, the student identifies the project and answers a set of structured questions about the proposed project. These questions are set in a way that gives the lecturer an idea of the complexity and feasibility of the project. Students may hand in more than one proposal, but must obtain a minimum of 50% for one of the proposals before the stipulated deadline communicated to them in their study guides. The proposal must be approved by the lecturer before the student can continue with the proposed 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. In the second progress report, students will include a link to a YouTube video that they have uploaded that shows the actual working of their project on a breadboard. There is also a set of questions that are answered with every progress report. The questions are the same for both progress reports, with significance differences relating to the time left in the semester. For example, a question regarding the percentage of progress with the PCB will count 2% at the beginning of the semester, but 10% towards the end of the semester. Projects II and Design Projects III are continuous evaluation modules. Table II lists the different assessments that are done during the semester, together with the type and percentage in relation to the final grade. The two progress reports (formative in nature) for the module Projects II contributes 10% to the final grade and for Design Project III it contributes 20%. A theory test is written in Projects II, as there is a small theory section in the syllabus. The oral presentation contributes 10% to the final grade for both projects. For instance, the Infrared Sensor was used by 26% of the students, while the Arduino UNO were used by 85% of the students. Components that were present in more than 33% of the projects were therefore considered for the proposed framework.

Because the final grade is a continuous variable and the project related components are dichotomous variables, 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 [28]. 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 [29]. The correlation was done between the different variables and the final grade awarded to the student at the end of the semester. Results are presented in the following section.

Many of the components are not used in all the projects. For example, the Infrared Sensor was used by 26% of the students, while the Arduino UNO were used by 85% of the students. Components that were present in more than 33% of the projects were therefore considered for the proposed framework.

TABLE II: EVALUATION AND WEIGHTINGS OF THE MODULES PROJECTS II AND DESIGN PROJECT III

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Type of assessment</th>
<th>Projects II</th>
<th>Design Project III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal</td>
<td>Formative</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Progress report 1</td>
<td>Formative</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Theory test (Projects II)</td>
<td>Formative</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Progress report 2</td>
<td>Formative</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Oral presentation</td>
<td>Formative</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Documentation</td>
<td>Summative</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Article</td>
<td>Summative</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Software design</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Schematic + PCB</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Construction</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Wiring</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>PCB</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Working</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Demonstration</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Hardware design</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Level of Project</td>
<td>Summative</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

V. RESULTS

Fig. 1 represents the correlation between evaluations that were done during the semesters in 2015 and 2016 and the final grade allocated to the student for the project. For instance “Hardware design” was one of the evaluations that were done during the semester and it has a correlation coefficient of 0.84 when correlated with the final grade, where “Progress Report 2” has a coefficient of 0.49 when correlated to the final grade (see Fig. 1).
Fig. 1. Correlation between semester evaluations and final grades of student projects (2015 and 2016)

Fig. 2 highlights the correlation between 18 different project variables and the final grade awarded to the student for the project at the end of the semester. The variables in Fig. 2 are sorted from the lowest correlation to the highest correlation with the final grade. For instance, projects with a cardboard enclosure had the lowest correlation coefficient (-0.2) and projects that used only a battery as the power source had the highest correlation coefficient (0.26) with the final grade.

VI. DISCUSSION

The aim of the proposed framework is to help future students make informed decisions regarding the choice of projects and components for the DBL modules Projects II and Design Project III. Fig. 1 illustrated the relationship between evaluations that were done during the semester and the final grade of the student. The evaluation of the hardware design component has a strong correlation with the final grade ($r = 0.841$). This suggests that future students need to pay special attention to the design of the hardware, as it has the greatest bearing on the final grade. Furthermore, the appropriate level of the selected project ($r = 0.813$) and the demonstration of the project ($r = 0.799$) is also shown to be critical for academic success in this module. Other correlations (higher than 0.7) were found for the PCB, wiring, working, documentation and construction of the project. It is noteworthy that a low correlation exists between evaluations that were done early in the semester (e.g. project proposal and progress reports) while higher correlations exist for the assessments done at the end of the semester (e.g. hardware and construction). This may be an indication that students grow in experience and acquire new skills as the semester progresses, as the weightings between these different evaluations remain similar (see Table II).

Fig. 2 highlights the correlation between 18 different project components and the final grade awarded to the students for the projects at the end of the semester. Of the original 53 components, only 18 are presented as these were present in more than 33% of the 74 electronic projects that were analysed. Projects with cardboard enclosures had the lowest correlation coefficient (-0.2) while projects that used only a battery as the power source had the highest correlation coefficient (0.26) with the final grade. Cardboard has the advantage of being much less expensive than wood but suffers from the drawbacks that it is not as visually aesthetically pleasing as wood or hardboard and is also not as structurally firm [30]. In most applications, direct power from the USB is preferable. However, in some applications using a battery as the power source could be more preferable, especially when the application is frequently moved or when power cords could present a hazard [31]. In this case, the electronic projects frequently involve robotics, where an automated vehicle is designed that will require mobility and autonomy. These correlations suggest that projects with a cardboard enclosure have a smaller chance of academic success, while projects with a battery power source have a greater chance of academic success.

VII. CONCLUSIONS

The purpose of this paper was to present a proposed framework that engineering students may consult regarding selecting an appropriate project and components for their electronic project that will lead to higher academic success. The framework was developed by analysing 74 electronic projects from 2015 and 2016 and correlating 53 components or variables to the final grades awarded to the students. Only 18 components were presented as they were present in more than 33% of the 74 electronic projects. Collecting data over a longer period of time with more projects can verify the results and strengthen the study.
Students who used battery power, spent more money on their project, used plug-in wires and DC motors attained a higher grade than students who did not use them. This proposed framework may provide guidance to future 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. Furthermore, the proposed framework may assist academics to provide better guidance to students in the early stages of their project concerning the selection of an appropriate electronic project and its associated components. In so doing, both academics and students will be able to learn from the experiences of others, which is a wise course of action to follow.

ACKNOWLEDGEMENTS

This research was supported by the Academic Development and Support Department at CUT who have initiated a Scholarship for Teaching and Learning programme. The work is also based on research supported in part by the National Research Foundation (NRF) of South Africa. Any opinions, findings, conclusions or recommendations expressed in this material are that of the author(s) and the NRF does not accept any liability in this regard.

REFERENCES


