A Study on Integrating Case-Based Learning into Engineering Curriculum

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SESSION: C1 Integration of theory and practice in the learning and teaching process

CONTEXT Republic Polytechnic in Singapore uses a range of lesson delivery pedagogies, namely: Problem-Based Learning, Interactive Seminar, Cognitive Apprenticeship and Project-Based Learning. Republic Polytechnic, School of Engineering has an interest in exploring methods to enhance students' learning in engineering modules. One idea is to explore the use of a topic-focused Case Study Paper that would span across a few lessons in an engineering module.

PURPOSE The purpose of the study is explore the usage of a Case Study Paper in a practical module for the school to enhance the student learning experience.

APPROACH This randomized experimental study involved engineering students who were taking Microcontroller Systems module in academic year 2016-2017 . A topic-focused Case Study Paper was added to the required student delivery of the module for this experimental study. A small group of 30 participants were randomly chosen from the cohort taking the module, and their Case Study Papers were analysed. The analysis performed were analysis using scoring rubric and Content analysis to categorize the students' work according to themes.

RESULTS Results from the scoring rubrics revealed that students needed help to improve on technical depth of the paper and clarity of presented diagrams. It also revealed students are good at transferring knowledge from other modules or from content learnt from Microcontroller Systems module to the Case Study Paper. Content analysis helped to answer these two questions:

- What are the applications that students proposed in their Case Study Paper that has a microcontroller?
- When students describe the applications, did they describe the major electronic components?

CONCLUSIONS While the results from the analysis of the Case Study Paper for the Microcontroller Systems module in this study has been quite positive, its effectiveness in improving students' learning is not conclusive due to the limitations of the study.

KEYWORDS Case-Based Learning, Case Study Method, STEM, Engineering Case Study.

Introduction

A polytechnic in Singapore adopts a range of pedagogies, namely: Problem-Based Learning (PBL), Interactive Seminar (IS), Cognitive Apprenticeship (CA) and Project-Based Learning (PjBL). The School of Engineering in the polytechnic has an interest in exploring methods to enhance students' learning in engineering modules. One idea is to explore the use of the Case Study Method that would span across a few lessons in a module.

Objectives of Study

The purpose of the study is to focus on exploring the usage of the Case Study Method in a hands-on practical module for the school to enhance the student learning experience. This randomized control trial study involved engineering students who were taking Microcontroller Systems module. A topic-focused Case Study Paper was added to the lesson plan of the module for this experimental study with institutional ethical approval.

Case studies are stories that are used as a teaching tool to show the application of a theory or concept to real situations. Cases can be fact-driven and deductive where there is a correct answer, or they can be context driven where multiple solutions are possible. Case studies have been widely used as a teaching tool in various disciplines and educational institutions. The use of case study method dates back to 1870, when Harvard Law School newly appointed dean, Christopher Columbus Langdell, introduced law-based case studies in the school. (Garvin, Sept-Oct 2003)

Methods

Participants of this study included second year students from the School of Engineering in the polytechnic in the academic year 2016–2017, taking the Microcontroller Systems module. This module was conducted using the polytechnic's Problem-Based Learning (PBL) pedagogy. Table 1 shows the typical daily routine for a student in the polytechnic using the Problem-Based Learning pedagogy. The starting time for the day's lesson for students of different years varies to avoid congestion in the canteens during break hours. There is an assigned lecturer and about 25 students per class. Individual students are required to submit a reflection at the end of each day's lesson, which is called a 'reflection journal' at the polytechnic.

However, in this experiment an assignment was added to write a Case Study Paper. The lecturer introduced the assignment to the students, and the topic for the paper was released in the first lesson in the Microcontroller Systems module. The students were to write the paper about an application of microcontroller(s) they had encountered in their daily life. The Case Study Paper included:

- Student's idea about the application
- Description and functionality of the system
- Input and Output(s) list
- Student's idea about a block diagram of the system

Scaffolding for this assignment was provided during the first four lessons of the module. Instructional scaffolding provides students with support to allow them to complete their tasks. Benson (1997) describes scaffolding as a bridge used to build upon what students already know to reach a new concept. Specifically, scaffolding came in the form of the reflection journals and guidance from the lecturer. For lessons one to three, there were specific reflection journal questions that helped students answer a part of the Case Study Paper. In lesson four, Learning Phase Three was used to help students finalize the Case Study Paper for submission.

Table 1: Lesson Routine in the Polytechnic's Problem-Based Learning Pedagogy

Duration within a session	Period	Description
60mins	Learning Phase 1	Students receive a problem as a trigger for learning. With the help of the lecturer, the students examine the problem and clarify what it is they know and do not know and formulate possible hypotheses. Each group identifies learning issues they will investigate. Groups employ research strategies to collect relevant information. Students collect different Information so that their knowledge may diverge at this point.[1]
45mins	Break	Lecturer leaves the class. Groups are on their own to continue to do their work or go for break.
90mins	Learning Phase 2	The groups of five meet individually with the lecturer to discuss their progress. Students continue in their group of five to review resource materials and peer teach what it is they have learnt from their research. Information convergence[2] should take place.
90mins	Study Period	Lecturer leaves the class. Groups are on their own to arrange for lunch break and prepare for presentation.
120mins	Learning Phase 3	Each team presents its findings to the other groups. Groups discuss, defend and justify their outcomes. Lecturer presents recommended answer to the problem.

Out of 164 students who submitted their Case Study Papers, 30 students were randomly selected for the study with their consent. Analysis was performed on these selected Case Study Papers. The analysis was separated into three parts:

- Analysis using scoring rubrics (Table 2)
- Content analysis to categorize the students' work according to themes
- Comparison of the quality of Case Study Paper to the quality of the reflection journals

The Valid Assessment of Learning in Undergraduate Education (VALUE) rubrics, developed by Association of American Colleges and Universities' (AAC&U) Liberal Education and America's Promise (LEAP) initiative, were referenced when creating the customized scoring rubrics in Table 2. Moskal (2000) states that by developing a pre-defined scheme for the evaluation process, the subjectivity involved in evaluating a student work product (she was discussing an essay, specifically) becomes more objective.

[1] From the Problem Statement, student work out what they know, what they do not know, and what they need to find out. The initial search for information is divergent and not all information will lead to the solution. This is encouraged in learning phase 1 to inculcate brainstorming and creative thinking.

[2] The lecturer work with each team to help them combine the information they had collected individually to lead to a possible solution for the problem of the day.

Table 2: Scoring Rubrics for Case Study Paper

CATEGORY	Excellent (4)	Very Good (3)	Satisfactory (2)	Weak (1)	Unsatisfactory (0)
Components of Case Study Paper	All required elements are present and additional elements that add to the report (e.g., thoughtful comments, graphics) have been added.	All required elements are present.	One required element is missing, but additional elements that add to the report (e.g., thoughtful comments, graphics) have been added.	Several required elements are missing.	All required elements are missing.
Amount of Information	All subtopics are addressed with at least 100 words each (except diagrams sections).	All subtopics are addressed with at least 80 words each (except diagrams sections).	All subtopics are addressed with at least 50 words each (except diagrams sections).	One or more subtopics are addressed with less than 50 words (except diagrams sections).	All subtopics are addressed with less than 50 words (except diagrams sections).
Quality of Information	Information clearly relates to the main topic. It includes three or more supporting details/examples.	Information clearly relates to the main topic. It provides at least two supporting details/examples.	Information clearly relates to the main topic. It provides at least one supporting detail/example.	Information clearly relates to the main topic. No supporting details/examples are given.	Information has little or nothing to do with the main topic.
Explanation of Application	Explanation is clear. There is technical depth in the explanation.	Explanation is clear.	Explanation is a little difficult to understand, but includes major components of the proposed application.	Explanation is difficult to understand and is missing several components of the proposed application.	No Explanation given.
Diagrams & Illustrations	Diagrams and illustrations are neat, accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are accurate and sometimes add to the reader's understanding of the topic.	Diagrams and illustrations are not accurate OR do not add to the reader's understanding of the topic.	No diagram and illustration.
Application of Transfer	More than two clear applications of knowledge and skills from previous learning (from current module or from previous modules).	At least two clear applications of knowledge and skills from previous learning (from current module or from previous modules).	At least one clear application of knowledge and skills from previous learning (from current module or from previous modules).	At least one vague application of knowledge and skills from previous learning (from current module or from previous modules).	No application of knowledge and skills from previous learning.

As Tedds and Brady (2009) write one of the limitations of an analysis based on scoring rubrics is that it can be highly interpretive, making it difficult to generalize the results. Content analysis is performed for this study to address the limitation of scoring by using a rubric. Two questions that the content analysis can help to answer are:

- What are the applications that students proposed in their Case Study Paper that has a microcontroller?
- When students describe the applications, did they describe the significant electronic components?

To answer the first question, major categories of applications were identified and their occurrence counted. The answer to this question can help to identify what are the easier categories for students to propose. To answer the second question, significant electronic components were identified and their occurrence counted. Collectively, these data can help to identify gaps in what students should include in their application descriptions.

Because the reflection journal in lessons one to three are used to provide scaffolding for students to complete their Case Study Paper, we hypothesize: (1) the content of the journals and the Case Study Paper should not deviate too far, and (2) the quality of the Case Study Paper should be better than the quality of the journals. Lessons one and two journals are used for the comparison analysis. Lesson three journals were not used as they were done offline on paper and not submitted for analysis for this study.

Results

Using the scoring rubrics, the Case Study Papers of the 30 students were rated. For each student, the final rubric score was computed from the average scores of the six categories that composed the rubric. From those average scores, the mean, median, and standard deviation were computed based on the students' average scores and tabulated. The histogram in Figure 1 shows that the distribution closely resembles the bell curve, with a steeper slope on the right side of the mean. It can also be observed that the distribution is all on the right side of the graph, with lowest score being 1.83.

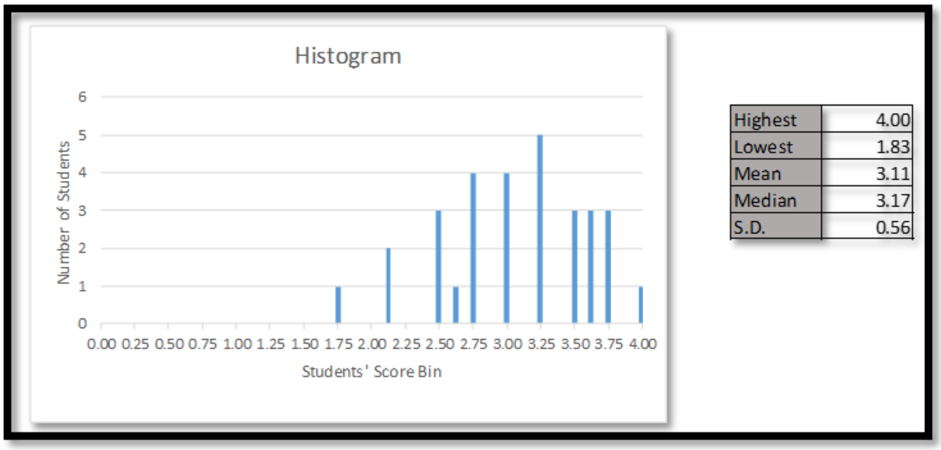

Figure 1: Histogram, Mean, Median, and S.D of Students' Average Scores

The mean score for each of the six rubrics category was computed and shown in Figure 2. The 'quality of information' category had the highest mean of 3.67, followed closely by the 'application of transfer' category and 'components' category with means of 3.6 and 3.5, respectively. The means for the 'explanation of application' category, as well as the 'diagrams and illustrations' category, are lower than the overall rubrics mean of 3.11, scoring 2.63 and 2.27 respectively. The students' average continual assessment grade is about 2.2 to 2.5 for Microcontroller Systems module. A rubric mean above this value can be considered as above average.

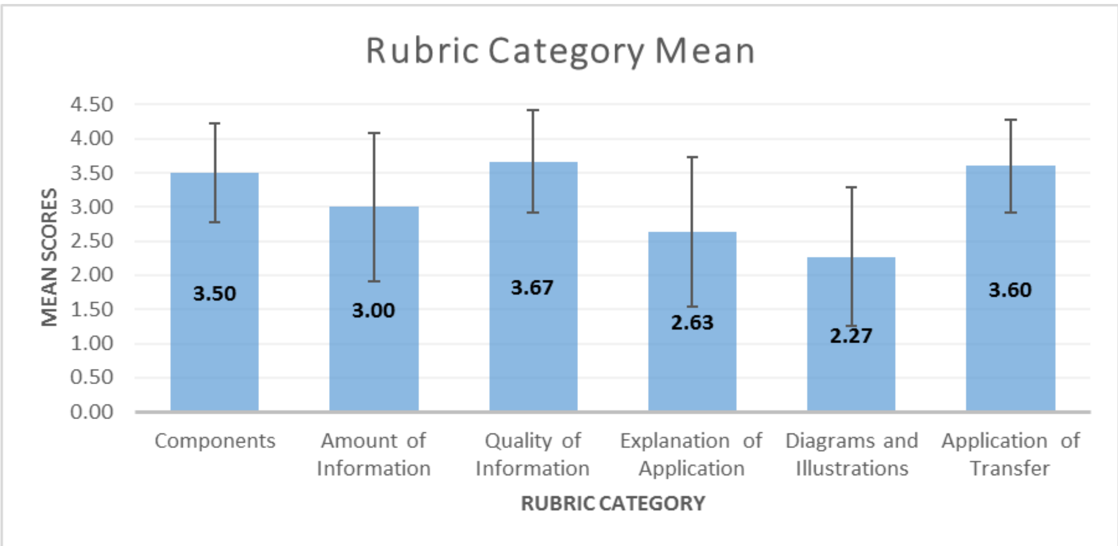

Figure 2: Students' Rubric Category Mean

Content analysis identified four types of applications the students wrote about: Household Equipment, Entertainment Devices, Office Equipment, and Miscellaneous. The distribution of the applications by categories is shown in Table 3. The application categories are mutually exclusive so there was a total of 30 applications.

Table 3: Student Identified Application Categories of the Case Study Paper Submissions

Categories	Occurrence
Household Equipment	15
Entertainment Devices	9
Office Equipment	2
Miscellaneous	4
Total	30

Further content analysis revealed that 29 out of 30 students described electronic components and wrote about their use. Among the electronics components mentioned in the papers, LEDs (Light Emitting Diodes), buttons, switches, keypads, sensors, buzzers and speakers were most prevalent. The applications proposed by the students are also examined to identify if these components should be included. LEDs should be included in 27 applications. Fourteen out of these 27 applications mentioned and described the use of LEDs. Buzzers and speakers should be included in 10 applications. All 10 of these applications described the use of buzzers and speakers. All 30 applications should include the description of buttons, switches or keypads, and 23 applications do mention and describe them. Sensors should be included in 25 applications, and 20 applications described them. The electric motor should be included in 19 applications, and it was included in 10 applications.

The students' Case Study Papers were compared to their reflection journals for lesson one and lesson two. The correlations between the reflection journals and the Case Study Paper were analyzed. The students would fall into one of the six mutually exclusive categories depending on how similar the entries in their reflection journals were to the sections of their Case Study Paper:

- Category One: Students with both lessons one and two reflection journals identical, almost identical, or identical subset (this means part of the RJ and the related section of the CSP contains exactly the same information in the same wordings.) to the application and system functionality description sections of their Case Study Paper.
- Category Two: Students with both lessons one and two reflection journals related to the application and system functionality description sections of their Case Study Paper.
- Category Three: Students with lesson one reflection journal related to the application section of their Case Study Paper and lesson two reflection journal identical, almost identical, or identical subset to the system functionality description section of their Case Study Paper.
- Category Four: Students with lesson one reflection journal identical, almost identical, or identical to the application section of their Case Study Paper, and lesson two reflection journal related to the system functionality description section of their Case Study Paper.
- Category Five: Students with lesson one not related to their Case Study Paper, and lesson two reflection journal related to the system functionality description section of their Case Study Paper.

- Category Six: Students with both lessons one and two reflection journal not related to their Case Study Paper.

Table 4 summarizes shows the number of students in each category when we correlate the similarity in quality of the entries in the reflection journals to the overall rubric scores on the Case Study Paper. For each category, the average rubric scores of all students in the category is shown.

Table 4: Summary of Six Categories Average CSP Rubric Score

	Average CSP Rubric Score	Number of Students
Category One	3.11	12
Category Two	2.93	10
Category Three	3.08	4
Category Four	3.67	1
Category Five	3.67	2
Category Six	3.33	1

Discussion

Referring to Figure 1, the overall scoring mean for the Case Study Paper is 3.11. This suggests that students performed above average for the Case Study Paper. Looking more deeply into the separate categories of the scoring rubrics, it can be observed that students performed better in some categories than in others. This analysis seems to suggest students are best at providing quality information and applying transfer of knowledge. Students are not very good at providing technical depth as reflected in the lower score for explanation of application category. The worst category is diagrams and illustrations category, which indicates that students need help to improve in this ability. One of the possible reason for the low mean score of 2.27 for this category is that the system functionality description and the block diagram were done in lessons two and three respectively. Most students probably did not visualize a block diagram in lesson two when explaining how their proposed application functions. In lesson three, these students probably did not refer back to their written functional description in lesson two while drawing the block diagram for their system. In lesson four, when the Case Study Paper is due for submission, a review to check for consistency between the system functional description and the block diagram was probably not done either.

The content analysis findings summarized in Table 3 revealed two major categories of applications described by students: Household Equipment and Entertainment Devices. This suggests that it is easy for students to relate to equipment commonly found in the home or systems used for entertainment as examples of microcontroller applications. This familiarity with certain types of equipment can be used to the instructor’s advantage as he/she can discuss these applications in class, and the students will understand the reference. The content analysis findings also indicate that 29 out of 30 students described at least one electronic component in their papers. This shows that most students are able to apply prior knowledge and skills from the Microcontroller Systems module and from other modules like Engineering Design and Digital Electronics. Closer analysis indicated that while most students included buzzers in their applications, many omitted the LEDs, sensors, switches, or motors in their system. This suggests that we need to help students better understand the complexity of the systems we want them to be familiar with.

Referring to Table 4, it can be observed that Category One has a higher average rubric score compared to Category Two. This means that students whose reflection journals in both lessons one and two were identical, almost identical, or identical to the sections in those students' Case Study Paper performed better than students whose reflection journals were only somewhat related to the sections of their Case Study Paper. This suggests that the strategy of using what had been written in reflection journals to write complete sections of the Case Study Paper is an effective one, which can also help the instructor guide the students in writing a Case Study Paper. Although there were only four students in Categories Four, Five, and Six, we do note those students had higher averages than the students in Category One. This suggests that a few students are strengthening what they wrote in their reflection journals to develop sections of their Case Study Papers. We need to think about how instructors can further encourage this kind of improvement.

Limitations of the Study

While the study provides new insights into the use of the case study method for the polytechnic and other engineering schools, there are some unavoidable limitations of this study. First, as this is an individual thesis work, the Principal Investigator is the only analyst of the study. Having at least two people rate both the RJs and Case Study Papers would allow for inter-rater reliability, which strengthens the rigor of the findings. Second, due to time constraints, this study was conducted with only 30 randomly selected students from the cohort of students taking the Microcontroller Systems module. Lastly, the results of the Microcontroller Systems module examinations for the cohort of students who wrote the Case Study Paper should be compared to the exam scores of the cohort of students who did not do the Case Study Paper. This can help reveal if the Case Study Paper helped students improve their performance in the module. However, prior Microcontroller Systems module examinations do not have any questions related to Case Study Paper. While the Mid Term Assessment (MSA, similar to a mid-term exam) for this cohort includes a question related to the Case Study Paper, there is no comparison from past results.

Recommendations

This study has shown the Case Study Paper has promise as an assignment in the Microcontroller Systems module. However, the analysis in this study has helped to identify some issues with the implementation of the Case Study Paper. These issues, however, can be resolved with more stringent requirements and better facilitation in future implementations. Instructors implementing the Case Study Paper in the Microcontroller Systems module in the future should consider these recommendations:

- The assignment should add a requirement that emphasizes technical depth.
- The lecturer(s) should provide more guidance to students on how to produce papers with more technical depth.
- The lecturer(s) should provide more guidance to the students on drawing and explaining block diagrams.
- The students should be directed to use a platform (e.g., DrawIO) that allows for the standardization of the block diagrams.
- The lecturer(s) can recommend that the students use household equipment or entertainment devices for their applications since these seem easier for the students to comprehend.
- The lessons on the usage of LEDs in microcontroller applications should be reviewed to create a better awareness among students about how LEDs are used in micro controller applications.
- The usage of motors should be reviewed in the other engineering modules.

- The lecturer(s) should recommend the students use the RJs to scaffold complete sections of the Case Study Paper; this seems to result in better submissions.
- A full-day lesson should be implemented on writing the Case Study paper in the lesson the Case Study Paper is due. This would allow students more time to review, edit, and add information to their Case Study Paper. The lecturer(s) would also have more time for guiding students.
- The Case Study Paper should be implemented in later lessons in the Microcontroller Systems module instead of lessons one to four. All basic I/Os can be covered prior to the Case Study Paper, and students would be better equipped with microcontroller knowledge and skills.

Conclusion

While the results from the analysis of the Case Study Paper for the Microcontroller Systems module in this study has been positive, its effectiveness in improving students' learning is not conclusive due to the limitations of the study. More analyses should be done by a team. For now, it is recommended that the Case Study Paper be implemented for a few more runs in the Microcontroller Systems module to collect more data for future studies.

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