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# Case Study to Analyze the Impact of Multi-Course Project-Based Learning Approach on Education for Sustainable Development

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**Abstract:** This work presents a multi-course project-based learning (MPL) approach implemented using two electrical engineering (EE) interdisciplinary undergraduate courses at Qatar University. Implementing an MPL approach helps in the development of critical thinking and collaborative decision-making skills. The attainment of these skills is also the outcome of education for sustainable development (ESD); the skills help students acquire the knowledge, attitudes, and values necessary to shape a sustainable future. The participating students' worked on a design project, which was used to assess the fulfillment of a set of student learning outcomes (SLOs), focusing on engineering soft skills and project management skills. The skills include the ability to communicate effectively, to work collaboratively in a team, to think both critically and creatively, and to manage projects efficiently with realistic constraints and standards. The challenges of implementing the MPL method are the organization of pedagogical activities that are planned for each of the courses involved, the coordination of the materials delivered by each course, and the supervision of around 90 students per year performing the MPL method. The experience of MPL deployment in the EE program was rated using student surveys. It was assumed that the MPL approach would be beneficial to the students based on the instructors' and students' feedback from the same courses in previous years. This was verified using chi-square statistics of the survey results. The implementation of the MPL also helped in increasing the average marks scored by the students in the design project. Some interesting feedback, statistical analyses, and improvement actions are reported for future upgrades. This work also contributes to the MPL pragmatic body of knowledge by exploring a successful initiative and its outcomes, which can help in attaining the skills needed for ESD.

**Keywords:** critical and collaborative thinking for ESD (education for sustainable development); electrical engineering education; multi-course project experience; chi-square statistics; multi-course intralevel project

## 1. Introduction

Conscious societies should use technology, innovations, and cooperation to change development trends towards sustainable growth, which is respectful of the environment. This requires a broad set of skills, such as creative problem solving and collaborative decision-making. [1,2]. There is a huge demand for electrical engineering graduates to incorporate the outcomes of such education

for sustainable development (ESD). This can help them to be efficient in using their knowledge from courses to solve complicated problems, and will guide them in self-directed, lifelong learning processes [3]. There is a need to modify traditional education methods and incorporate innovative teaching methods where the students are no longer passive participants and they are equipped with the ESD skill sets and knowledge that the market demands [4–9]. Recent similar work, where the authors emphasized modifications to incorporate ESD in curricula, is taken as a reference for the work presented in this paper [10].

Two junior-level courses were used to assess the design and problem-solving skills of undergraduate electrical engineering students at Qatar University. The first course is titled “Electronics Engineering” (ELEC 333), and the second “Sensors and Instrumentation” (ELEC 371). The content, as well as the educational strategy of the courses, were modified in order to incorporate ESD, fulfill the requirements set by the industry, and to increase the students’ levels of interest toward design, problem-solving, and independent learning. In the study, the students were asked to work on a multi-course project, i.e., a single project that is used in the assessments of multiple courses. The guidelines were designed in such a way that the students could work on a project that involved the concepts studied in the courses and develop the skills required for a sustainable future. The project-grading rubric was also designed to evaluate whether the course-learning outcomes of both courses were met. This study was carried out in the fall semester of 2015, spanning September 2015 to January 2016.

Previously, there were two different projects for the courses; this was overwhelming for the students. Student-learning outcomes for both courses could be assessed within a single project based on the instructors’ requirements and feedback from the student. Students are motivated when they believe that the learning outcomes are meaningful, under their control, and can help in solving problems faced in real life [3,4]. Theoretical concepts were taught in the courses “Electronics Engineering” and “Sensors and Instrumentation”, while experiments were done in the “Electronics Engineering Lab” course and the embedded lab of the “Sensors and Instrumentation” course. The majority of the students assumed that the best form of skills would be learnt from the labs and practical projects. However, different projects in different courses did not provide motivation because the projects were overwhelming for the students, and they could not develop an effective working prototype using the concepts presented in each course; this is why the multi-course project strategy was implemented [11].

A multi-course, project-based learning (MPL) experience was shared with a group from Montana Tech of the University of Montana [12]. It described the implementation of MPL in a software development task in their Computer Science department courses that they argued was an integral part of ESD. There was also recent work done by the Nanjing Institute of Technology where researchers emphasized the notion that multi-course practical lessons in project form can help to promote student understanding and consciousness of the application of professional knowledge to an engineering project [13]. An interesting approach was carried out by the Virginia Military Institute, where the authors tried to work on a multi-semester project [14]. The authors described the implementation of the project and showed how it addressed skill set deficits in conventional curricula. However, none of the stated works provided details on how the projects were designed and implemented, and did not present a detailed statistical analysis regarding the effectiveness of the approach. This paper provides a detailed description of how the authors implemented a multi-course project in a sequence of steps (Figure 1), which will be discussed in detail later. One of the major motivations of this case study, besides changing the traditional curriculum to incorporate ESD, was to confirm the effectiveness of a multi-course project in achieving student learning outcomes and assisting project-based learning (PBL). PBL helps in the development of inquiry processes when learning real-world topics, and is also attractive to students [15].

This paper is organized as follows. Section 2 presents an overview of the implemented multi-course project learning strategy which is suitable for these courses. The implementation of this study, starting from the review phase, is presented in Section 3; this section also provides the details of the project

guidelines, the project-grading rubric, and the lab schedule, and gives details of the conducted survey. Section 4 provides the survey results and an evaluation of the performance of the MPL study in terms of improving students' grades, along with a discussion of the results. Finally, Section 5 presents conclusions and suggestions from the authors for improvements based on instructor and student feedback.

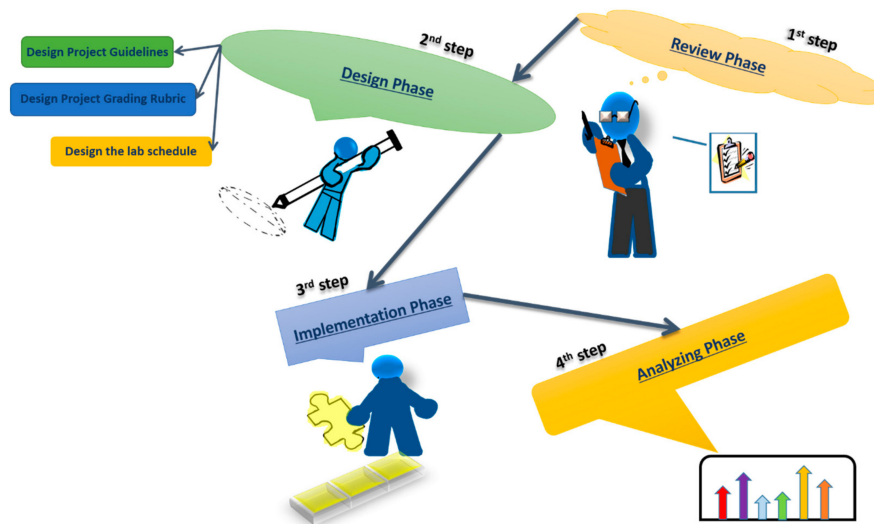


Figure 1. Block diagram of the MPL case study.

## 2. Educational Strategy in PBL

One of the most important building blocks of MPL is project-based learning (PBL), which is also one of the most popular teaching models that help students in applying the competencies they have acquired during the course on real-life problems. PBL relies on an active, integrated, and constructive process in learning, influenced by social and contextual factors, which is very important in developing competencies in students for an enhanced sustainable future [16–18]. The PBL teaching approach should include the following characteristics: student-centered learning, small student groups learning, teacher as a mentor or guide, encountering authentic problems before any preparation, problems used as a tool to achieve the required knowledge, and self-directed learning to acquire new knowledge [9,18]. The successful implementation of PBL into engineering education done in Aalborg University, Denmark can be taken as a reference [18–20].

According to the authors, clear and precise project guidelines stating the deliverables and grading rubric is needed for a multi-course project; this is to avoid any confusion in the students on how they should present the project and highlight the requirements of each course. It is also imperative that the project-grading rubric should be in line with the course learning outcomes that the project assessment is aiming to meet. The MPL incorporates PBL and thus requires clear and precise guidelines, involving teamwork and adapting the students' prior knowledge [21]. PBL believes in collaboratively working in groups to solve problems, with the teacher only being a facilitator of collaborative learning [16–18,22]. In addition, students are equipped with critical thinking and creative skills [17,22]. These approaches help the students to be prepared for the demanding market, which longs for sustainability and students who are more communicative in delivering their knowledge in their professional careers [23]. Studies involving surveys to see the effect of PBL in teaching ESD in European higher education institutions were conducted in [24], which helped to update the theoretical framework and provided a more precise perspective on how sustainability competencies can be better developed in class. There was a similar study done on a large scale in [25] where the impact of PBL on the engineering students at a technical university in Malaysia was investigated and it was found that lab-based courses with hands-on experimental studies had a more positive effect. Similar studies were done for Germany and Vietnam in [26] and [27], respectively.

### 3. Research Method

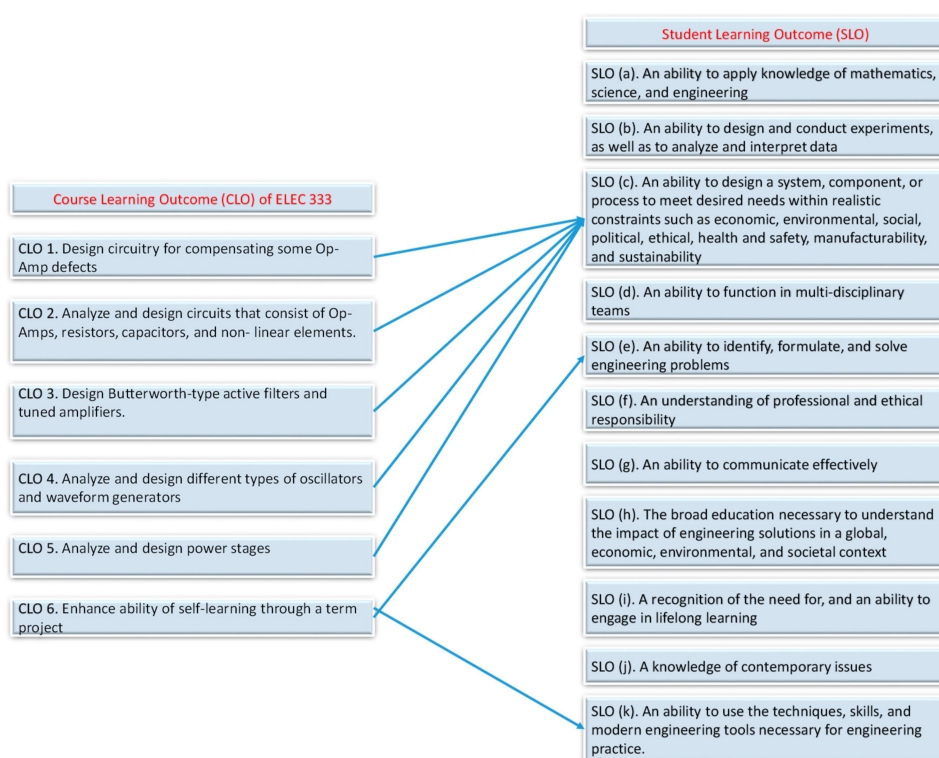
The study evaluates a multi-course project-based learning paradigm in comparison to an independent course project-based learning paradigm, which was carried out in four phases: a review phase, a design phase, an implementation phase, and an observation and reflection phase (Figure 1). The first action-planning or review phase involves the teacher planning the actions to be taken in the study, in the form of linking the learning strategies to the tasks that will be given to the students. In the second phase, the design of the project and its evaluation plan is completed. In the third phase, the action implementation is carried out according to what was planned. The fourth phase is an observation and reflection phase, where activities are recorded throughout the study. The reflection phase is done at the end with the data obtained during the study to critique the approach and suggest improvement [28].

#### 3.1. Study Participants

This research was conducted at Electrical Engineering Department, Qatar University, Doha, Qatar. The subjects of this research were students of ELEC333 (Electronic Engineering) and ELEC371 (Sensors and Instrumentation) in the fall semester of the 2015/2016 academic year with 90 students, consisting of 54 male students and 36 female students.

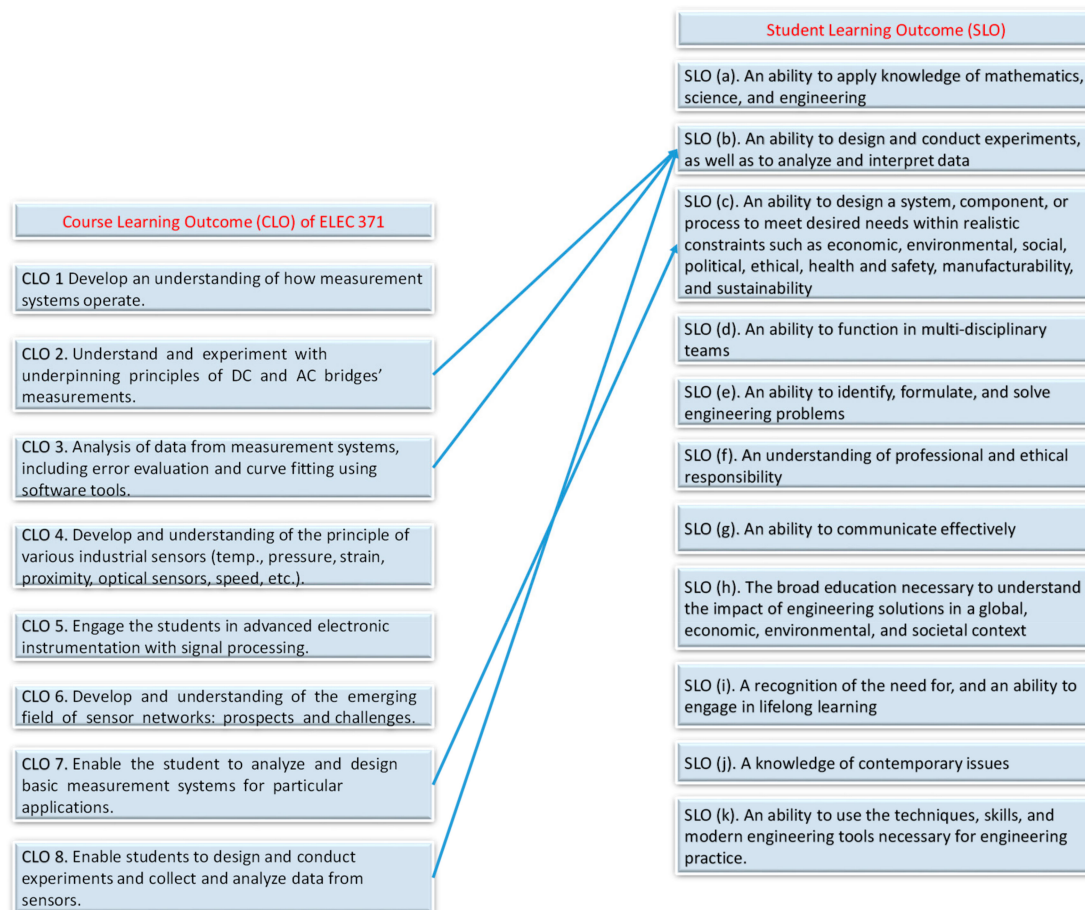
#### 3.2. Review Phase

The course instructors first reviewed the course learning outcomes and checked if there was any possibility of developing a project that could be used to assess some of the learning outcomes of the courses. Figures 2 and 3 shows the mapping of the respective course learning outcome (CLO) with the student learning outcome (SLO) of a program which has Accreditation Board for Engineering and Technology (ABET) accreditation. The Electrical Engineering Department of Qatar University is an ABET-accredited higher education unit.



**Figure 2.** Mapping of the course learning outcome (CLO) of the ELEC 333 (Electronic Engineering) course with the student learning outcome (SLO).

After careful review of CLOs with the SLOs for these courses, the authors confirmed that a multi-course project could be very effective as an assessment tool for most of the course learning outcomes for these courses (ELEC 333 and 371). A design term project was assigned to assess the combined CLOs for these courses.



**Figure 3.** Mapping of CLO of the ELEC 371 (Sensors and Instrumentation) course with the SLO.

### 3.3. Design Phase

Based on the results of the discussion of the research team, design phase planning was carried out for designing the study. Learning, according to MPL, starts with the determination of project guidelines, project-grading rubric, planning projects, and arranging schedules. Figure 1 shows the steps of activity involved in the implementation of the multicourse project.

- Design Project Guidelines

It was made sure that the students were informed of the specific learning outcomes of each course that would be assessed using this study and that the project complemented the materials students were learning in the course and the labs via self-learning. Moreover, it was confirmed that the MPL study was to assess the course learning outcomes without repetition of the assessment.

- Design Project Grading Rubric

The three forms of GroupWise evaluation of the MPL were designed: experimental skills were to be evaluated by the experimental demonstration, scientific writing skill was to be evaluated through report writing and professional communication, and presentation skills were to be evaluated using oral presentation followed by a question and answer session. Project grading rubrics and weightages were set according to the course-learning outcome of the different courses. Project guidelines (Figure A1),

project grading rubric (Figure A2) for ELEC 333 and 371 and the lab schedules (Figure A3) for the courses can be found in the Appendix A.

- Design the lab schedule

Dedicated lab sessions were scheduled to provide hands-on training on some of the concepts needed for the project. It was made sure that the flow of the lab schedule helped in the timely progress of the project.

### 3.4. Implementation Phase

This phase of the study is involved in monitoring and evaluating the study progress throughout the project, and ends with the completion of project assignments. Finally, using the detailed lab schedule, the students are assisted in implementing their project. The authors also placed deadlines before the actual due date to check the progress of the student and provide useful feedback to help them proceed.

- Project Management

Projects are meant to improve the creativity of the students. It can also enhance the students' conceptual understanding of electronics, sensors, and instrumentation and their application in daily life, especially in relation to measurement. It also helps students to learn, more than what was covered in the lectures, using self-learning techniques. In this learning, four or five students form a group with different levels of understanding and ability to work together. This simple multi-course project begins with the project design stage followed by verifying the design in the simulation phase, and finally testing it with a real prototype.

- Project Assessment

Two sets of information (survey-based and evidence-based) were used in this study to evaluate which technique is more suitable: MPL or single course PBL. At the end of the course, an anonymous survey was carried out among students enrolled in the program. The anonymous survey was tailored based on [15]. Instructions were given to the participants that the study was to see the feedback of the students about the effectiveness of multi-course projects in the mentioned courses in electrical engineering. The questionnaire was prepared carefully so that there were no repetitive questions and used the authors' expertise in preparing surveys that provide results that can be analyzed for meaningful conclusions [29]. Extreme care was taken to maintain the anonymity of the study and confidentiality of responses by preventing the identification of data obtained from the participants. Furthermore, the identification of participants was prevented by analyzing and reporting the data in a cumulative manner. Table 1 shows the survey questionnaire conducted to gather the student's feedback and the questionnaire. From the previous experience of the authors, who were the instructors of these courses, and feedback from students who took the course previously, a positive and efficient learning experience was expected from the project approach.

At the end of the semester, to evaluate whether the estimation complies with the findings or not, students' and instructors' written feedback, project grades of the students in the previous semester and the current semester where the multi-course project was implemented, were recorded. The students' multicourse project grades were used for assessment. Male and female students were evaluated to see whether the performance of MPL vs. single course PBL is generally effective in a particular student group or both groups.

**Table 1.** Survey questionnaires.

Questions Statements
1. The implementation of multicourse project-based learning has made the two courses (ELEC333 and ELEC371) more interesting.
2. The multi-course project-based learning has improved my understanding of the theory taught in these courses.
3. I would be interested in taking another multi-course project.
4. The effort imposed by the multi-course project is worthwhile because of the extra skills and knowledge that I have gained.
5. The multi-course project has increased my affinity (likeness) to electronics as well as sensors and instrumentation.
6. MPL can help in delivering better solutions to engineering problems since the concepts taught in the different theory courses can be utilized more efficiently.
7. MPLs can improve real-life problem-solving skills.
8. MPLs enhance creativity.
9. MPLs improve teamwork skills.
10. MPLs can develop independent learning skills.
11. MPLs require students to think differently from the typical classroom way.
12. Having laboratory sessions dedicated to advising students regarding the progress of their multi-course projects have helped them in improving their solutions, skills, and knowledge.
13. The resources available at the laboratory were sufficient for completing the multi-course based project.
14. In the MPL study, project topics given were diverse and interesting.
15. The MPL approach should be used in other courses too.

### 3.5. Observation and Reflection Phase

This study targets the following effects of MPL on the students' grades and observations, which were reflected from students' grades and feedback from the survey.

- Effect on Students' Project Grades

The project grades after the MPL implementation were compared with other semesters where MPL was not implemented. These results can be helpful in deciding whether the MPL approach is better than the PBL approach or not.

- Overall Observations

This study was designed to observe several key issues in sustainable learning outcomes in engineering education. The key factors, which were evaluated as a part of this study and reported in the result section, are (i) the overall effect on students' learning outcomes; (ii) creative thinking skill improvement; and (iii) constraints in the implementation of actions.

## 4. Analysis

Data analysis were carried in this study in several ways: (i) analyzing the evidence-based indicator, i.e., the grade of the project, (ii) chi-square statistics of the survey study, and (iii) the creative-way-of-thinking indicator.

- Evidence-Based Indicator

The project grades of the students in the previous semester and the 2015 fall semester, where the multi-course project was implemented, were compared as evidence-based indicators. Course-wise, average project grades from different semesters were compared and male- and female-group grades were compared as well.

- Chi-Square Statistics

A Chi-Square ( $\chi^2$ ) statistic is a test that measures how expectations compare to actual observed data (or model results). The data used in calculating a chi-square statistic must be random, raw, mutually exclusive, drawn from independent variables, and drawn from a large enough sample.

The formula for a chi-square ( $\chi^2$ ) statistic is

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

where,  $c$  is degrees of freedom,  $O$  is the observed value(s), and  $E$  is the expected value(s).

The survey questions were designed in such a way so that the answers help in analyzing the assumptions of whether MPL is actually a helpful approach for the students. From the feedback from the instructors of the same course in the earlier semesters, it is assumed that it would be a very helpful approach. This was evaluated by using chi-square distribution [30] as chi-square analysis is the most efficient way of evaluating survey results with different expected results [31]. All the questions in the survey were asked and the authors expected positive results for the questions, i.e., the authors' prediction. Analysis was done to check the effectiveness of the MPL based on the results obtained from the survey and conducting chi-square analysis considering alpha level ( $\alpha$ ) = 5%, the degree of freedom ( $c$ ) = 4 (i.e., number of categories–1, as there were five categories—Strongly agree, Agree, Neutral, Disagree, Strongly Disagree). The authors assumed that the students would respond positively (Strongly Agree, Agree) for all the questions and this assumption was analyzed with the observed response and chi-square analysis was conducted to confirm if the assumption should be accepted or rejected.

- The Creative-Way-of-Thinking Indicator

Innovation in system design, user-interface, and presentation with minimal help from the instructor was considered a creative way of thinking. The indicator of this was calculated by the scores obtained by students in each aspect. The indicator of success in this action research is if the ability of students to think creatively in each aspect reaches above 60%.

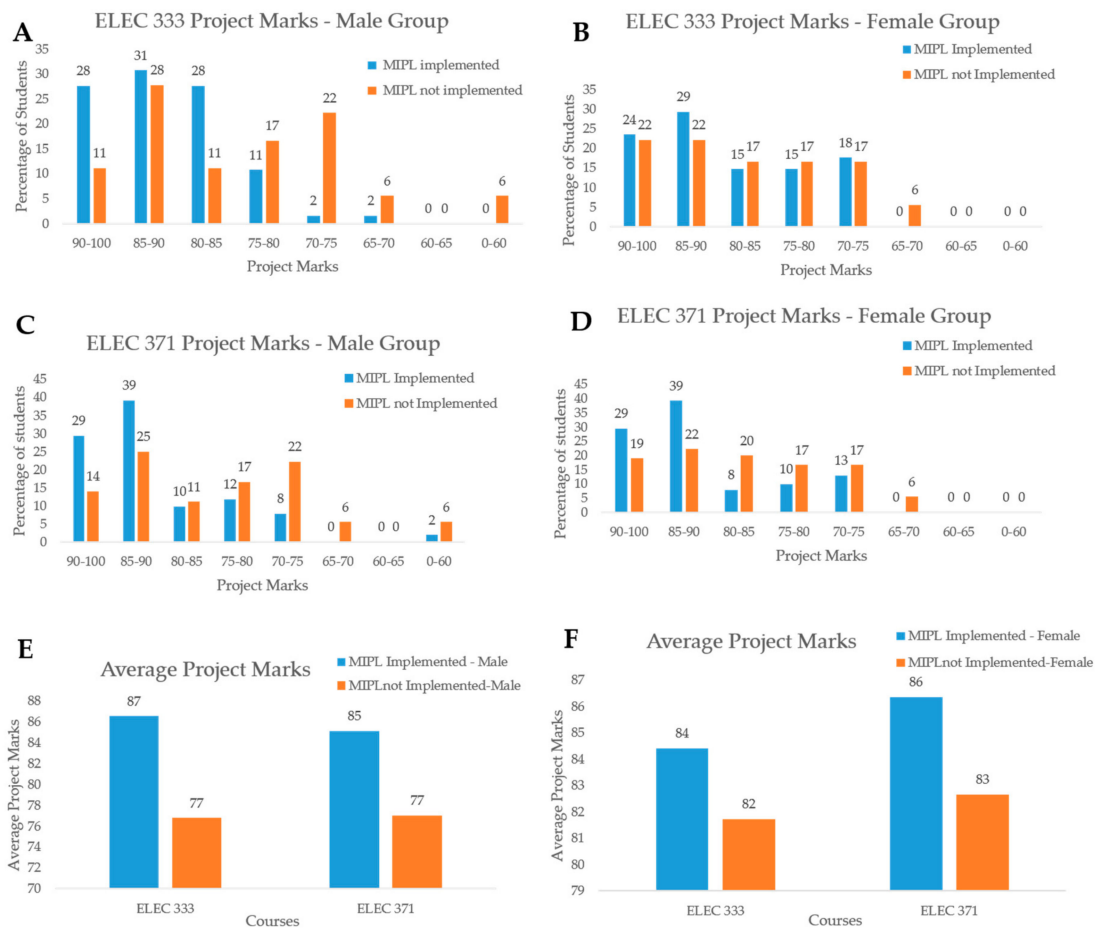
## 5. Result and Discussion

### 5.1. Description of Evidence-Based Indicator

Based on the results of project groups in their term project performance, evidence-based evaluation was carried out. Since MPL involved planning projects, arranging schedules, monitoring, and evaluating throughout the project, and ended with the completion of project assignments, the assessment of outcome was done in three steps: demonstration, presentation, and report evaluation. In addition to being a means of enhancing student creativity, this project was expected to have an impact on increasing students' conceptual understanding of amplifiers, sensors, instrumentation, and their application in daily life.

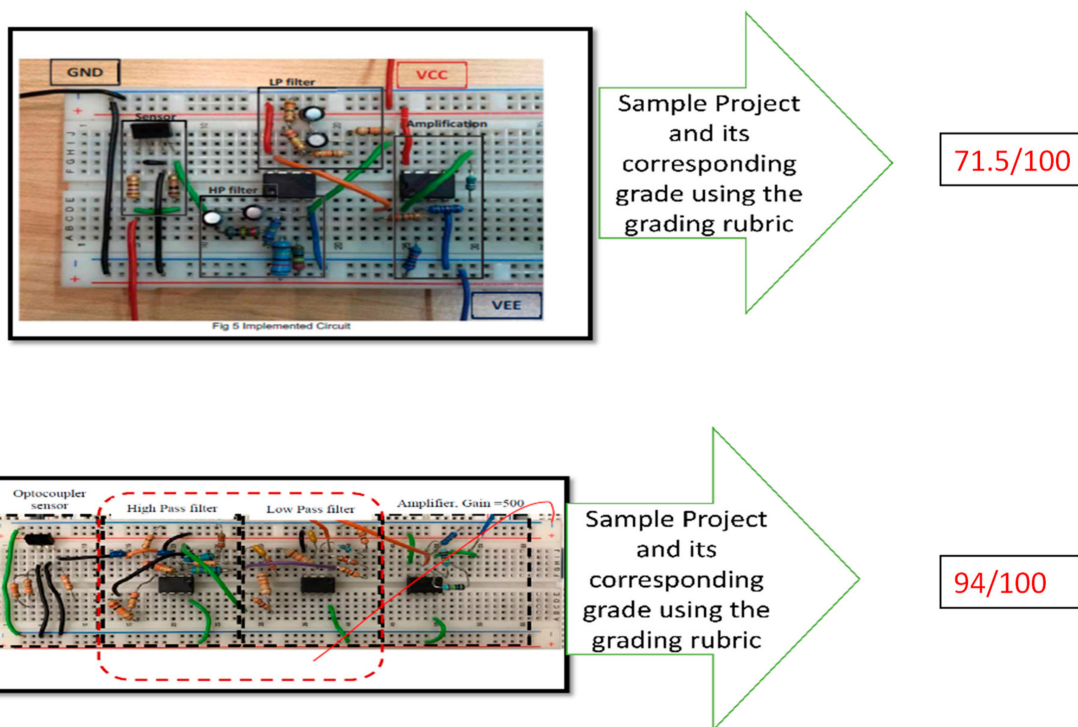
As evident from Figure 4, the MPL has definitely helped in increasing the male average project grades (out of 100) from 77 and 77 to 87 and 85, respectively (Figure 4E) for ELEC 333 and ELEC 371; a similar increase is also seen for the female group, i.e., from 82 and 83 to 84 and 86 (Figure 4F). The number of students doing well in the project, i.e., getting project grades in the range 80 and above, has also increased. Many projects in the earlier semesters helped talented students but there were also many students who did not achieve the desired learning outcomes and received poor grades with less understanding of the project. With the new approach, only 2% of the students did not do well and received scores less than 60 out of the total score 100, as seen in Figure 4.





**Figure 4.** Comparison of the project grades of ELEC 333 ((A): male group, (B): female group), ELEC 371 ((C): male group, (D): female group), and average project grades ((E): male group, (F): female group).

Once the project is assigned, the students are asked to study more about the problem proposed in the project and come up with a solution using the concepts learned during the course. The students came up with the design of the solution, followed by simulating it in a simulation tool and finally implementing it practically. Students in groups also discussed the selection of tools and components used in the design so that students understand the components and their functionality. This is done to equip students with creative thinking skills. During the implementation of the designed system, students also discuss and present related successes and failures of the trial design and try to reflect on its successes and failures. For groups that have failed to achieve success, their overall score reflected the fact. Every activity carried out by students is always followed by an observation of their creative thinking skills. Figure 5 presents a sample design project prototype with the marks achieved using the project grading rubric.



**Figure 5.** Sample projects and their corresponding grades, which were graded using the designed rubric.

### 5.2. Description of Chi-Square Statistics

The survey results were as per the assumptions, giving very positive feedback regarding the MPL implementation. Chi-square statistical analysis was done on the survey results to validate the assumption that MPL is an effective pedagogical approach and is preferred by the students. Chi-square analysis is done on the students' responses, as shown in Table 2. In addition, chi-square analysis was done separately based on male and female (36 and 54, respectively) responses in order to confirm the results. It was found that the results were similar (Table 2).

**Table 2.** Chi-square statistics results on the answers to the survey questions.

Question Statement	Prediction	Accept or Reject Based on the Chi-Square Analysis ( <i>chi – square critical value = 9.49 with Degree of Freedom = 4, <math>\alpha = 5%</math></i> )
The presence of a multi-course practical project has made the two courses (ELEC333 and ELEC371) successful and more interesting.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 3.325 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 4.4 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 2.5 < \text{Chi – square critical value}$ Thus, Do Not Reject
The multi-course project-based learning has improved my understanding of the theory taught in these courses.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 5.375 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 3.6 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 7.6 < \text{Chi – square critical value}$ Thus, Do Not Reject
I would be interested in taking another multi-course project.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 7.125 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 5.7 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 4.6 < \text{Chi – square critical value}$ Thus, Do Not Reject
The effort imposed by the multi-course project is worthwhile because of the extra skills and knowledge that I have gained.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 5.7 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 2.2 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 7.6 < \text{Chi – square critical value}$ Thus, Do Not Reject
The multi-course project has increased my affinity (likeness) to electronics as well as sensors and instrumentation.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 6.825 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 1.9 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 4.2 < \text{Chi – square critical value}$ Thus, Do Not Reject
MPL can help in delivering better solutions to engineering problems since the concepts taught in the different theory courses can be utilized more efficiently.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 3.625 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 2.5 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 3.9 < \text{Chi – square critical value}$ Thus, Do Not Reject
MPLs can improve problem-solving skills.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 2.5 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 2.5 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 2.8 < \text{Chi – square critical value}$ Thus, Do Not Reject
MPLs enhance creativity.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 3.85 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 2.3 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 5.3 < \text{Chi – square critical value}$ Thus, Do Not Reject

Table 2. Cont.

Question Statement	Prediction	Accept or Reject Based on the Chi-Square Analysis ( <i>chi – square critical value = 9.49 with Degree of Freedom = 4, <math>\alpha = 5%</math></i> )
MPLs improve teamwork skills.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 32.525 > \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 14.9 > \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 13.2 > \text{Chi – square critical value}$ Thus, Reject One of the student learning outcomes of the electrical engineering program is to promote teamwork. Thus, this aspect should be enhanced while designing the project next time it is offered.
MPLs can develop independent learning skills.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 12.35 > \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 4.4 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 9.1 < \text{Chi – square critical value}$ Thus, Reject if we do the chi-square analysis for all students but Do Not Reject if we do it separately for male and female students One of the student learning outcomes of the electrical engineering program is to develop independent learning skills. Thus, this aspect should be enhanced while designing the project next time it is offered. Male students believe that it helped in independent learning skills whereas female students were not completely convinced.
MPLs require students to think differently from the typical classroom way.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 6.65 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 4.1 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 5.2 < \text{Chi – square critical value}$ Thus, Do Not Reject
Having laboratory sessions dedicated to advising students regarding the progress of their multi-course projects have helped in improving their solutions, skills, and knowledge.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 1.45 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 3.8 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 1.7 < \text{Chi – square critical value}$ Thus Do Not Reject
The resources available at the laboratory are sufficient for completing the multi-course projects.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 192.3 > \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 79.5 > \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 33.9 > \text{Chi – square critical value}$ Thus, Reject This aspect has to be also taken into consideration when implementing such initiatives.

Table 2. Cont.

Question Statement	Prediction	Accept or Reject Based on the Chi-Square Analysis ( <i>chi – square critical value = 9.49 with Degree of Freedom = 4, <math>\alpha = 5\%</math></i> )
In the MPL study, project topics given are diverse and interesting.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 13.525 > \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 4.7 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 8.2 < \text{Chi – square critical value}$ Thus, Reject if we do the chi-square analysis for all students but Do Not Reject if we do it separately for male and female students This aspect has to be also taken into consideration when proposing the project titles to the students in the following semester.
The MPL approach should be used in other courses too.	Almost all the students should strongly agree with this statement	$\chi_c^2 = 3.625 < \text{Chi – square critical value}$ $\chi_c^2(\text{male students}) = 4.1 < \text{Chi – square critical value}$ $\chi_c^2(\text{female students}) = 2.4 < \text{Chi – square critical value}$ Thus, Do Not Reject

A histogram of the overall students' responses representing the answers to the survey questions is presented in Figure 6a–o. In Figure 6a–h, it is evident that both the male and female students have answered positively for the questions. Similar positive feedback can also be seen in Figure 6k,l,o. These all give a positive impression regarding the MPL implementation done, whereas Figure 6i,j,m,n had some negative feedback and should be considered as suggestions for improvement.

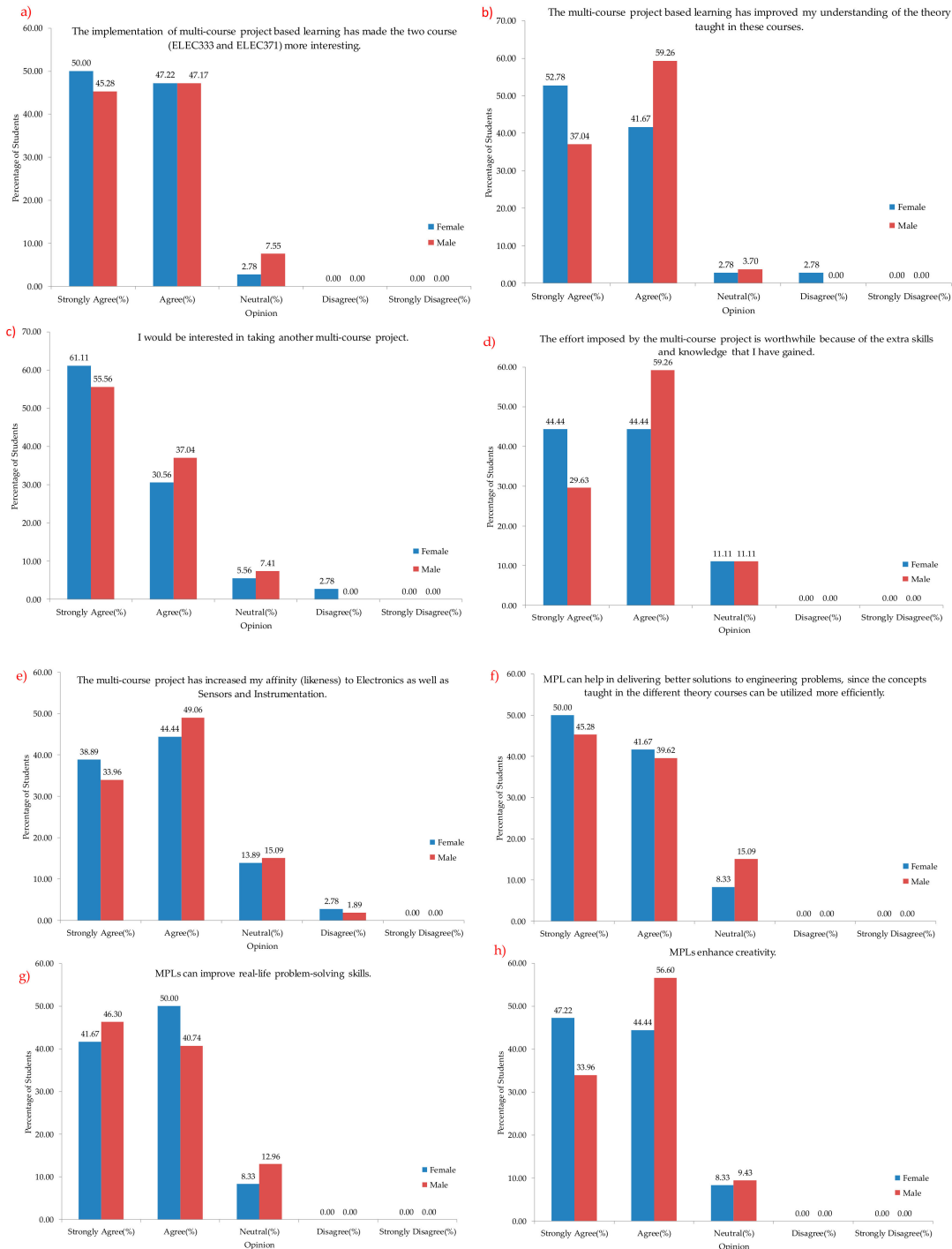


Figure 6. Cont.

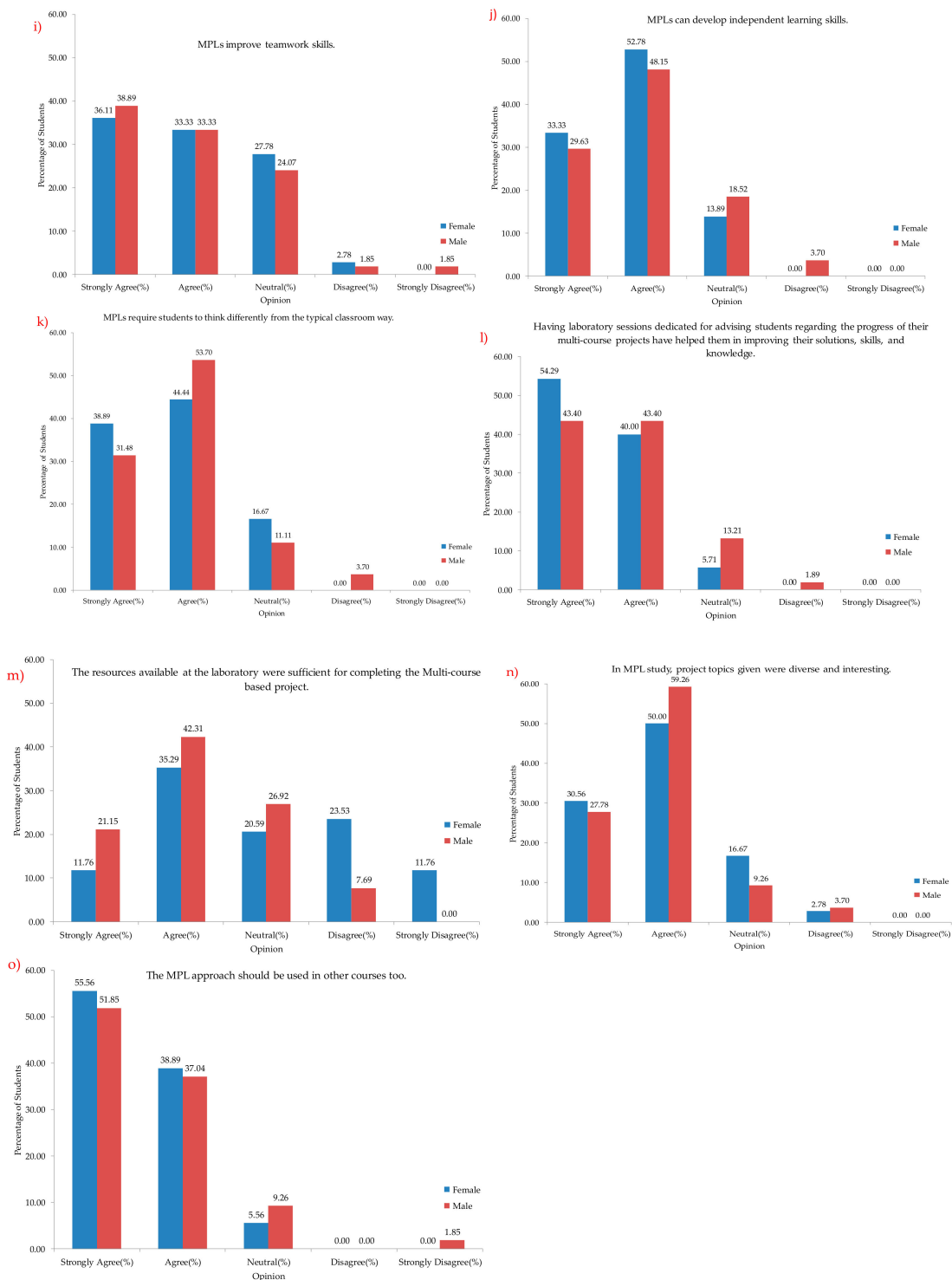


Figure 6. Statistics of the answers to the survey questions 1–15 (a–o).

### 5.3. Students' Creative Way of Thinking

Creative thinking is the imperative skill required for raising awareness amongst students regarding sustainable solutions. Increasing student creativity with the application of multi-project-based learning models also had a positive response verified from the students' responses and project grades. The results of the student reflection questionnaire (97% and 92%; Figure 6a), stated that the experience made the courses interesting, which is motivated by the application of this model (91% and 92%; Figure 6c), and helped in making learning more effective and understandable (94% and 96%; Figure 6b),

respectively, for male and female. Eighty-seven percent of male students and 91% of female students feel that this approach also helped them to enhance their creative thinking skills by utilizing the concepts they received in classroom learning (Figure 6h). Seventy-eight percent of male students and 86% of female students also advocated that the approach helped them in self-learning, which helps them to be aware of the topics themselves in addition to what is taught in the lecture.

#### 5.4. Constraints in the Implementation of Actions

The study was designed to motivate students to look for sustainable solutions with the help of competencies developed during the course of the project. This study certainly did not run smoothly; there were some obstacles that the authors as instructors and students who involved in the experiment have faced. The limitations in the process involved some students who could not manage to enhance their understanding by assuming that the learning is too difficult and it involves additional tasks. Some students also had issues regarding working in teams or groups, with some students not contributing at all to the projects, and some students contributing too much and intimidating other team members. This can cause students with low abilities to feel insecure in presentations and practices [15]. These are issues that already exist in project work and, thus, are also seen in MPL. In order to deal with the issues of increasing the motivation of such students, the instructor should be innovative. Instructors must be able to solve problems, especially in dealing with students with low abilities, lack of motivation, and lack of focus, to improve teacher–student relations [15]. Moreover, there were certain feedback from students that suggested measures to be taken to improve the experience. Based on the students' responses, several modifications have to be made in future studies to improve the MPL experience.

- (a) The multi-course project topics should be more diverse and interesting.
- (b) Resources available at the laboratory should be sufficient for completing the multi-course projects.
- (c) The lab schedule should be modified to teach students to develop their independent learning skills.
- (d) More emphasis should be put on the teamwork experience, and laboratory experiments should be modified to have sessions on team-building exercises.

In summary, the outcomes of this MPL study contributes more than similar works done in PBL-based studies [32–35] in the following manner:

- This paper discusses the step-by-step implementation of MPL which can help attain the competencies required for ESD.
- This paper has analyzed the effects of MPL implementation for two undergraduate-level courses in terms of student performance and also student perception through a survey.
- This paper has also highlighted some of the improvements that can be made in order to make the acquisition of ESD competencies more effective.
- The authors believe that implementing MPL for undergraduate levels is more effective for training and making students aware of always trying to work towards a sustainable future.

## 6. Conclusions

The paper has provided a detailed description of the implementation of MPL study for junior-level electrical engineering courses at Qatar University. An MPL study is imperative for incorporating competencies that are required for sustainable development, such as creative and critical thinking. These approaches help the students to be prepared for the demanding market, which longs for sustainability. The authors have tried to incorporate MPL in their courses to equip the students with these competencies and to make them aware of the ESD during the process. The authors have tried to provide systematic instructions on how such an approach could be implemented for electrical engineering courses at programs following ABET accreditation, where it is very important to ensure that the student learning outcomes are met. The survey conducted at the end of the semester provided positive feedback on this approach. There were some suggestions that are useful for improving the



approach. This case study would be useful for motivating more of such approaches for engineering programs. The approach has been useful in advocating the fundamental principles of PBL. The implementation results of the MPL model make learners more creative, and thus, it becomes easier for the learners to understand the study material presented by the teacher. Moreover, MPL is also able to provide opportunities for students to apply knowledge in a real context because their teacher has already delivered certain topics related to the material. Furthermore, the implementation of this multi-project based learning can be a solution, making learning more productive and fun while reducing the overload of individual project-based learning schemes.


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## Appendix A



Department of Electrical Engineering  
ELEC 371+ELEC 333 + ELEC 334  
Course Project - Fall 2015

Dr. Farid Touati, Prof. Mohieddine Benammar, Dr. Muhammad Chowdhury, Eng. Antonio Gonzales & Eng. Amith Khandakar

The aim of the project is to subject the student to a typical design problem that might be faced during his/her engineering practice. Therefore, the students are expected to complete their projects with no or minimum assistance from the instructors. Also, remember that the objective of this project is to pick a subject and try to learn more by going deeper than what was (or wasn't) covered in class.

There are three options for the project:

- Option 1 (below): Does not require approval from the instructors of the course.
- Option 2 (below): Does not require approval from the instructors of the course.
- Option 3: You have to prepare and propose a project that combines sensors and Op-Amps. The proposal must be discussed with and approved by the instructors of the courses.

**Deliverables (to be submitted two weeks before the end of the semester):**

- 1) A proof of concept must be demonstrated
- 2) A detailed simulation must be demonstrated
- 3) A detailed report must be presented

The details of each option is as follows:

**Option 1:**  
Design and construct a battery-operated and portable 3-lead ECG monitor that uses 3 patch-type electrodes, necessary signal amplification and filtering, and display of the ECG signal on an oscilloscope.

Teams who will be able to display the ECG signal on an LCD, a smart phone or a tablet will receive 30% (of their Term project grade) as bonus.

**Option 2:**  
Design and construct a battery-operated and portable metal detector that uses an inductive loop as sensor together with an Op-amp based oscillator to detect metals buried under ground. The minimum requirement is to be able to detect reliably a 50 Dirhams coin under a 1cm-thick cardboard.

Teams who will be able to detect smaller objects (example 25 Dirhams coin) and/or buried at depth higher than 2cm will receive a bonus. The bonus will depend on the performance of the detector.

**Option 3:**  
Prepare a proposal for a Sensors and Op-Amp based circuit project.

Your proposal must include the following but not limited to:

1. Title.
2. Names of the students.
3. Objectives.
4. Block diagram (*preferably schematic diagram*) and project description.
5. Main electronic components and equipment needed for the project.

**Project Report:**

The report will include:

1. Introduction and problem statement
2. Background and literature review
3. Design constraints and applicable standards
4. Proposed Solution(s)
  - 4.a) Theory
  - 4.b) Simulation
  - 4.c) Practical Implementation and Performance Analysis (discussion of results)
5. Conclusion
6. References
7. Appendix (include here codes, datasheets, etc.)

**Project Assessment:**

The project will be assessed also based on the following points:

1. Problem well formulated in the report and during demonstration
2. Diversity of sources of information used (books, papers, web sites, etc.)
3. Design constraints and objectives are well defined
4. Demonstrate ability to apply appropriate electrical design
5. Use of simulation tools
6. Use of equipment/instrumentation
7. Performance constraints defined/met
8. Cost constraints defined/met
9. Safety issues are investigated /met
10. Investigation of various possible solutions
11. Discussion of results and explanation of sources of discrepancies.
12. Solution employing up-to-date tools

Figure A1. Project Guidelines.

Student Name	Project Title	Total Marks	
		Examiner/s:	

Performance Indicators	Rubrics	Maximum score	Score	
Report structure (does it follow the template?)	Abstract	/5	0.5	
	Acknowledgement		0.5	
	Table of Contents		0.5	
	Introduction, problem statement, and objectives		0.5	
	Background		0.5	
	Design constraints and applicable standards		0.5	
	Methodology		0.5	
	Testing, Results, and Discussion		0.5	
	Conclusion and Future Work		0.5	
	References		0.5	
	Exceeded Maximum Number or Pages (2 marks deduction for each page exceeded)			
	English language		Spelling mistakes	/5
	Grammatical errors	2.5		
Introduction, problem statement and objectives	Is there a proper introduction for the subject?	/10	5	
	Is the problem well formulated?		2.5	
	Are the objectives well defined?		2.5	
Background	Is there any background information relative to the topic of the project?	/5	3	
	Are there any other similar products or projects?		1	
	Is there proper referencing to the information provided?		1	
	Are the design constraints clearly defined?		5	
	Are there any safety issues that need to be considered?	/15	5	
	Are there any cost limitations?		1	
	Are there any international or local standards that are applicable to the project? If yes, were they identified and considered with proper referencing?		4	
Methodology	Were different solutions considered before arriving at the proposed one?	/20	2	
	Is the proposed solution clearly defined?		2	
	Theoretical analysis (Design calculations)		10	
	Simulations of the designed circuit is presented		3	
	Practical implementation is presented?		3	
	Proper testing using suitable instruments and equipment for the simulated circuit with acceptable results are presented		10	
Testing, results and discussion.	Proper testing using suitable instruments and equipment for the implemented circuit with acceptable results are presented	/35	10	
	Comparison between theoretical, simulated and practical results were made		8	
	Limitations of the implemented design are identified and suggestions for improvements have been discussed.		2	
	Uncertainty errors have been identified, calculated and presented.		5	
	Reference is included in the report.		/5	3
Proper referencing is presented in the report.	1			
Diverse list of reference is presented in the report.	1			

Figure A2. Project Report Grading Rubric.

Week No.	Date (Sundays)	Lab activities	Pre-lab and post lab activities	Week No.	Date (Tuesdays)	Lab Topics	Lab activities	Pre – Lab and Post – Lab Activities
1	15 Sept. 2015	<ul style="list-style-type: none"> <li>Lab Orientation</li> <li>Lab Policies and Guidelines</li> <li>Safety Issues</li> <li>Lab Report Format</li> <li>Policies on Lab reports and pre lab concerns.</li> <li>Lab Activities.</li> <li>Forming of lab groups</li> <li>Familiarization with the K&amp;H KI-200 Linear Circuit Lab System.</li> <li>Lab work for Lab 1.</li> <li>Review on LabVIEW Programming.</li> <li>Introduction to K&amp;H KI-200 Linear Circuit Lab Module.</li> <li>Deadline for the submission of the Lab Report in the Blackboard by the end of Wednesday(23/09/2015)</li> </ul>	Start with the pre-lab task for Lab 2	1	15 Sept. 2015	Lab0 Introduction to Transducers and the Instrumentation (LI Kit)	<ul style="list-style-type: none"> <li>Lab Orientation</li> <li>Introduction to Lab Rules.</li> <li>Safety Issues.</li> <li>Lab Report Format.</li> <li>Policies on Lab reports and pre lab concerns.</li> <li>Forming of lab groups</li> <li>Introduction to Transducers and Instrumentation (LI Kit).</li> </ul>	<ul style="list-style-type: none"> <li>Study the Manual for Lab1.</li> <li>Start preparing the pre-Lab for Lab 1.</li> </ul>
				22 Sept. 2015 No Lab (Eid Al-Adha Holiday)				
2	29 Sept. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 2</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 2 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Start with the pre-lab task for Lab 3.</li> </ul>	2	29 Sept. 2015	Lab1 Measurement Fundamentals and Data Analysis	<ul style="list-style-type: none"> <li>Lab work for Lab 1.</li> <li>Deadline of the online submission of lab report for Lab1.</li> </ul>	<ul style="list-style-type: none"> <li>Start preparing the pre-Lab for Lab 2.</li> <li>Do some research on the Term Project.</li> </ul>
3	06 Oct. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 3</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 3 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Start with the pre lab task for Lab 4.</li> </ul>	3	06 Oct. 2015	Lab2 Wheatstone Bridge Measurements	<ul style="list-style-type: none"> <li>Lab work for Lab 2</li> <li>Deadline of the online submission of lab report for Lab2.</li> </ul>	<ul style="list-style-type: none"> <li>Do some research on the Term Project.</li> </ul>
4	13 Oct. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 4</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 4 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Start with the pre lab task for Lab 5.</li> </ul>	4	13 Oct. 2015	<ul style="list-style-type: none"> <li>Term Project Start up</li> <li>Initiation: Introduction to discrete sensors</li> </ul>	<ul style="list-style-type: none"> <li>Term Project Start up Initiation</li> </ul>	<ul style="list-style-type: none"> <li>Start preparing the pre-Lab for Lab 3.</li> </ul>
5	20 Oct. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 5</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 5 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Continue with the pre lab task for Lab 5.</li> <li>Prepare for the groups for the term project.</li> </ul>	5	20 Oct. 2015	Lab3 Temperature Measurements	<ul style="list-style-type: none"> <li>Lab work for Lab 3</li> <li>Deadline of the online submission of lab report for Lab3.</li> </ul>	<ul style="list-style-type: none"> <li>Start preparing the progress report.</li> <li>Work on the Term Project</li> </ul>
6	27 Oct. 2015	<ul style="list-style-type: none"> <li>Project initiation.</li> <li>Distribution of the components for the project.</li> <li>Lab work for Lab 5</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 5 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project</li> </ul>	6	27 Oct. 2015	Term Project	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> <li>Discuss the progress of the project to the supervisor.</li> <li>Deadline of the submission of the term project proposal</li> <li>Acquisition of the sensors and other components for the project.</li> </ul>	<ul style="list-style-type: none"> <li>Continue preparing the progress report.</li> <li>Work on the Term Project</li> <li>Start preparing the pre Lab for Lab 4</li> </ul>
7	03 Nov. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 6</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 6 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Continue with the pre lab task for Lab 5.</li> <li>Work on the Term Project</li> </ul>	7	03 Nov. 2015	Lab4 Environmental Measurements.	<ul style="list-style-type: none"> <li>Lab work for Lab 4.</li> <li>Deadline of the online submission of lab report for Lab4.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the term Project</li> </ul>
8	10 Nov. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 7</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 7 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> </ul>	8	10 Nov. 2015	Term Project	<ul style="list-style-type: none"> <li>Prepare a progress report</li> <li>Work on the Term Project</li> <li>Discuss the progress of the project to the supervisor.</li> </ul>	<ul style="list-style-type: none"> <li>Continue preparing the progress report.</li> <li>Work on the Term Project.</li> <li>Start preparing the pre Lab for Lab 5</li> </ul>
9	17 Nov. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Start with the pre lab task for Lab 7.</li> <li>Work on the Term Project.</li> </ul>	9	17 Nov. 2015	Lab5 Linear Position / Force Applications	<ul style="list-style-type: none"> <li>Lab work for Lab 5.</li> <li>Deadline of the online submission of lab report for Lab5.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> <li>Continue preparing the Term project progress report.</li> </ul>
10	24 Nov. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> </ul>	10	24 Nov. 2015	Term Project	<ul style="list-style-type: none"> <li>Submission of the Term project progress report</li> <li>Work on the Term Project</li> <li>Discuss the progress of the project to the supervisor.</li> </ul>	<ul style="list-style-type: none"> <li>Start preparing the Final Term project report</li> <li>Work on the Term Project.</li> <li>Start preparing the pre Lab for Lab 6</li> </ul>
11	01 Dec. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 7</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 7 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Start with the pre lab task for Lab 8.</li> <li>Work on the Term Project</li> </ul>	11	01 Dec. 2015	Lab6 Light Sensors	<ul style="list-style-type: none"> <li>Lab work for Lab 6.</li> <li>Deadline of the online submission of lab report for Lab6.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project</li> <li>Continue preparing the Final Term project report.</li> <li>Start preparing the pre Lab for Lab 7</li> </ul>
12	08 Dec. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> <li>Prepare for the Final Practical Exam</li> </ul>	12	08 Dec. 2015	Lab7 Rotational Speed or Position Measurement.	<ul style="list-style-type: none"> <li>Lab work for Lab 7.</li> <li>Deadline of the online submission of lab report for Lab7.</li> </ul>	<ul style="list-style-type: none"> <li>Review for the Final Practical Exam</li> </ul>
13	15 Dec. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> </ul>	13	15 Dec. 2015	Term Project / Final Practical Exam Revision	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> <li>Review for the Final Exam</li> </ul>	<ul style="list-style-type: none"> <li>Continue preparing the Final Term project report.</li> </ul>
14	22 Dec. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> </ul>	14	22 Dec. 2015	Final Practical Exam	<ul style="list-style-type: none"> <li>Final Practical Exam</li> </ul>	<ul style="list-style-type: none"> <li>Finalize the Final Term Project Report.</li> </ul>
15	29 Dec. 2015	<ul style="list-style-type: none"> <li>Lab work for Lab 8</li> <li>Deadline for the submission of the lab report in the blackboard for Lab 8 at the end of the lab session.</li> </ul>	<ul style="list-style-type: none"> <li>Work on the Term Project.</li> </ul>	15	29 Dec. 2015	Term Project Demonstration /Grading	<ul style="list-style-type: none"> <li>Project Demonstration.</li> <li>Submission of the Final Term Project Report.</li> </ul>	

(a)

(b)

Figure A3. Lab Schedule for (a) Electronics Engineering, (b) Sensors and Instrumentation.

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