Enhancing Student Learning Through Use of Case Study Paper in Republic Polytechnic, Singapore

by

Yew Hua Tham

M.Phil., Computer Engineering
Nanyang Technological University, 2000

B.ASc., Computer Engineering
Nanyang Technological University, 1999

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
OCT 26 2016
LIBRARIES
ARCHIVES

Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the

Massachusetts Institute of Technology

September 2016

©2016 Yew Hua Tham. All rights reserved.

The author hereby grants to MIT permission to reproduce and to distribute publicly paper and electronic copies of this thesis document in whole or in part in any medium now known or hereafter created.

Signature redacted

Signature of Author: _____
Yew Hua Tham
System Design and Management Program
July 26, 2016

Signature redacted

Certified by: _____
Lori Breslow
Senior Lecturer, MIT Sloan School of Management
Thesis Supervisor

Signature redacted

Accepted by: _____
Warren Seering
Weber-Shaughness Professor of Mechanical Engineering

MITLibraries

77 Massachusetts Avenue
Cambridge, MA 02139
http://libraries.mit.edu/ask

DISCLAIMER NOTICE

Due to the condition of the original material, there are unavoidable flaws in this reproduction. We have made every effort possible to provide you with the best copy available.

Thank you.

The images contained in this document are of the best quality available.

This page intentionally left blank

Enhancing Student Learning Through Use of Case Study Paper in Republic Polytechnic, Singapore

By

Yew Hua Tham

Submitted to the Systems Design and Management Program on July 26, 2016
in partial fulfillment of the requirements for the degree of
Master of Science in Engineering and Management

Abstract

While the dominant lesson delivery style in Republic Polytechnic in Singapore is its unique One-Day-One-Problem approach using the Problem-Based Learning pedagogy, there have been other lesson delivery methods adopted by Republic Polytechnic in recent years. While the case study method has not yet been adopted by School of Engineering in the polytechnic, the school is keen to explore its effectiveness in enhancing students' learning in engineering modules.

This thesis is a study of the effectiveness of a trial implementation of the case study method for E206 Microcontroller Systems module in the school. The cohort taking the Microcontroller Systems module in semester one in 2016 wrote and submitted a case study as part of lesson four in the module. A random sample of 30 students from the cohort were selected to participate in the analysis on the effectiveness of the trial implementation. Assessment using a rubric and content analysis are performed on the papers submitted. The submitted papers are cross-referenced to students' reflection journals for consistency in quality. The reflections journals are designed to help students write their Case Study Paper. While the findings show positive results, the effectiveness of the case study method in an engineering module is not conclusive due to the limitations of the study. It is recommended that the Case Study Paper be implemented for a few more runs of the Microcontroller Systems module to collect more data for future follow-up studies.

Thesis Supervisor: Lori Breslow
Title: Senior Lecturer, MIT Sloan School of Management

This page intentionally left blank

Acknowledgements

I would first like to thank my thesis supervisor, Dr. Lori Breslow, of the MIT Sloan School of Management. The door to Dr. Lori's office was always open whenever I needed her expert advice on my research work. She consistently allowed this thesis to be my own work, but steered me in the right the direction whenever she thought I needed it. I have certainly learnt much in the field of academic research from her. Without her, I would not be able to complete this thesis study that matters so much to me.

I would also like to thank my sponsor, Republic Polytechnic, Singapore. The sponsorship allows me to complete my one year of studies here in MIT. I am very grateful for the opportunity given.

I would also like to express my appreciation to my director and colleagues in School of Engineering, Republic Polytechnic, Singapore. It is with strong recommendations from Dr. Wang Jianguo, Director of School of Engineering, Republic Polytechnic, that I am able to study here in MIT. In addition, Dr. Wang approved this thesis study which involves staff and students from School of Engineering, Republic Polytechnic. This study is made possible with the support of my co-worker, Mr. Kwek Chin Wee, module chair of Microcontroller Systems module. He executed my plans on implementing the Case Study Paper, recruited the participants of the study, and collected the Case Study Paper submissions for me. Chin Wee's focus and ability in supporting me in this study have ensured that the study was conducted smoothly. Other colleagues that have given their support and blessings to this thesis study are Mr. Soh Lai Seng, Academic Assistant Director of School of Engineering, Dr. Eric Teo, Programme Chair of Diploma in Electrical and Electronic Engineering, Ms. Lim Chiew Yen, Assistant Programme Chair of Diploma in Electrical and Electronic Engineering.

I must express my gratitude to my parents, and my siblings for the support and for taking care of things back home in Singapore while I am here studying in MIT in the USA.

Last but not least, I need to thank my wife, Zhemin, who have given up her job in Singapore, followed me here to the USA, and provided me with unfailing support and continuous encouragement in this one year of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without her. Thank you, Dear.

This page intentionally left blank

Table of Contents

Acknowledgements 5

List of Figures 10

List of Tables 11

Chapter 1: Introduction 13

1.1: Motivation 13

1.2: Purpose and Research Objective of Study 13

1.3: Stakeholders of the Study 14

1.4: Clearance to Conduct Study Involving Human Subjects 15

1.5: Chapters Organization 15

Chapter 2: Background 17

2.1: Polytechnics in Singapore 17

2.2: Republic Polytechnic 18

2.3: PBL 19

2.4: Republic Polytechnic's One-Day-One-Problem Pedagogy 19

2.5: Alternative Lesson Delivery Methods in Republic Polytechnic 21

2.5.1: Variants to One-Day-One-Problem Lesson Delivery 22

2.5.2: Interactive Seminar 22

2.5.3: Block Class 23

2.6: Microcontroller Systems Module 24

Chapter 3: Literature Review 27

3.1: Reflection Journal as Teaching and Learning Tool 27

3.2: Reflection Journal in Republic Polytechnic 28

3.3: One-Minute Paper and Mud Card as Teaching and Learning Tools 30

3.4: One-Minute Paper and Mud Card in Republic Polytechnic 33

3.5: Case Study Method 33

3.6: Case Study Method in Republic Polytechnic 36

Chapter 4: Methodology for Case Study Paper 37
4.1: Subjects 37
4.2: Case Study Paper Topic 37
4.3: Scaffolding through the Reflection Journals (RJs) 38
4.4: Timeline 39
4.5: Grading 40
4.6: Anti-Plagiarism Rules 40
4.7: Data Collection 40
4.8: Analysis 41
4.8.1: Scoring Rubrics 41
4.8.1: Content Analysis 44
4.8.2: Comparison of quality of Case Study Paper to quality of RJs 44
Chapter 5: Results 47
5.1: Scoring Rubrics Results 47
5.1.1: Components Category 49
5.1.2: Amount of Information Category 50
5.1.3: Quality of Information Category 51
5.1.4: Explanation of Application Category 52
5.1.5: Diagrams and Illustrations Category 53
5.1.6: Application of Transfer Category 54
5.2: Content Analysis Findings 55
5.3: Comparing Case Study Paper to RJs 60
Chapter 6: Discussion 69
6.1: Scoring Rubrics Discussion 69
6.1.1: Components of Case Study Paper Rubric Category 69
6.1.2: Amount of Information Category 70
6.1.3: Quality of Information Category 70

6.1.4: Explanation of Application Category 70
6.1.5: Diagrams and Illustrations Category 71
6.1.6: Application of Transfer Category 71
6.2: Content Analysis Discussion 72
6.3: Discussion on Case Study Paper to RJs Comparison 74
6.4: Discussion on Additional Findings 76
6.5: Limitations of the Study 76
Chapter 7: Recommendations and Conclusion 79
7.1: Recommendations 79
7.2: Conclusion 80
References 81
Appendix A: Participants Consent Form 85
Appendix B: Case Study Paper Topic Released to Students 87
Appendix C: Case Study Paper Presentation Week One 89
Appendix D: Case Study Paper Sample 93
Appendix E: Case Study Paper Presentation Week Two 99
Appendix F: Case Study Paper Presentation Week Three 101

List of Figures

FIGURE 1: STAKEHOLDERS SPOKE-AND-WHEEL DIAGRAM 14
FIGURE 2: LESSON DELIVERY STYLE IN REPUBLIC POLYTECHNIC (UPDATED IN SEPT 2015) 24
FIGURE 3: ASSESSMENT PERCENTAGE DISTRIBUTION FOR E206 MICROCONTROLLER SYSTEMS 26
FIGURE 4: HISTOGRAM OF STUDENTS' AVERAGE SCORES 48
FIGURE 5: STUDENTS' RUBRIC CATEGORY MEAN 49
FIGURE 6: HISTOGRAM OF STUDENTS' SCORES IN COMPONENTS CATEGORY 50
FIGURE 7: HISTOGRAM OF STUDENTS' SCORES IN AMOUNT OF INFORMATION CATEGORY 51
FIGURE 8: HISTOGRAM OF STUDENTS' SCORES IN QUALITY OF INFORMATION CATEGORY 52
FIGURE 9: HISTOGRAM OF STUDENTS' SCORES IN EXPLANATION OF APPLICATION CATEGORY 53
FIGURE 10: HISTOGRAM OF STUDENTS' SCORES IN DIAGRAMS AND ILLUSTRATIONS CATEGORY 54
FIGURE 11: HISTOGRAM OF STUDENTS' SCORES IN APPLICATION OF TRANSFER CATEGORY 55

List of Tables

TABLE 1: DAILY ROUTINE IN REPUBLIC POLYTECHNIC UNDER ODOP PEDAGOGY 21
TABLE 2: INTERACTIVE SEMINAR DAILY ROUTINE 23
TABLE 3: SCORING RUBRICS 43
TABLE 4: SCORING RUBRICS RESULTS 47
TABLE 5: MEAN, MEDIAN AND S.D. OF STUDENTS' AVERAGE SCORES 48
TABLE 6: IDENTIFIED APPLICATION CATEGORIES OF THE CASE STUDY PAPER SUBMISSIONS 55
TABLE 7: RJS CORRELATION TO CASE STUDY PAPERS 61
TABLE 8: RJ COMPARISON TO CASE STUDY PAPER CATEGORIES DISTRIBUTION 62
TABLE 9: RJS CORRELATION TO CASE STUDY PAPERS CATEGORIES 66
TABLE 10: CATEGORY ONE STUDENTS' CSP RUBRIC SCORE 67
TABLE 11: CATEGORY TWO STUDENTS' CSP RUBRIC SCORE 67
TABLE 12: CATEGORY THREE STUDENTS' CSP RUBRIC SCORE 68
TABLE 13: CATEGORY FOUR STUDENT'S CSP RUBRIC SCORE 68
TABLE 14: CATEGORY FIVE STUDENTS' CSP RUBRIC SCORE 68
TABLE 15: CATEGORY SIX STUDENT'S CSP RUBRIC SCORE 68
TABLE 16: SUMMARY OF SIX CATEGORIES AVERAGE CSP RUBRIC SCORE 75

This page intentionally left blank

Chapter 1: Introduction

1.1: Motivation

Polytechnic education in Singapore is similar to technical colleges in the U.S., offering diplomas in various technical disciplines, ranging from STEM to non-STEM fields. A diploma in a typical polytechnic in Singapore is a 3-year course. Republic Polytechnic in Singapore uses a unique One-Day-One-Problem approach to Problem-Based Learning pedagogy as the main lesson delivery. Over the years, there have been both more traditional and innovative lesson delivery methods adopted by Republic Polytechnic (to be discussed in a later chapter).

One component that has been in place until now regardless of teaching approaches in Republic Polytechnic is the daily reflection journal, more informally known by its acronym, RJ. The lecturer of the class sets the topic for the reflection journal in line with the lesson students are taking for that particular day. The reflection journal can be technical or non-technical in nature, and it allows students to make qualitative reflections on the lesson of the day. Republic Polytechnic, School of Engineering (referred as "the school") has an interest in exploring methods to enhance students' learning in engineering modules other than the reflection journal. One idea is to implement a topic-focused Case Study Paper that would span across a few lessons in a module.

1.2: Purpose and Research Objective of Study

The purpose of the study is to focus on exploring the usage of a Case Study Paper in a practical module for the school to enhance the student learning experience. This would be a randomized control trial study involving engineering students taking the selected module. A topic-focused Case Study Paper is added to the required student delivery of the selected module for this experimental study.

The primary research objective of the thesis is to implement and analyze the effectiveness of a Case Study Paper that covers a few lessons of E206 Microcontroller Systems module in the school. Assessment using a rubric and content analysis are performed on the papers submitted. The submitted papers are cross-referenced to students' reflection journals to explore consistency in quality. The reflections journals are designed to help students write their Case Study Paper. The methodology and approach on how the Case Study Paper was incorporated in this study will be covered in a later chapter.

The aim of the study is to find alternative ways to improve students' learning experience. The results of the study can help to provide insight into whether the Case Study Paper can be applied for other modules and if it should be permanently used for the Microcontroller Systems module.

1.3: Stakeholders of the Study

This study involves two educational institutions: MIT and Republic Polytechnic. Figure 1 provides a clear picture of the primary stakeholders involved in this experimental study.

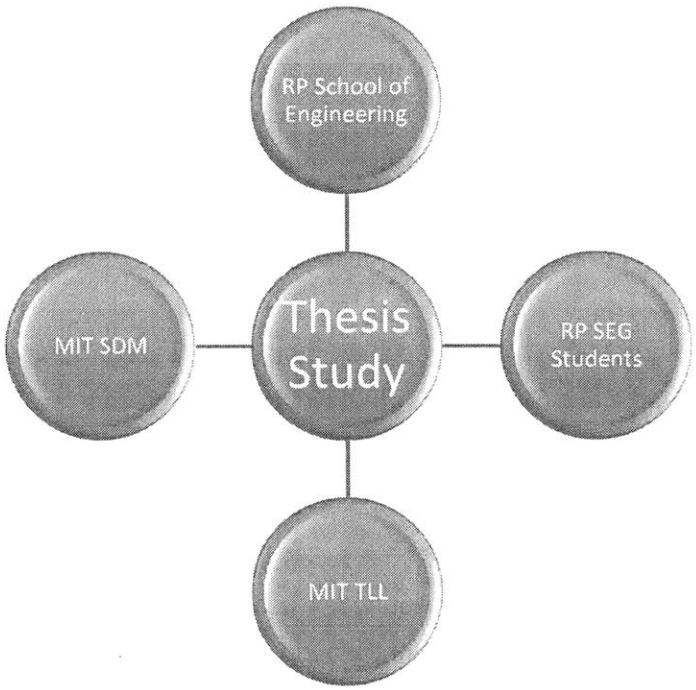


Figure 1: Stakeholders Spoke-and-Wheel Diagram

The Principle Investigator of the study is doing this research as part of his requirement in the System Design and Management Program leading to a Master of Science degree from MIT. As a lecturer in Republic Polytechnic School of Engineering, he is also interested in exploring new teaching components and methodology to improve his students' learning experience. The study is under the auspice of the Systems Design and Management (SDM) group in MIT with supervision and guidance from the former director of the MIT Teaching and Learning Laboratory (TLL). Student subjects are sampled from Republic Polytechnic School of Engineering students who completed the Case Study Paper in Microcontroller Systems module. The management in

the School of Engineering in Republic Polytechnic is supportive of the study and is keen to know its outcome and recommendations.

1.4: Clearance to Conduct Study Involving Human Subjects

As this study involves human subjects under the auspices of MIT and Republic Polytechnic, applications for exempt status need to be completed before the study could be carried out. MIT COUHES (Committee on the Use of Humans as Experimental Subjects) has granted approval for the study to be carried out under exempt status, with COUHES Protocol number 1602374682. Republic Polytechnic's Institute Review Board (IRB) for projects involving human subjects has granted approval for the study to be carried out with the Human Subject Research (HSR) code CED-M-2016-001. Informed consent has been obtained from students selected for the study. Appendix A shows the student consent form.

All study personnel have taken and passed the training course on human subjects research, and are certified to participate in studies involving human subjects.

1.5: Chapters Organization

Chapter 2 of the thesis provides more background information for readers not familiar with the Singapore education system. Chapter 3 is a literature review on teaching components that can be effective in improving students' learning experience. Chapter 4 covers the methodology for implementation of the Case Study Paper. Chapter 5 presents the results and discussion. Chapter 6 concludes the study with recommendations.

This page intentionally left blank

Chapter 2: Background

This chapter provides some background information for the reader to better appreciate the motivation for the thesis study. Information presented here zooms in from macro to micro levels, covering the roles of polytechnics in Singapore, Republic Polytechnic and its unique flavor of problem-based learning pedagogy, other new content delivery methods in Republic Polytechnic, and the module used for the study.

2.1: Polytechnics in Singapore

Polytechnics in Singapore offer an alternative education path for students after completing their 10th grade equivalent (Cambridge GCE "O" level or equivalent).

As an alternative to junior colleges (equivalent to high school in the USA) for post-secondary studies, polytechnics offer industry-oriented education to equip graduates with technical skills and knowledge for the industry. About 40% of the 10th grade graduate cohort enroll in polytechnics in Singapore. There are five polytechnics in Singapore, offering 3-year diplomas in various fields of study. Collectively, these five polytechnics offer a wide range of courses to meet current demands of the industry, including engineering and engineering management, IT, business and accountancy, technology arts, digital media, tourism and hospitality management and science. There are also specialized courses for specific industries such as nursing, marine engineering, nautical studies, optometry and aeronautical disciplines. (Education in Singapore, 2007)

The primary roles of polytechnic education in Singapore are to graduate students to meet industry demands, prepare fresh graduates for university education, and to provide post-employment andragogy education. The Ministry of Education in Singapore states that:

> Polytechnics were set up with the mission to train professionals to support the technological and economic development of Singapore. Reflecting the wide range of abilities, aptitudes and interests of their students, the polytechnics seek to train students with relevant and specific skills for the workplace to give Singapore a competitive edge as we move into a knowledge-based economy. Today, polytechnic graduates are valued as practice-oriented and knowledgeable professionals, much sought after by industry. The polytechnics are also a significant provider of continuing education and post-employment professional development programmes and services. (Post-Secondary Education, 2016)

Polytechnic education emphasizes practice-based learning. All five polytechnics include work attachments or internships with industry partners in the curriculum to help students gain valuable on-the-job experience. This internship can vary from six weeks to six months depending on the polytechnic and the diploma course of study. Polytechnics also offer mandatory general modules (a module is a semester-long course in the context of the USA) regardless of disciplines or diplomas to help students acquire important life skills. These general modules focuses on key skills such as communication and presentation skills, problem-solving and cognitive skills. (A Guide to Polytechnic Education, 2016)

2.2: Republic Polytechnic

Established in August 2002, Republic Polytechnic is the youngest of the five polytechnics in Singapore. The polytechnic received its first intake of over 800 students in July 2003 at its former Tanglin Campus. In March 2006, the polytechnic moved to its current campus in Woodlands and supports about 14,000 students. The polytechnic currently consists of seven academic schools and one academic center, offering forty-two diplomas in the fields of Applied Science, Engineering, Enterprise and Communication, Events and Hospitality, Infocomm, Sports, Health & Leisure, and Technology for the Arts. (Republic Polytechnic: Introduction and Background, 2016)

The signature teaching pedagogy of Republic Polytechnic is its adaptation of Problem-based Learning (PBL) using the One-Day-One-Problem (ODOP) method. The ODOP PBL pedagogy was used to deliver all lessons in the initial years of the polytechnic. Today, PBL and ODOP are still the mainstay of many lessons in Republic Polytechnic. The physical infrastructure of the polytechnic's Woodlands campus was designed and built to support the ODOP teaching pedagogy.

2.3: PBL

Problem-based Learning is a student-centered pedagogy in which students gain knowledge and skills by working in groups to solve a real-world problem. PBL originated at McMaster University Medical School in Canada in the late 1960s. Since then, PBL has been implemented in many programs across numerous disciplines around the world. The goals of PBL are to develop intrinsically motivated, self-directed learners with effective problem solving and collaboration skills. In PBL, the problem could be a challenge or a description of a difficulty, a curious outcome, or an unexpected happening; it could also be an incident where there are interesting elements, or an episode or occurrence that requires either a solution or some explanation. PBL as a theory of learning contends that students do not learn by simple accumulating knowledge - they need to construct a personal understanding of concepts.

PBL uses the constructivism approach to instruction. Constructivism was developed by Piaget and influenced by Montessori, Dewey, Glasersfeld, and Vygotsky. Bransford, Brown and Cocking (2000) explained that humans generate new knowledge based on pre-existing knowledge. A person's mental model used to comprehend new knowledge is largely affected by his/her pre-existing knowledge. Educators and teachers should capitalize on understanding a learner's pre-existing knowledge and provide guidance and facilitation for the learner to construct new knowledge. Leo Lionni (1970) illustrated the idea of constructing new knowledge from pre-existing knowledge in simple form in his children's book "Fish Is Fish". According to the abstract:

> Fish Is Fish describes a fish who is keenly interested in learning about what happens on land, but the fish cannot explore land because it can only breathe in water. It befriends a tadpole who grows into a frog and eventually goes out onto the land. The frog returns to the pond a few weeks later and reports on what he has seen. The frog describes all kinds of things like birds, cows, and people. The book shows pictures of the fish's representations of each of these descriptions: each is a fish-like form that is slightly adapted to accommodate the frog's descriptions— people are imagined to be fish who walk on their tailfins, birds are fish with wings, cows are fish with udders. This tale illustrates both the creative opportunities and dangers inherent in the fact that people construct new knowledge based on their current knowledge. (Lionni, 1970)

2.4: Republic Polytechnic's One-Day-One-Problem Pedagogy

The One-Day-One-Problem pedagogy described by O'Glady & Alwis (2002) is Republic Polytechnic's approach to implementing the PBL pedagogy. The approach entails students spending exclusively one whole day working on a single problem. Over the course of a week, students will work on five different, but related, problems. Translating this to implementation, it

means that students have only one module's lesson per day, and can only take five modules per week. (As noted above, a module in Singapore's education context is a course in the USA education context.) Originally, each module ran for a full term of 16 instructional weeks per term. In each term, under the ODOP system, students can complete five modules.

Over the years, there have been revisions to the number of weeks per term and accommodations to tests, exams, and grading. In Singapore's education context, an end of semester or term summative assessment is classified as an exam while any in-term summative assessment is classified as a test. The latest modifications shortened the term to 13 instructional weeks. Continual Assessment, which are the grades from the 13 daily lessons, composes 20%-40% of a full module grade, while the other 60%-80% comes from the mid-semester exam and the end-semester exam, with a recommended weightage of 30%:70% between the mid-semester and end-semester exams. The final Continual Assessment (CA) grade is usually based on the average of the 13 CA grades given after each lesson. There are variations to teaching pedagogy, which will be discussed in a later section, and this leads to differences in the assignment of CA grades.

In Republic Polytechnic's ODOP classroom or laboratory, students are seated in five teams of five, totaling 25 students, with a lecturer/facilitator in the classroom. A module with more than 25 students have multiple classes. With more classes, it is usual to have a team of lecturers teaching the same module, with each lecturer teaching a few classes. The day's lesson is mainly divided into three sessions with the lecturer/facilitator and two independent breakout sessions.

Table 1 shows the typical daily routine for a student in Republic Polytechnic under the ODOP pedagogy. The starting time for the day's lesson for students of different years varies to avoid congestion in the canteens during break hours. More information on grade distribution and class timing can be found at Republic Polytechnic's website. (RP Academic Information, 2016)

Duration within a day	Period	Description
60mins	Learning Phase One	Students receive a problem as a trigger for learning. With the help of the lecturer/facilitator, the students examine the problem and clarify what it is they know and do not know and formulate possible hypotheses. Each group shall identify learning issues they will investigate. Groups employ research strategies to collect relevant information. Information divergence[1] takes place.
45mins	Break	Lecturer/Facilitator leaves the class. Groups are on their own to continue to do their work or go for break.
90mins	Learning Phase Two	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/Facilitator leaves the class. Groups are on their own to arrange for lunch break and prepare for presentation.
120mins	Learning Phase Three	Each team presents its findings to the other groups. Groups discuss, defend and justify their outcomes. Lecturer/facilitator presents recommended answer to the problem.

Table 1: Daily Routine in Republic Polytechnic under ODOP Pedagogy

The students' responsibility for the lesson is not over when the day's lesson is over. Students have to complete a reflection journal (RJ) based on a question set by the lecturer/facilitator. The reflection journal is a tool to improve students' awareness of learning and to reflect on the way they have learnt in their groups.

Each student is then assessed individually for his or her learning by the lecturer/facilitator. The lecturer/facilitator reviews the group and individual submissions, the in-class observations of progress and the contribution by each student and their reflection journal and then assigns a CA grade for the lesson to each student. The CA grade can be A, B, C, D, or F, based on a daily assessment grading rubric.

2.5: Alternative Lesson Delivery Methods in Republic Polytechnic

Over the years, the polytechnic realized that for optimum delivery of learning contents, it needed to incorporate flexibility in the lesson delivery method. One-Day-One-Problem is great for some

[1] From the Problem Statement, student work out what they know, what they do not know, and what they need to find out. 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 converge the information to lead to a possible solution for the problem of the day.

modules, but not for all modules. The ability of students varies in different cohorts; some cohorts needed more handholding while others are more independent. The module-to-module nature of the content also poses difficulty in a "one size fits all" delivery method. For this reason, Republic Polytechnic has and is still going through a phase of changes to adopt other delivery methods and components to improve students' learning. This section discusses some of the newer delivery methods that the polytechnic is currently using.

2.5.1: Variants to One-Day-One-Problem Lesson Delivery

There are modules that function generally well under the One-Day-One-Problem lesson umbrella with minor variations.

One variant is to include mini-lectures, which are bite-sized, directed teaching within the learning phases. Such mini-lectures are usually about 10-15 minutes long. The idea is to provide a scaffold to equip students with enough knowledge to solve the next portion of the day's problem. When done incrementally, this leads to solving the entire problem for the day. This has an advantage over traditional lecture style especially in a hands-on module, since information and scaffolding are provided when needed.

Another variant to the ODOP lesson delivery is to remove the student team presentations, and replace the end-of-lesson summative assessment with observation of students' work and an oral exam. This variant works especially well with practical hands-on modules.

2.5.2: Interactive Seminar

A new lesson delivery method that has been implemented in recent years is the Interactive Seminar. Simply put, this method incorporates a 2-hour morning lecture and a 2.5-hour tutorial/recitation in the afternoon with a lunch break in-between. This delivery method is used for higher year mathematics modules that require students to do some exercises after the lecture. While this method has its strength, it is similar to the ODOP delivery in that students can only take one module lesson in a day. Another challenge is the infrastructure. For the Interactive Seminar, it is economical to provide lectures to bigger groups of students of about 50 to 100 while splitting the students up into groups of 25 for the recitation phase. The polytechnic has very limited lecture theatres and its classrooms can only accommodate 25 students. This limitation is due to the original infrastructure support for only ODOP style PBL

lessons. To deliver an Interactive Seminar to bigger groups of students, modifications were done to combine some existing classrooms into bigger classrooms. Table 2 shows the daily routine of the Interactive Seminar lesson delivery.

Duration	Period	Description
120mins	Learning Phase One	Lecture
60mins	Break	
150mins	Learning Phase Two	In-Class Tutorial/Recitation

Table 2: Interactive Seminar Daily Routine

2.5.3: Block Class

There are types of modules that do not fit into ODOP or Interactive Seminar delivery methods. Examples are lectures (traditional lesson delivery) in the School of Hospitality restaurant and culinary practicum, or the School of Technology music and theory practice, to name a few. With the need to optimize students' learning and time in mind, block classes of various durations have been implemented. With the latest update in September 2015, there are five different durations of block classes, namely, 2-hour block, 2.25-hour block, 2.5-hour block, 3.25-hour block and 4.5-hour block. The starting and ending times of these blocks are fixed and published in Republic Polytechnic's website. (RP Academic Information, 2016) Block class modules can be combined in such a manner to allow students to take more than one module lesson in a day, resulting in students completing more than five modules in a term. Depending on the nature of the lesson using Block Class, the same limitation in availability of lecture theatres or large classroom exists.

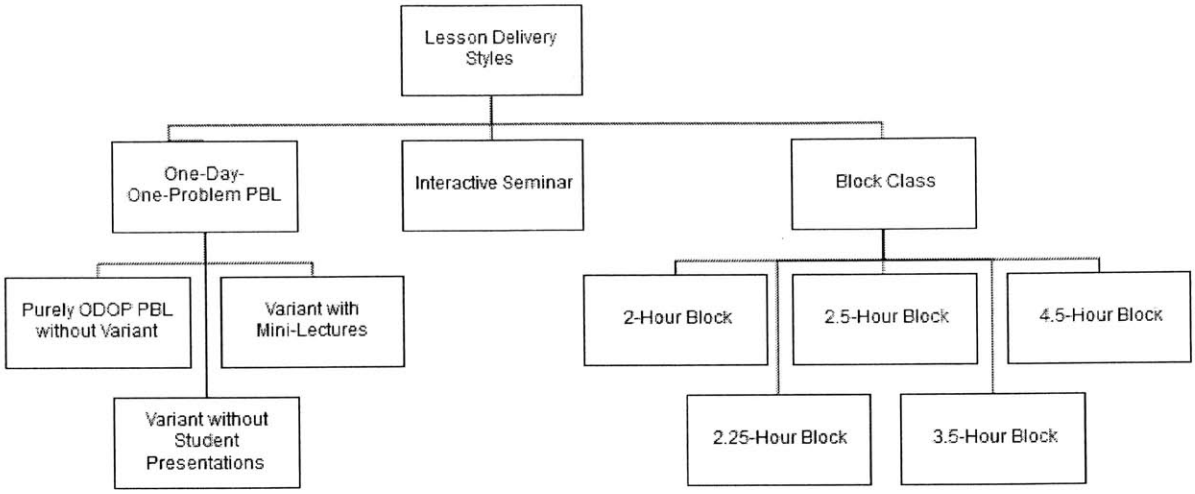


Figure 2: Lesson Delivery Style in Republic Polytechnic (Updated in Sept 2015)

Figure 2 shows the pictorial summary of current lesson delivery styles in Republic Polytechnic. Another major change, regardless of lesson delivery style, is that Continuous Assessment (CA) grades can vary in terms of granularity; for example, one CA grade can be given per four lessons in the module.

2.6: Microcontroller Systems Module

The Microcontroller Systems module is the subject of this study. This module is a core module for students in Republic Polytechnic's School of Engineering, Diploma in Electrical and Electronic Engineering. (RP SEG DEEE Information, 2016) There are three specialization tracks for students in the diploma programme to choose from: Digital Media and Communications, Biomedical Electronics, and Microelectronics. Students taking either the Digital Media and Communications or Biomedical Electronics track take the Microcontroller Systems module in year two of their study. Currently, the module is only offered in semester one, which is from April to September. All modules are coded with an alphabet and a three-digit code. For the Microcontroller Systems module, the module code used in the polytechnic is E206 ('E' for School of Engineering modules). The cohort size of students taking the Microcontroller Systems module in semester one of FY2016/2017 is 192. The module synopsis published in the polytechnic website says:

> The typical architecture of microcontrollers and microcontroller programming are addressed in this module. Students will learn basic topics which include input/output ports, memory architecture, flow charts, LCD controlling, Pulse Width Modulation, and event polling. Students will also learn interesting topics related to interrupts such as external interrupts, timers and timer interrupts, Analog-to-Digital conversion and ADC interrupts,

high and low priority interrupts, match output comparison with interrupts and serial communication. (Tham, 2008)

The author of this thesis, also the principal investigator of the study, has been teaching the Microcontroller Systems module in the polytechnic for nine runs (nine years), and has been the module chair of this module for eight runs, making various major and minor changes in the module to improve the learning experience of the students. One major change made in 2007, was to move away from an assembly language curriculum to a C language curriculum in view of evolving market trends and needs. A more recent change made in 2013, was to add the Arduino platform to the curriculum in addition to the legacy Microchip PIC18 platform. The motivation for this thesis study is to explore more enhancements to improve the students' learning experience in this module, which could be used as an exemplar for other School of Engineering modules.

The Microcontroller Systems module uses variants of ODOP PBL lesson delivery styles in its lessons. Lecturers for the module are given mini-lecture presentation materials with facilitation guidelines to provide the mini-lectures at the right time within the lesson. Learning phase one introduces the problem of the day to students, relating it to real-world problems. There are more mini-lectures in this phase. In learning phase two, there are more students' hands-on activities, one-to-one guidance, and possibly some mini-lectures. Learning phase three is mostly students' hands-on activities and one-to-one guidance. Most of the lessons in the module would not require student teams to present as assessment is on their practical lab work. The lecturer still provides a summary of the lesson with a final closing presentation. Students' class participation and assessment of individual work are taken into consideration for the holistic CA grade for the lesson. There is a reflection journal (RJ) question set by the lecturer of the class at the end of each lesson. The deadline to submit the RJ is recommended to be 11.59pm on the day of the lesson, but the lecturers have the freedom to decide otherwise.

The assessment percentage distribution for E206 Microcontroller Systems is 40% for Continual Assessment (CA), and 60% for Summative Assessment (SA). The CA is evenly distributed among the 13 lessons, with one CA grade for each lesson. CA grades in Republic Polytechnic can be A (4), B (3), C (2), D (1), or F (0). The SA is further split into the Mid-Semester Assessment (MSA, which is a mid-semester exam) and the End-Semester Examination (ESE) with the weightage of 30%:70%. The examination scores in Republic Polytechnic are then mapped through a pre-approved grading distribution to grades. SA grades can be A (4), B+ (3.5), B (3), C+ (2.5), C (2),

D+ (1.5), D (1), E (0.5) or F (0). The assessment percentage distribution for E206 Microcontroller Systems is shown in Figure 3.

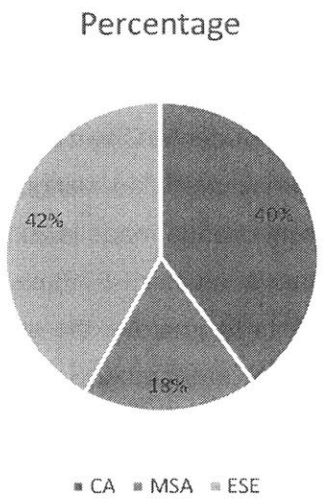


Figure 3: Assessment Percentage Distribution for E206 Microcontroller Systems

At the end of the semester, the grade point scores of all the components in the module are weighted and added together to obtain an aggregate score for each student. The institute's Board of Examiners determines the grade mapping at the school and polytechnic level. Module grades can be: Distinction (GPA=4), A (GPA=4), B+ (GPA=3.5), B (GPA=3), C+ (GPA=2.5), C (GPA=2), D+ (GPA=1.5), D (GPA=1) or F (GPA=0). The minimum grade to pass a module is D. While many other institutions have a difference in GPA for Distinction and A grades, with a maximum GPA of five, Republic Polytechnic does not have such a differentiation. In the polytechnic, Distinction and A grades have the same maximum GPA of four. To qualify for Distinction grade for a module, the following criteria must be satisfied:

- Student must attain an A grade for the module
- Student must be in the top 5% of the module

Modules grades distribution usually take the shape of a bell curve with peaks between B to C, depending on the module.

Chapter 3: Literature Review

While there are many pedagogical methods and tools available, this chapter will devote itself to a review of some them, such as the reflection journal, the one-minute paper, the mud card, and the case study method. The reflection journal is one of the formal teaching and learning tools used in Republic Polytechnic across all lesson delivery styles and its effectiveness is worth reviewing in this chapter. The other tools reviewed in this chapter can be easily used for lessons in Republic Polytechnic without extensive change in lesson delivery style. The minute paper asked students to answer specific questions on the lesson and should take a few minutes to complete. The one-minute paper is a shorter version of the minute paper. The mud card is used more as a tool for feedback to the instructor than a learning tool. Finally, this chapter reviews the usage and effectiveness of the case study method, which is the focus of this study.

3.1: Reflection Journal as Teaching and Learning Tool

The reflection journal can be called a reflective journal, learning journal, or reflective learning journal in the literature. Gleaves, Walker and Grey (2008) believes that reflection journal writing enable students to critically review processes of their own learning and behaviors and to understand their ability to transform their own learning strategies. Boud, Keogh, and Walker (1985) documented that self-reflection enhances professional practice since the learner is involved in processes that explore experience as a means of deepening understanding. Sumsion and Fleet (1996) mentioned that:

> These processes include looking back on experiences, decisions and actions; recognizing values and beliefs underlying these actions and decisions; considering the consequences and implications of beliefs and actions; exploring possible alternatives; and reconsidering former views. Processes such as these are expected to lead to informed, thoughtful and deliberate analysis or contemplation of one's beliefs and actions.

Sumsion and Fleet (1996) stated that these processes are expected to assist learners in becoming reflective practitioners. Donald Schön (1983) wrote about professionals being reflective practitioners. The use of reflection journals as a learning tool therefore highlights the role of self-reflection in learning.

A reflection journal provides opportunities for the learner to reflect and write about new information or ideas, thus better understanding and remembering them. O'Rouke (1998) states that by writing

a reflection journal, connections between new information or ideas and prior or existing knowledge also deepens learning. Studies have shown that writing journals improves students' learning and cognition skills while not necessarily having a direct impact on their grades. A study done by Selfe, Petersen and Nahrgang (1986) on the use of journals in a USA college-level mathematics course showed that journals did assist students in developing abstract thinking and conceptualizing the meaning of technical definitions, but did not necessarily assist students with earning high grades on achievement tests. Furthermore, students appeared to develop better strategies in problem solving through writing as compared to merely memorizing calculations. Moon (2004) summarized a number of studies that examined the effects of journal writing on student academic achievement across a variety of disciplines. Her findings are in line with Selfe, Petersen and Nargang (1986). Lew and Schmidt (2011), however, in one of their studies, were able to correlate moderate inter-relationships between refection journals and academic performance, although to a limited extent.

Reflection journals have been adopted as a learning tool in many nursing curricula. Wong, Kember, Chung, and Yan (1995) performed a study to develop and test coding systems for written reflective journals. The reflective journals submitted by nursing students were subjected to content analysis. In their study, by using two levels of content analysis, they were able to reliably classify students into three categories of non-reflector, reflector and critical reflector.

There are controversial studies by Woodward (1998) and Bain, Ballantyne, Parker and Mills (1999) that revealed that journals were far from reflective and were merely diary entries describing an event or activity. On this note, to improve on the quality of reflection journals, the journal question and scope is important. A good journal question should prevent students from just recording diary entries.

When the reflection journal is graded and the grade contributes to the module or course of study, then it becomes a teaching and assessment tool for the teacher in addition to being a learning tool for the student.

3.2: Reflection Journal in Republic Polytechnic

While Republic Polytechnic is adopting more content delivery methods other than the One-Day-One-Problem PBL style, there is one common component across all the delivery methods in the polytechnic, and that is the reflection journal, which is commonly known as RJ. At the end of each lesson, students are required to write a reflection journal related to the lesson. The journal

question is usually set by the lecturer of the lesson but sometimes set by the module chair of the module. There is a list of common journal questions for the lecturers to choose from to get started, and the lecturers can come up with their own questions. The questions can be technical or non-technical or they can even by philosophical. The objective of the reflection journals is to draw a meaningful conclusion to the lesson by getting students to reflect on how they have learnt, identify insights into how they are learning, and integrate theories learnt in class into their own experience.

The deadline for student to submit their reflection journals is recommended to be 11.59pm on the same day of the lesson. The lecturers of the class can choose to follow the recommendation or deviate from it. From the author's experience in lecturing in the polytechnic, extending the submission time beyond the next morning does not improve students' reflection on the lesson. In fact, if the extension goes beyond the start of the next lesson (usually the next morning), the quality of reflection usually suffers. To be student centric, a common practice among the lecturers is to allow case-by-case exceptions for submission of reflection journals beyond the recommended deadline to cater to students who are working late nights after lessons. O'Glady and Alwis (2002) described the reflection journal in Republic Polytechnic as part of the bigger reflective thinking approach incorporated into One-Day-One-Problem. While the reflection journal is written after the lesson, they emphasized that reflective thinking is not what students start to do after the lesson; it is what students do during the lesson in order to acquire content. This ties in with the discussion on the reflection journal submission deadline. Students need time to recollect the acquired content of the lesson to write a quality reflection journal. If this time overlaps with the next day's lesson, the recollection process is hampered, previous content is mixed with new content, and hence the quality of the reflection journal suffers.

Lew, in her capacity as a staff member of Republic Polytechnic, conducted various studies on students of the polytechnic, which have been published. Several of her articles are related to reflection journals. Lew and Schmidt (2011) collected reflection journals of 690 School of Applied Science first year students twice – once at the beginning of the academic year and once at the end of the academic year in 2007-2008. A content analysis was performed on the collected reflection journals. Outcomes of the study revealed that students reflected on both the process and content of their learning, including critical reviews of past learning experiences, learning strategies and summaries of what was learned. The findings suggest that self-reflection on both how and what students have learned does lead to improvements in academic performance, although to a limited extent. In a correlated larger scale study, Lew and Schmidt (2011A) collected reflection journals of 3460 first year students from the polytechnic across all schools using the

same methods and performed a similar content analysis. Reflections journals for an entire week were collected at the start of the academic year and at the end of the academic year in 2007-2008. This study revealed similar findings to the previous one. Additional findings indicate that students showed improvements in their reflective skills as they progressed through the academic year. The findings, when taken together, suggest that reflection journals can be used to promote self-reflection and learning.

While widely accepted that reflection journals can promote self-reflection and learning in students, "noise" can distort the quality of reflection journals. Such "noise" includes poorly structured reflection questions, students lacking time to do reflections due to other personal or financial commitments, using reflection journal as an instrument of attack, plagiarism, or simply writing to what the lecturers wanted (Lew & Henk, 2006). While several kinds of "noise" are uncontrollable, random, and in small numbers analogous to "white noise" in engineering, the lecturer can control the quality of the journal question. In short, to prompt good reflection journal submissions, lecturers need to think and reflect on what makes good journal questions, which is part art and part science. New lecturers with the polytechnic go through a week-long training, which includes guidance to setting journal questions. However, it takes years of practice to perfect the art.

While there are multiple methods to encourage self-reflection and improve learning in students, Republic Polytechnic has been using the reflection journal as the main end-of-lesson reflection learning tool since its inauguration. The reflection journal is effective and easy to implement in the polytechnic's system. While other methods of self-reflection and learning improvement are being explored in the polytechnic, currently those would serve as supplements to the reflection journal and not as a replacement.

3.3: One-Minute Paper and Mud Card as Teaching and Learning Tools

The original minute paper was developed by Angelo and Cross (1993). They described it as a tool that provides a quick and extremely simple way to collect written feedback on student learning. The great advantage of the minute paper as a feedback tool for the instructor is that it provides manageable amounts of timely and useful feedback with a minimum investment of time and energy. The minute paper is also a useful learning tool for the students to reflect on the lesson; it is a shorter form of the reflection journal. The more popular one-minute paper was later developed with the idea of the student spending only one minute to fill in a paper instead of the originally proposed five minutes by Angelo and Cross (1993). The concept and method used for the one-

minute paper is straightforward. At the end of the lesson, the instructor requests students spend one minute to write down one main point (or the most important point) from the day's lesson, the muddiest point about the topic, and what they would like to hear more about on the topic. This was traditionally done on a piece of paper. The instructor then collects the papers and read them. This is a teaching tool rather than a learning tool. Students benefit from the use of the one-minute paper when the instructor responds to the students' feedback via the one-minute paper. Some of the instructor's response would occur naturally in later lectures as the module progress, some with extra handouts especially prepared, and some with oral remarks in class.

The mud card is a more focused variation of the one-minute paper, and centers on asking students what is the muddiest point of the lesson. The mud card is a teaching tool for the teacher but not so much of a learning tool for students. Students learn only when teachers take actions on the feedback from the mud card. The muddiest point was originally developed by F. Mosteller at Harvard while teaching an undergraduate statistic course. The implementation is the same as the one-minute paper, except that the idea of a "card" instead of a piece of "paper" suggests shorter and more focused responses. This supposedly helps the instructor focus on helping students clear up their confusion in the following lecture.

Harwood (1996) has shown that the one-minute paper is particularly useful for teaching large classes. He used the one-minute paper in his general chemistry classes for science and engineering majors. The research findings show that the one-minute paper is a very effective mechanism for improving the communication between the instructor and the students. Harwood (1996) used the one-minute paper for five years prior to publication of an article about it, and he observed very positive effects in improving students' learning. Ashakiran and Deepthi (2013) replicated Harwood's (1996) findings in a later study. In the study, Ashakiran and Deepthi (2013) employed the one-minute paper for post-graduate students during a continuous medical education (CME) lecture to assess its effectiveness for achievement of objectives. Students in the study reflected that the use of the one-minute paper was thinking centered and provided the opportunity for them to ask questions. Ashakiran and Deepthi (2013) concluded that the one-minute paper is inexpensive, easy to use, and an instant assessment means that reflects the achievement of learning objectives. It is a thinking-centered assessment tool, which provides ample opportunity for active learning.

With the evolution of technology and its use in classroom, the one-minute paper and mud card quickly moved from physical paper and card to digital form. This move makes the collection and listing/categorization easier for lecturers/teachers who are digital savvy. In a class that allows the

usage of laptops and other digital devices and is connected to the internet, the instructor can simply post a mud card question using a web form[3] like Google forms and allow students a minute to answer that question online. Martin (1999) explored various useful assessment techniques that are suitable for the technology-enabled classroom. He extended the idea of using mud cards beyond the physical classroom. He used it digitally over the internet where it was particularly useful for distance learners. During Martin's research in 1998-1999, web forms were not available and the idea of technology was restricted to older technologies like email. Martin (1999) concluded that the mud card is particularly useful in combination with instruction using technology. Sewell, Karen and Colvin (2010) replicated Martin's research on assessment tools for distance learners much later in 2010 as more advanced technologies were available. They published a paper to help lecturers/teachers design and use effective assessment strategies for their online lessons. The mud card is one of the online assessment strategies that they found to be effective.

The mud card is not always successful as a feedback tool to improve the quality of teaching. At MIT, the System Design and Management (SDM) core course attempted to use mud cards in its 2015a cohort for feedback on the course, but it was not very successful. The SDM core course ran for three terms: fall term, January independent activity period, and spring term. The lesson delivery environment is perfectly suited for online feedback tools, with a mixture of students physically in class and distance students participating in the lecture via the MIT WebEx system. The total number of students from the cohort taking this course was 92. The mud card was implemented by using Google forms and asking students after the lecture "What was the muddiest point in today's lecture?" and "What point(s) was not clear to you?" in the fall term. The responses from students were used for clarification and teaching points in subsequent recitation or lecture. Not many students participated in answering the mud card at the end of each lecture. This was partly because students had to rush to attend another lecture, and also because the course was assignment based and students have the tendency to ask questions only when they faced issues with the assignments. The mud card was subsequently discontinued in the later part of the fall term and not implemented in the later terms. In replacement, the SDM core module currently uses an online forum for questions, answers, and sharing of information.

To counter the low participation rate from students for mud cards, other technologies can be used to elicit a simpler response from students. For instance, King (2011) used the clicker[4] to get students to respond to questions with fixed answer options. King (2011) incorporated the

[3] Web form or webform on a web page allows a user to enter data that is sent to a server for processing.
[4] The "clicker," very similar to the remotes we use to run our television sets, which sends student responses by infrared signals to a computer system that displays the results instantly.

muddiest-point questions into a general chemistry course. His findings have shown that about 75% of the students who answered other clicker questions during class also answered the muddiest-point clicker question at the end of class. While the use of the clicker improved response rate for the electronic mud card, it restricts answers to only a few given options and hence subjected to hindsight bias from the instructor who designed the answer options. The other restriction is that it does not allow distance learners participation.

In short, the success in using the one-minute paper or the mud card is varied and depends the following factors:

- Instructor response to feedback: Does the instructor respond to the feedback? Are the responses/actions from the instructor based on the mud card or one-minute paper helpful to the students?
- Perception from students on the usefulness of the feedback from the one-minute paper or mud card
- Students' willingness to provide feedback
- Availability of technology: More advanced classroom technology makes it easier to collect feedback
- Size of the cohort: What is the optimum size of a class for one-minute paper or mud card to be effective?

3.4: One-Minute Paper and Mud Card in Republic Polytechnic

There is no formal record of usage of the one-minute paper or the mud card in Republic Polytechnic. Unlike the reflection journal, they are not formally incorporated into the lesson delivery. Individual lecturers have used these feedback tools on their own to improve their lesson delivery. There are opportunities to perform a study on the effectiveness on usage of the mud card in the polytechnic. Formal incorporation of the mud card as a feedback tool can follow if there are positive findings from such a study.

3.5: Case Study Method

The case study method is discussed here as it correlates to the thesis study. 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. Harvard University's law school, medical school and business school, as well as MIT's Sloan School of Management, are good exemplars that use case studies in their curricula extensively.

The use of case study method in Harvard University dates back to 1870 when Harvard Law School newly appointed dean, Christopher Columbus Langdell, introduced law-based case studies in the school. Langdell introduced the Socratic Method where lecturers question students about the facts of the case. The Socratic Method is still being widely used today as one approach to the case study method. While Langdell's case study pedagogy received initial resistance, it later became the dominant form of legal education and was adopted by many other elite law schools. A graduate from Harvard Law School, Wallace P. Donham, who became the second dean of Harvard Business School in 1919, introduced the case study method in the school. Under his direction, the school developed the first business casebook and later many more cases for multiple courses. Harvard Business School's case-based teaching method had gained popularity since 1921. (Garvin, Sept-Oct 2003)

In using the case study method, the answer to the case questions are not the most important. Ladd (1978) stated the purpose of studying business cases is not always to learn specific answers to specific problems, but to become familiar with analysis and decision making. Ladd (1978) emphasized the process of arriving at answers rather than with answers themselves. Some of the courses in MIT's Sloan School of Management, like the Managerial Finance course (15.401/15.411) and Financial Accounting course (15.501/15.516), supports this philosophy by grading case answers submitted by students based on the process and analysis rather than the correct answer.

The required deliverable of case studies by students is dependent on the set objectives of the curriculum and the time available. Some examples of deliverables are:

- Individual or team presentation of the proposed solution to the class
- Individual or team write up on the proposed solution that is submitted at the beginning of the lesson in which the lecturer leads the class discussion on the case
- Verbal individual or team participation in class discussion on the case

Blank (1985) explored the effectiveness of the case study method for undergraduate courses in agricultural economics in California Polytechnic State University. He divided the students taking introductory agricultural economics into a control and treatment group. The treatment group did

case studies in teams of three to five and the students were regrouped with each new case study. Student performance was measured using scores from the relevant course examinations which correlated to the effectiveness of the case study method. Blank (1985) concluded that the case study method could improve the effectiveness of learning when used as teaching aids. The results indicated that the technique improved students' understanding of complicated material when combined with lecture presentations. Blank (1985), however, cautioned that case studies often do not allow students to "feel" the decision maker's position. He explained that it is difficult for students to fully understand the nature of the environment being described in a case if those students are analyzing the case data in a relaxed, academic atmosphere while having no personal stake in the outcome of decisions being made.

Pilato and Ulrich (2014) published more recent research on the effectiveness of case study method and their findings mirrored that of Blank (1985). They studied the effectiveness of case studies for honors students taking the principles of accounting module in St John's University. In this variation of case study usage, participating students first analyzed the case and researched the solutions individually. They were then assigned to learning teams of about five and were tasked to work together to prepare a presentation for the class. Some groups were selected to present the case to the class, followed a question-and-answer session. After the in-class discussion, students were to prepare a written report on the case. The same selected groups were then asked to present again at the end of the semester to a panel of high-profile accounting professionals. Pilato and Ulrich (2014) concluded that the case study method of teaching principles of accounting is effective. Students successfully learned the course material, as evidenced by the cumulative final exam scores. While largely successful, Pilato and Ulrich (2014) reported a few areas that could be improved, which include:

- Strengthen balance of lecture weeks and workshop weeks
- Focus on the written report
- Use more relevant new case studies
- Present chapters better
- Schedule the professionals to attend presentations earlier in the semester
- Reduce the class size

3.6: Case Study Method in Republic Polytechnic

The case study method is used in the curriculum when it can better allow students to apply knowledge and skills to real-world problems. The module chair of a module may decide use case studies with approval from management. Currently, there is no formal study on the effectiveness of the case study method in the polytechnic. Prior to this thesis study, the case study method was not used in School of Engineering. This thesis describes a study on effectiveness of implementing a variation of the case study methods. Students were given a general technical question and were expected to deliver a written Case Study Paper after a few weeks. Due to the open-endedness of this case study, there would be no single correct answer and students would come up with different solutions. The methodology of the Case Study Paper will be discussed in the following chapter.

Chapter 4: Methodology for Case Study Paper

4.1: Subjects

Participants of this study included second year students from the School of Engineering at Republic Polytechnic in Singapore in the academic year 2016–2017, taking the Microcontroller Systems module. They are enrolled in a three-year Diploma in Electronics and Electrical Engineering (DEEE) course. There are a total of 192 students taking the Microcontroller Systems module. Only those students who submitted the Case Study Paper and the RJs for weeks one to three qualifies for the study.

4.2: Case Study Paper Topic

The topic for the Case Study Paper was released to the students on the first week of lessons in E206 Microcontroller Module, as attached in Appendix B. The lecturer of the class introduced the Case Study Paper to the students. The presentation slides are attached in Appendix C. The assignment was:

> *You are to deliver a Case Study Paper on an application of microcontroller(s) you have encountered in your daily life. This would be an individual written assignment with guidance from your lecturer.*
>
> *The Case Study Paper should include:*
>
> - *Your idea of the application*
> - *Description and functionality of the system*
> - *Input(s) and Output(s) list and functionality*
> - *Your idea of the block diagram of the system*
> - *Your idea of the program flowchart for the system (can be simplified)*
>
> *The assignment should be submitted electronically, with a minimum of two A4-pages long including block diagrams. You should use font size 11 and 1.5 lines spacing.*

4.3: Scaffolding through the Reflection Journals (RJs)

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. Scaffolding for this study is provided in the first four weeks of lesson to help students work towards completing their Case Study Paper.

Since the polytechnic has reflection journals (RJs) as a formal end-lesson tool, the study made use of the RJs as a scaffolding tool for delivering the Case Study Paper. One main reason for using the RJs as scaffolding is to make use of an existing tool that the polytechnic uses. The other reason is to avoid having students write separate RJs for the lesson. This approach streamlined students' deliverables. The approach is not to replace the RJ, but to make use of it as a scaffolding tool.

The protocol for these RJs deviated a little from the normal RJs. The lecturers released the RJ question during of the Case Study Paper segment of each lesson, and discussed the RJ question with the students. The lecturers provided useful feedback on students' RJs to help them improve on their Case Study Paper. A sample answer to the RJ question based on the Case Study Paper was also provided for the students each week.

For weeks one to three, the final one hour of lesson in learning phase three was set aside for the Case Study Paper. The lecturers guided the students to complete their RJs in class during this time. While some students were unable to complete their RJs in class, they had at least started on the them with an idea for how to complete them. Appendix D contains the complete Case Study Paper sample provided to students. Appendix C, Appendix E, and Appendix F contain presentations of the partial sample paper used for weeks one, two and three respectively.
In week four, learning phase one and two for this week was curriculum as usual. Learning phase three in the afternoon focused on the final preparation of the Case Study Paper for students to submit at the end of the lesson.

The RJ questions for the first three weeks of E206 Microcontroller Systems lessons were synchronized and given as:

> *Week One: What are some of the common applications/machines/systems you encounter that possibly use a microcontroller? List at least three such applications/machines/systems, ranging from simple, mid-complexity, and complex (it is ok to use your own judgment to decide on the level of complexity). Which one would you possibly use for your Case Study Paper?*
>
> *Week Two: Recall the application/machine/system you chosen for your Case Study Paper in your previous RJ. Describe the functionality of the system.*

Week Three: Recall the application/machine/system you chosen for your Case Study Paper in your previous RJs. What are the inputs and outputs (I/O) of the system? Draw a simplified I/O module block diagram and describe the functionality of each I/O.

4.4: Timeline

A summary of how the Case Study Paper was integrated into the module is as follows:

Academic Week	Delivery
Week One	Lecturer in class introduced Case Study Paper using presentation slides in Appendix C in the afternoon. Lecturer released Case Study Paper (as in Appendix B) to students prior to presentation. Lecturer released week one RJ question and presented sample answer to the question. Lecturer assisted students in scaffolding the Case Study Paper with RJ topic of the week in the last hour of lesson.
Week Two	Lecturer released week two RJ question and presented sample answer to the question as per presentation slides in Appendix E. Lecturer assisted students in scaffolding the Case Study Paper with RJ topic of the week in the last hour of lesson.
Week Three	Lecturer released week three RJ question and presented sample answer to the question as per presentation slides in Appendix F. Lecturer assisted students in scaffolding the Case Study Paper with RJ topic of the week in the last hour of lesson.
Week Four	Afternoon learning phase three used for Case Study Paper, used to help students get the paper in order for submission. In-class submission of Case Study Paper at the end of the lesson.
Week Five	Thirty students who completed the Case Study Paper randomly selected. Participants signed the consent form for the study. The template for the consent form is in Appendix A.
Week Six	Extracted RJs for week one to three for the 30 randomly selected students. RJs and Case Study Papers de-identified and sent to PI for content analysis.

4.5: Grading

The quality of work produced by students for the Case Study Paper will affect their CA grades for the lesson. This is necessary to make students understand the importance of putting in effort into the Case Study Paper. It is important to note that this grading is not the same as the rubrics scoring results discussed in this chapter in a later section. The grade was given by the instructor while the score using the rubrics was generated by the PI.

A student's CA grade for the first four weeks would be a combination of his/her class performance for other segments and the quality of RJs and Case Study Paper. Specifically, a CA grade would be lowered by full grade when a student failed to submit an RJ for weeks one to three. A CA grade would be raised by one full grade when a student submitted a high-quality RJ for weeks one to three, capping at 'A' grade. A CA grade would be lowered by two full grades when a student failed to submit his/her Case Study Paper for week four. A CA grade would be raised by two full grades when a student submitted a high-quality Case Study Paper for week four, capping at 'A' grade.

4.6: Anti-Plagiarism Rules

While students were allowed to discuss their Case Study Paper, they had to submit their work individually. It was made clear to them that copying each other's work or copying work from books/internet would be considered as plagiarism and a zero grade would be awarded. Students were taught how to quote references from internet/books.

4.7: Data Collection

After students had submitted their Case Study Paper in week four of the module run, the module chair randomly selected 32 students and sought their consent for the study. Out of the 192 students in the cohort, 164 students submitted their Case Study Papers, achieving a submission rate of 85%. All 32 students who were invited to participate in the study accepted the invitation to participate. Of these 32 students, 7 (22%) were females and 25 (78%) were males. These students signed on the consent form (template in Appendix A) to indicate that they had agreed to participate in the study. No further participation was required from the selected students. Their RJs for weeks one to three, and their Case Study Papers, were extracted and de-identified by the module chair who labelled them as Student 1 to Student 32. The de-identified RJs and Case

Study Papers were then forwarded via secured network to the PI for analysis. Since the submissions were done electronically, the data collection process was simplified.

Two students (Student 19 and Student 23) were removed from the study as they did not submit their week two reflection journal. The other 30 students submitted both their week one and week two reflection journals in addition to their Case Study Paper submission. Of these 30 students, 6 (20%) were females and 24 (80%) were males.

Since the sample is randomly taken and the sample size is 30, following the central limit theorem,[5] the results from this study sufficiently represent the students in the cohort taking the Microcontroller Systems module.

4.8: Analysis

Analysis was performed on the Case Study Papers submitted by the 30 randomly selected students. The analysis was separated into three parts:

- Analysis using scoring rubrics (Table 3)
- Content analysis to categorize the students' work according to themes
- Comparison of quality of Case Study Paper to the quality of RJs

4.8.1: Scoring Rubrics

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 for the module. The scoring rubrics in Table 3 provide a descriptive scoring for the quality of students' Case Study Paper. 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.

The scoring rubrics identify the required qualities to be displayed in a Case Study Paper to demonstrate proficient performance. The scoring rubrics were developed based on the

[5]The central limit theorem (CLT) states that, given certain conditions, the arithmetic mean of a sufficiently large number of iterates of independent random variables, each with a well-defined finite expected value and finite variance, will be approximately normally distributed, regardless of the underlying distribution.

purpose and objectives of the Case Study Paper, which is aimed to improve students' learning experience by examining real-world examples of Microcontroller Systems.

Moskal and Leydens (2000) discussed intra-rater and inter-rater reliability issues related to the use of scoring rubrics. The PI of the study used the scoring rubrics to rate the Case Study Papers of the students. Consistency of assessment scores is maintained and hence intra-rater reliability is met. While the Case Study Paper submissions should ideally be rated by more than one rater and benchmarking should done to ensure inter-rater reliability is maintained, this study is an individual thesis work and hence the PI is the only rater. This concern is noted and subsequent follow up research can add more raters to the study.

The scoring rubrics is based on six main categories:

- Components of Case Study Paper
  There are four main components required in the Case Study Paper, namely: application idea, system functionality description, I/O (Input/Output) list, and block diagram. Other optional components that are considered as additional elements in the scoring rubrics are the inclusion of a flowchart, references, and appendices.

- Amount of Information
  The number of words in each of the section except the block diagram section in the Case Study Paper are counted. The section with the least words is used and rated according to the scoring rubrics. For example, if one of the section contained between 80-99 words while the other sections contained more than 100 words, then according to the rubric, the score for this category would be three.

- Quality of Information
  This category looks at supporting details or information provided in the Case Study Paper. The supporting details can be the descriptions of I/O (Input/Output) or pictures or photos of I/O used in the paper.

- Explanation of Application
  This category measures the clarity and technical depth of the explanation of the proposed microcontroller application.

- Diagrams & Illustrations

This category measures the neatness and accuracy of the block diagrams and illustrations.

- Application of Transfer

  This category looks for applications of knowledge and skills students learnt from other modules or from Microcontroller Systems module.

Each paper submitted was rated according to these six categories in five levels of quality as shown in Table 3. Using this analysis tool, a score was generated for each of the 30 students' submission of the Case Study Paper. Mean, median and standard deviation were then computed. Table 3 below is the rubric in its entirety.

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.

Table 3: Scoring Rubrics

4.8.1: Content Analysis

The broader definition of content analysis encompasses rubric scoring discussed in this section earlier. For the purpose of this thesis, content analysis refers to the process of identifying major themes and grouping the students' work according to those themes. Some literature refers to this method as thematic analysis, which is a type of content analysis used by social scientists (Ryan and Bernard, 2003). In this method of analysis, themes or categories are identified from the data being analyzed. For each category identified, occurrences of the concepts in the data are being counted. 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. In this thesis, undertaking a content analysis is meant to address the limitation of scoring by using a rubric. Two questions that the content analysis can help to answer for this study 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 major electronic components?

To answer the first question, major categories of applications are identified and their occurrence counted. The answer to this question can help to identify what are the easier application categories for students to propose.

To answer the second question, major categories of electronic components are identified and their occurrence counted. The number applications that should ideally contain the major components identified are also counted. Collectively, these data can help to identify gaps in what students should include in their application descriptions.

4.8.2: Comparison of quality of Case Study Paper to quality of RJs

Weeks one to three RJs are completed with the guidance of and assistance from lecturers, and they provide scaffolding for students to complete their Case Study Paper. The goal is that the content of the RJs and the Case Study Paper should not deviate too far, and the quality of the Case Study Paper should be better than the quality of the RJs but not worse.

The original idea of the research design was to check each student's case paper against their RJ submissions for weeks one to three for consistency, progress, and quality. However, because the polytechnic's online RJ submission platform does not allow drawing and submission of diagrams, which is required for week three's RJ, students submitted that RJ either as part of their Case Study Paper, or in a separate offline document instead of via the online RJ submission platform. Due to the inconsistencies in submission protocol for week three's RJ, it is not analyzed in this study. The diagram(s) submitted in the Case Study Paper was analyzed using the grading rubrics.

Weeks one and two RJs are used for the comparison analysis.

This page intentionally left blank

Chapter 5: Results

5.1: Scoring Rubrics Results

Table 4 tabulates the Case Study Paper scoring rubrics results of the 30 students rated by the PI of the study. The scoring for each category follows the rubrics in Table 3 (p. 43) in the previous chapter. For each category, a score of four is given for excellent, three for very good, two for satisfactory, one for weak, and zero for unsatisfactory. Students' ID are from Student 1 to Student 32, with Student 19 and Student 23 removed (p. 40). For each student, the final rubric score is computed from the average scores of the six categories.

		Category						
		Components	Amount of Information	Quality of Information	Explanation of Application	Diagrams and Illustrations	Application of Transfer	Student Average Score
Student Score	Student 1	3	2	3	1	1	3	2.17
	Student 2	3	2	4	3	2	3	2.83
	Student 3	3	3	4	2	2	4	3.00
	Student 4	3	2	4	3	2	4	3.00
	Student 5	3	4	2	1	2	3	2.50
	Student 6	4	4	4	3	1	4	3.33
	Student 7	3	3	4	3	1	3	2.83
	Student 8	4	4	4	4	3	4	3.83
	Student 9	4	4	4	1	1	2	2.67
	Student 10	4	3	4	3	2	4	3.33
	Student 11	4	2	1	1	3	2	2.17
	Student 12	4	2	4	2	2	4	3.00
	Student 13	3	1	4	2	3	4	2.83
	Student 14	3	4	4	4	4	4	3.83
	Student 15	4	2	3	1	1	4	2.50
	Student 16	2	1	4	3	1	4	2.50
	Student 17	4	2	4	4	2	2	3.00
	Student 18	3	4	4	4	2	4	3.50
	Student 20	4	3	4	4	1	4	3.33
	Student 21	4	4	4	3	3	4	3.67
	Student 22	4	1	4	1	3	4	2.83
	Student 24	3	4	4	3	3	3	3.33
	Student 25	4	4	3	3	3	4	3.50
	Student 26	4	4	4	4	4	4	4.00
	Student 27	4	2	4	4	4	4	3.67
	Student 28	1	3	2	1	1	3	1.83
	Student 29	4	4	4	2	2	4	3.33
	Student 30	4	4	4	3	3	4	3.67
	Student 31	4	4	4	3	4	4	3.83
	Student 32	4	4	4	3	2	4	3.50

Table 4: Scoring Rubrics Results

From the rated scores, the mean, median, and standard deviation is computed based on the students' average scores and tabulated in Table 5. Sample standard deviation is used as the 30 students represents a sample from a larger population. In this case, the population refers to the cohort of students taking the Microcontroller Systems module in semester one of academic year 2016. Figure 4 shows the histogram of the students' average scores.

Highest	4.00
Lowest	1.83
Mean	3.11
Median	3.17
S.D.	0.56

Table 5: Mean, Median and S.D. of Students' Average Scores

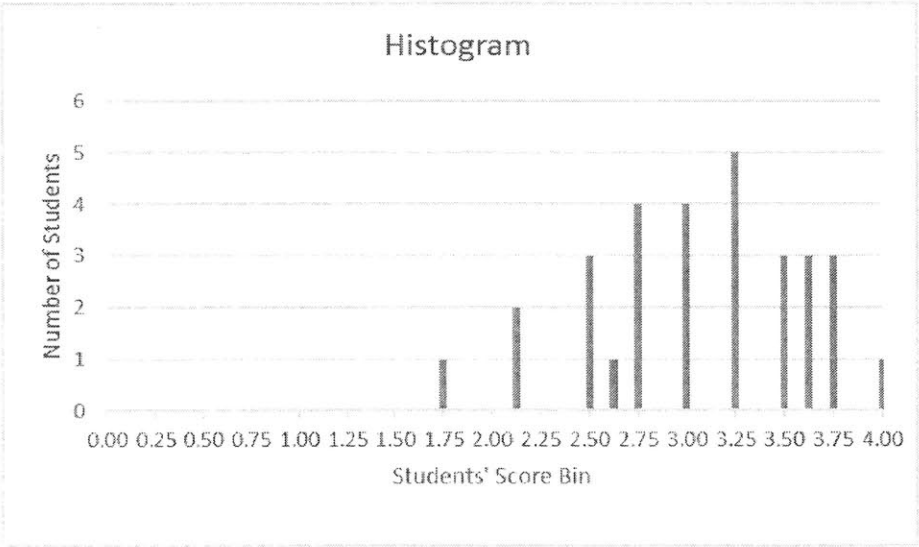


Figure 4: Histogram of Students' Average Scores

Using the rubrics score, the overall scoring for any student can range from a minimum of zero to a maximum of four. The scoring rubrics results of the Case Study Paper submissions showed that the lowest scoring student obtained a score of 1.83, and the best scoring student obtained a perfect score. The mean is 3.11 and the standard deviation is 0.56. The histogram in Figure 4 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 nothing less than 1.83.

The mean score for each of the six rubrics category is computed and shown in Figure 5. 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. Analyzing each category of the rubrics can provide valuable insights to how the students have performed in each category. The rest of this section reports the results of the analysis of each category.

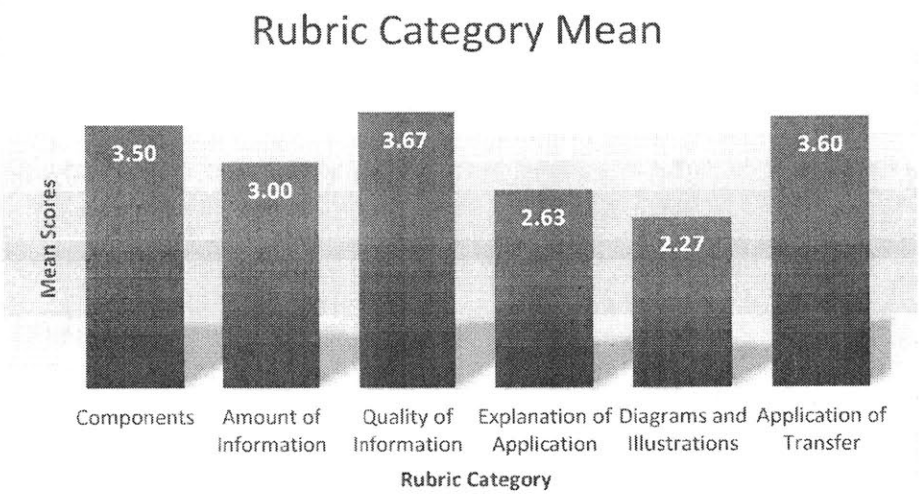


Figure 5: Students' Rubric Category Mean

5.1.1: Components Category

The histogram for the students' scoring results for the components category is shown in Figure 6. The students' mean score is 3.5. Eighteen students submitted their Case Study Papers with additional components in addition to all required components, scoring above the category mean. Ten students submitted their Case Study Papers with all required components, obtaining a score of three in this category. One student had at least one required component missing in the Case Study Paper, obtaining a score of two in this category. One student had more than one required component missing in the Case Study Paper, obtaining a score of one in this category. A total of 93.33% of the students obtained scores of three or four.

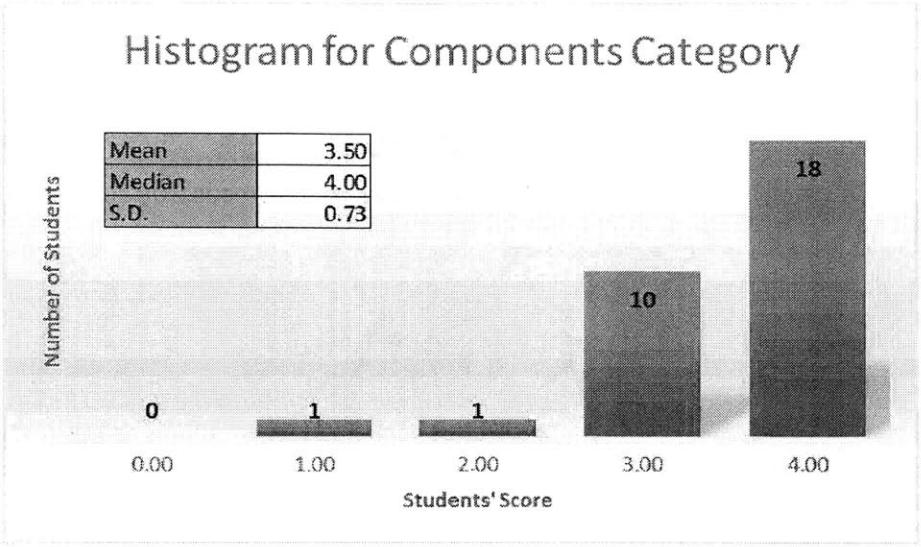


Figure 6: Histogram of Students' Scores in Components Category

5.1.2: Amount of Information Category

The histogram for the students' scores for the amount of information category is shown in Figure 7. The students' mean score is three, slightly lower than the overall rubrics mean of 3.11. Fourteen students wrote at least 100 words in each section of their paper, obtaining a score of four in this category. Five students wrote between 80-99 words in at least one section, obtaining a score of three in this category. Eight students wrote between 50-79 words in at least one section, obtaining a score of two in this category. Three students wrote less than 50 words in at least one section of their paper, obtaining a score of one in this category. A total of 63.33% of the students scored at or above the category mean.

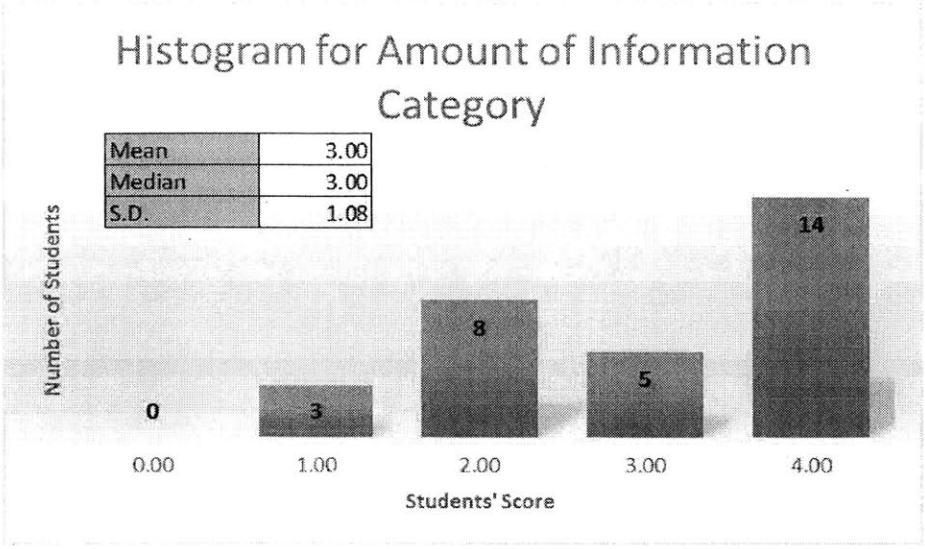


Figure 7: Histogram of Students' Scores in Amount of Information Category

5.1.3: Quality of Information Category

The histogram for the students' scoring results for the quality of information category is shown in Figure 8. Twenty-four students provided three or more supporting details related to the main topic in their Case Study Paper, obtaining a score of four in this category. This number represents 80% of the students. Three students provided two supporting details related to the main topic in their Case Study Paper, obtaining a score of three in this category. Two students provided only one supporting details related to the main topic in their Case Study Paper, obtaining a score of two in this category. One student did not provide any supporting details on the I/Os used for his/her application, obtaining a score of one in this category.

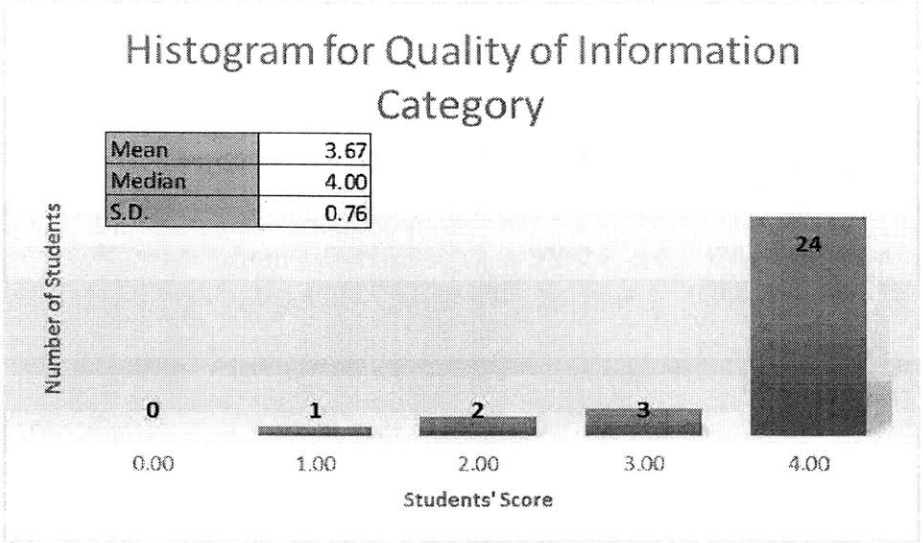


Figure 8: Histogram of Students' Scores in Quality of Information Category

5.1.4: Explanation of Application Category

The histogram for the students' scoring results for the explanation of application category is shown in Figure 9. The mean score of 2.63 for this category is the second lowest in all the categories. Seven students provided detailed and clear explanation of their microcontroller application, obtaining a score of four in this category. Twelve students provided clear explanation of their microcontroller application, but lacked technical depth in their explanation, obtaining a score of three in this category. Four students did not explain their application clearly, but the major components of the application are present, obtaining a score of two in this category. Seven students did not explain their application clearly and have major components of the application missing from their explanation, obtaining a score of one in this category.

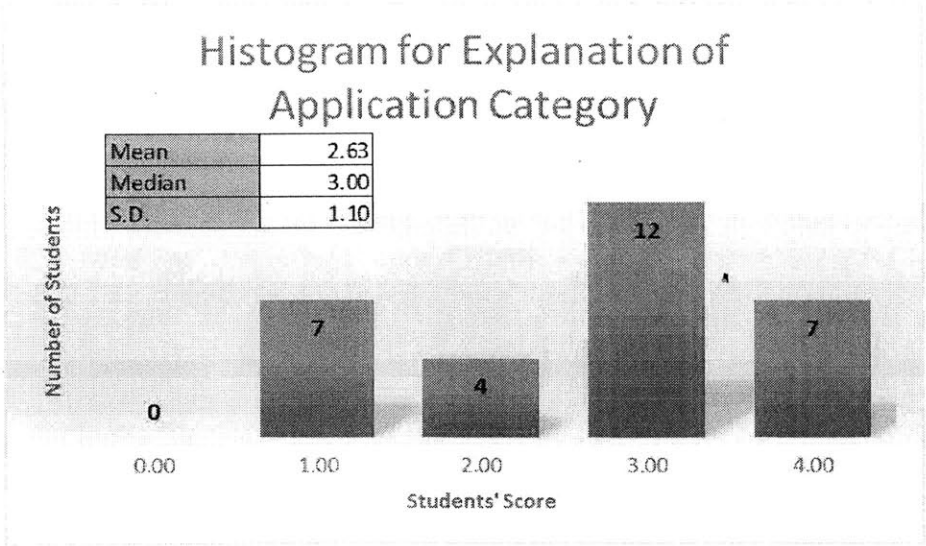


Figure 9: Histogram of Students' Scores in Explanation of Application Category

5.1.5: Diagrams and Illustrations Category

The histogram for the students' scoring results for the diagrams and illustrations category is shown in Figure 10. Among the six categories of the scoring rubrics, the students did worst in this category with a mean score of 2.27. Four students provided neat and accurate diagrams with an explanation that add to the reader's understanding of the proposed application, obtaining a score of four in this category. Eight students provided accurate diagrams that add to the reader's understanding of the proposed application, obtaining a score of three in this category. Ten students provided accurate diagrams but lacked explanations, obtaining a score of two in this category. Eight students provided inaccurate diagrams of their proposed application, obtaining a score of one in this category.

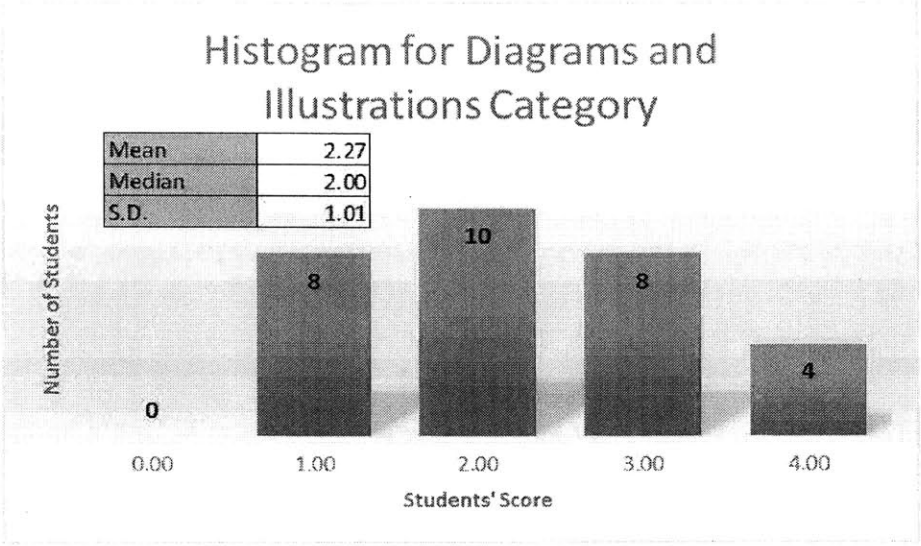


Figure 10: Histogram of Students' Scores in Diagrams and Illustrations Category

5.1.6: Application of Transfer Category

The histogram for the students' scoring results for the application of transfer category is shown in Figure 11. The students' mean score in the category is 3.6, the second highest in the six categories as shown in Figure 5. Twenty-one students provided at least three clear applications of knowledge or skills from previous learning, obtaining a score of four in this category. Six students provided two clear applications of knowledge or skills from previous learning, obtaining a score of three in this category. Three students provided one clear applications of knowledge or skills from previous learning, obtaining a score of three in this category.

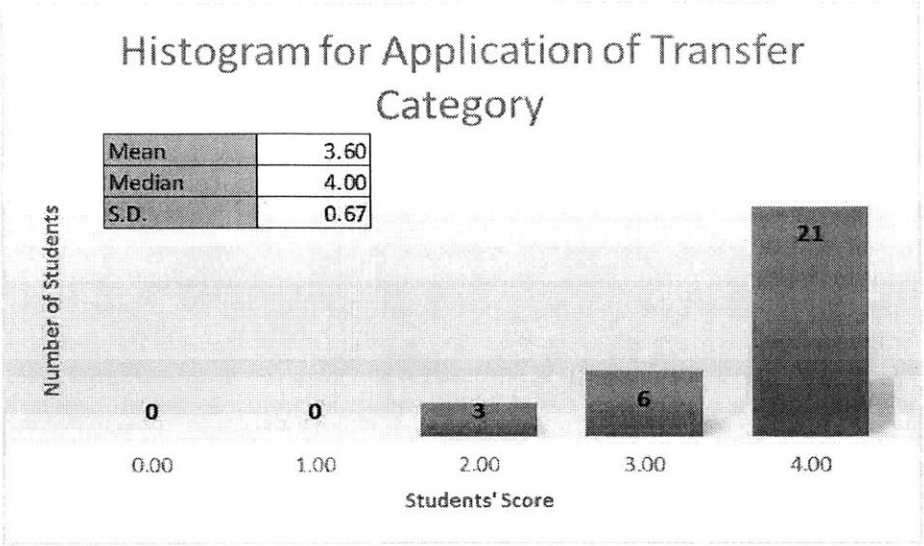


Figure 11: Histogram of Students' Scores in Application of Transfer Category

5.2: Content Analysis Findings

The first kind of content analysis performed was to identify the types of applications the students wrote about. This can provide insights on what are the easiest types of applications for students to write on. By careful examination of the 30 Case Study Paper submissions, the proposed application categories are identified and placed in one of the four categories: Household Equipment, Entertainment Devices, Office Equipment, and Miscellaneous as shown in Table 6. The application categories are mutually exclusive so there were a total of 30 applications (since there are 30 students).

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

Table 6: Identified Application Categories of the Case Study Paper Submissions

The category for Household Equipment has 15 occurrences, indicating 15 out of 30 students described applications that are household equipment. These include the microwave oven, the washing machine, the air-conditioner, the smart fan, the rice cooker, the doorbell, the home

security system, and the fire alarm system. An example of this category is Student 4's write-up on the washing machine:

> Microcontroller receives analog inputs that can sense water level, laundry load and volume. Data can be stored for customizing programs. Microcontroller adjusts water and cuts power automatically. It can also detect failures. Clocks and timers can implement sleep mode and add delays in operations. A buzzer is also present and it generates different alert tones. Important parts of washing machine are controlled electrically. Power on the machine can be switched on after putting the clothes and detergent. Buttons on the machine can perform various programs one wants. One of them is the button that allows water valves to open and make hot and cold water to enter the machine to fill the drums. The washing process will then begin after water reaches the desired level. Inner drum rotates back and forth to create soapy water. Afterwards, the valve opens and water drains out from it. Water valves are opened again to allow clean water to enter the drums. It rotates back and forth again to rinse the clothes. This process is then repeated several times to get rid soapy water on the clothes. Once rinsed, drum rotates at high speed and clothes are tossed to the sides of inner drum. It makes the clothes dry. The pump removes the remaining water and the process comes to an end. (Student 4)

(All quotations from students in this thesis are their original work, and have not been corrected for grammar or punctuation.)

The category for Entertainment Devices has nine applications, including the smart phone, the camera, the game console, a sound system, flying drones, the MP3 player, and the remote control car. An example of this category is Student 9's description of the smart phone:

> Basically, a phone enables users to make calls and receives calls, texts from other users (wireless connection) but as the time goes by, technology getting better and convenient for human use. For example, we can go online-shopping, entertainment, google information for school work (web browser), listen to music on music player, keep track our health, locations etc. at any time-anywhere by just holding a lightweight, easily portable device on hands without the use of carrying big devices (desktop, laptop, radio etc.) around because SIM card (a small chip) is inserted in phone that make small devices like phone acts like a big device. Depending on different applications, those mentioned above need to connect to connect to cellular network and some do not (for example: simple calculation, allow user to view images taken from with the use of camera or after screenshot down from online etc.). In conclusion, phone make our life easier. (Student 9)

There are only two students who described applications that are office equipment. The applications described are the calculator and the inkjet printer, submitted by Student 1 and Student 3 respectively. Student 3's description of the inkjet printer application is as below:

> Inkjet printer uses one of the most popular printing technologies today, and the relatively low cost and multi-purpose printing abilities makes inkjet printers a good choice for small businesses and offices. Inkjet printers uses quick-drying, water-based ink and a print head

> with an assembly of small nozzles that spray ink onto the surface of the paper. The print head is driven by a belt-fed motor that moves the print head across the paper. Inkjet printers are usually low cost and scale slightly upwards based on print quality, extra features and the ability to print on larger formats. (Student 3)

There are four applications that do not fit into any of the three categories, and hence they were placed in Miscellaneous category. These application ideas include the vending machine, the solar street light system, and the escalator. There are two students that used the vending machine as application, in which one of them described:

> Vending machine is a machine that will dispense any item that the company wants. Some vending machine can dispense food while some can dispense stationaries. Vending machine is very important in schools because it gives student to buy materials for school quicker. With vending machine operating 24hours. The student can get the item they want without worrying about the item they want cannot be received. Most modern vending machines accept coins and notes. A vending machine is where you dispense an item. A coin will be inserted to the coin slot and will be check for fake coins. After it has discovered the coin is not a fake. It will then count or find out the amount of money/value. The counter will then input the numbers to the LCD. The value will then match with the value of an item. If it is equal, It will dispense the item. It uses mid-complexity microcontroller as the input is by the user pressing the button of an item that the user would want. The input will be converted to output and lit up the LED for the item that the user has chosen. After dispensing the item. It will check whether the item has more in stock. If it does not, it will show 'out of stock'. (Student 2)

Further analysis of the 30 submitted papers shows that students wrote about the usage and description of electronic components, which makes sense as these papers were written for a module on micro controllers. Electronic components can be passive or active, and generally operate with D.C. voltages. They can be LEDs, IC chips, resistors, capacitors, various types of sensors, switches, etc. Twenty-nine out of 30 students described at least one electronic component. Ideally, all papers should mention and describe electronic components related to their applications, but one student did not describe any electronic components. This student obtained a score of one for the "explanation of application" and "quality of information" categories on the rubric.

Among the electronics components mentioned in the papers, LEDs (Light Emitting Diodes), buttons, switches, keypads, sensors, buzzers and speakers are most prevalent. LEDs, buzzers and speakers are outputs from a system. Buttons, switches, keypads and sensors are inputs to a system. The applications proposed by the students are also examined to identify if these components should be included.

Out of the 30 analyzed applications, LEDs, which are simple visual output indicators, should be included in 27 applications. Fourteen out of these 27 applications mentioned and described the use of LEDs. The students described the purpose of the LED(s) in their microcontroller application. As the usage of LEDs are different for different applications, the descriptions of the usage of LEDs are not the same. An example of a good description for the LED usage is for an inkjet printer:

> LED Display: To display Errors/Results and troubleshooting codes. The micro-controller receives signals from print-head driver and paper sensors, which allows the program to display messages on the LED Display. (Student 3)

Out of the 30 analyzed applications, buzzers and speakers, which are output components that produce sound, should be included in 10 applications. All 10 of these applications described the use of buzzers and speakers. A buzzer is more primitive and can only produce simple audio tones, while a speaker is more complex and can produce sound with much better quality. Student 14 provided a technical description of how a speaker works:

> It converts the electrical signal back into sound energy through the diaphragm. By moving back and forth, the speaker increases and decreases the air pressure in front of it thus creating sound waves. (Student 14)

While the usage of buzzers and speakers varies for different applications, the general point all students included is that the buzzers and the speakers are used to provide audio feedback to the human user(s) for follow-up actions. Some examples are buzzer descriptions from Student 8, Student 10, and Student 22 are:

> Buzzer: whenever the appliance finished its task or a button is pressed, the user will be informed by the sound (Student 8)

> Every single beep sound was made while you are selecting an option on the microwave-oven. Longer beep sounds are to let you know that your food is done. (Student 10)

> Buzzer: An audio signalling device to indicate if there is an obstacle in front of the vehical. (Student 22)

All 30 analyzed applications should include the description of buttons, switches or keypads, and 23 applications do mention and describe them. A common use mentioned is the power on/off switch. Further analysis revealed that there are 14 occurrences of power on/off switch. A representative example of an expression of on/off switch is Student 4's description, which explained from an electronic circuit viewpoint how the switch operates:

> Turning on the switch activates the system as power passes through it. No power supply passes through when the switch is off. (Student 4)

Out of the 30 analyzed applications, sensors should be included in 25 applications, and 20 applications described them. Sensors is a very wide category. They are used to sense specific environmental information and the sensed data are used as inputs to a system. The sensors described in the papers are light sensors, pressure sensors, water sensors, humidity sensors, infra-red sensors, motion sensors, proximity sensors, heat sensors, and smoke sensors. The description of the use of sensor(s) depends on the application proposed by the students. As an example, Student 21 described the motion sensor and the temperature sensor in his/her write-up on a smart fan application:

> Temperature sensor: DHT11 sense the temperature of the room and adjust the fan speed to make sure the room is always cooling. Its signal will be send to the fan to change it's speed.
>
> motion sensor: PIR Motion Detector module is built in the fan and detect movement of the user, when motion is detected the module will send a signal to switch on the led light. (Student 21)

Out of the 30 analyzed applications, the electric motor should be included in 19 applications, and it was included in 10 applications. Motors are internal electrical parts, not electronic components. They are neither inputs nor outputs of an application. The motors described in the 10 papers serve different purposes depending on the application proposed. They include the motor driver in the printer, the motor to drive the drum of the washing machine, the motor to drive the turntable in the microwave, the fan motor in the air-conditioner, the motor to drive the zoom function in the camera, the motor to drive the wheels of the remote control car, motor in the electric fan, and motor to drive each propeller of the drone. An example is Student 30's description of the motor in his/her microwave oven application write-up:

> This motor helps to generate the turning plate making sure all portion of the food are evenly cook by the heat. (Student 30)

While reading through the Case Study Papers, it has been noted that 15 out of 30 students explained the importance of their proposed applications. Examples are quotations from Student 5, Student 6, and Student 31:

> As you know the term "rice cooker" is basically telling you that it is made just to cook rice. But there's a lot of different uses for a rice cooker for example besides cooking rice we can use it to steam vegetables, chicken and a lot more. You can even cook different types of dishes in the rice cooker. (Student 5)

> Automatic solar light is a simple application of microcontroller, it is pretty sure that this inventions is really cool "solar street light" which were widely using now a days to reduce the power consumption and it is really helpful to save the electrical energy. (Student 6)

> I am doing the fire alarm as I am interested in fire. How it is considered a dangerous thing but at the same time it is also very helpful to the mankind. Without fire we cannot even do our daily routines at all. For example eating, we will all be eating raw food instead of cook food. Not only does it give more favour to the food but it kills all the undesirable bacterial found in raw food. The fire also serves as a main source of heat and a necessity in many scenario. But on the other hand if you play with fire there is a very undesirable outcome it may cause lives. Prevention is better than cure so I will be doing a case study on the Fire alarm system. (Student 31)

5.3: Comparing Case Study Paper to RJs

The students' Case Study Papers were compared to their RJs for week one and week two. RJs for weeks one to three were used as scaffolding for students to prepare for their Case Study Paper, leading up to submission in week four. As mentioned in Chapter 4 (p. 44), week three's RJ was either done offline or directly on the Case Study Paper and hence it is not analyzed here.

Week one RJ relates to the application section of the Case Study Paper. The RJ for this week asked students to suggest three application ideas and to use one for their Case Study Paper. Ideally, a subset of this RJ can be used for the application section of the Case Study Paper. Week two RJ asked students to describe how the system functions, which is also one of the sections in the Case Study Paper.

The correlations between the Case Study Paper and the RJs can be categorized into the following groups:

- Identical: The entire RJ is copied and pasted into the Case Study Paper. Week one RJ to the application section and week two RJ to the system functionality description section of the Case Study Paper.
- Identical Subset: Part of the RJ is copied and pasted into the Case Study Paper. This happened for week one RJ which, ideally, should have three application ideas, and only one should be used for the Case Study Paper.

- Almost Identical: The RJ is copied and pasted into the Case Study Paper with editing and additional information provided in the Case Study Paper.
- Related: The RJ is not copied into the Case Study Paper, but there is correlation. Some students provided additional information and details in the Case Study Paper, while other students restructured their sentences based on similar information.
- Not Related: The contents of the RJ and the contents Case Study Paper is not related. Ideas and information are not the same.

Table 7 records the categorized findings on the correlations of week one and week two RJs to the students' Case Study Paper.

		Week One RJ	Week Two RJ
Student ID	Student 1	Almost Identical	Almost Identical
	Student 2	Related	Related
	Student 3	Related	Identical
	Student 4	Identical Subset	Identical
	Student 5	Identical	Identical
	Student 6	Related	Related
	Student 7	Related	Related
	Student 8	Almost Identical	Almost Identical
	Student 9	Related	Related
	Student 10	Related	Related
	Student 11	Related	Related
	Student 12	Related	Related
	Student 13	Related	Related
	Student 14	Identical	Identical
	Student 15	Identical	Identical
	Student 16	Related	Identical
	Student 17	Identical Subset	Identical
	Student 18	Related	Related
	Student 20	Not Related	Not Related
	Student 21	Not Related	Related
	Student 22	Related	Related
	Student 24	Related	Almost Identical
	Student 25	Related	Almost Identical
	Student 26	Almost Identical	Identical
	Student 27	Almost Identical	Related
	Student 28	Identical	Identical
	Student 29	Identical	Identical
	Student 30	Not Related	Related
	Student 31	Identical Subset	Identical
	Student 32	Identical Subset	Identical

Table 7: RJs Correlation to Case Study Papers

	Week 1 RJs	Percentage (Week 1)	Week 2 RJs	Percentage (Week 2)
Identical	5	16.67%	12	40.00%
Identical Subset	4	13.33%	0	0.00%
Almost Identical	4	13.33%	4	13.33%
Related	14	46.67%	13	43.33%
Not Related	3	10.00%	1	3.33%
Total	30	100%	30	100%

Table 8: RJ Comparison to Case Study Paper Categories Distribution

The RJs were counted by their categories and the results shown in Table 8. From the table, it is observed that 46.67% of the week one RJs and 43.33% of the week two RJs are related to their respective Case Study Papers. Students in this category have an idea of what they wish to propose as the microcontroller application. Some students in this category have given more thought than others, wrote down more information, and used this information to write their Case Study Papers. An example of this is Student 3's submission who wrote in his/her week one RJ:

> Some of the common applications, machines and systems of a micro controllers would be Remote Controllers, Washing machines, Printers and many more. Ranging from Simple complexity, Mid-complexity and High-complexity. The Remote Controllers would have a level of Simple complexity(Assuming Toy car/Toy Plane RC and TV RC), due to their straight forwardness in programming the I/O pins. Washing Machines would have a level of Mid-complexity, as usually washing machines comes in fully automatic, semi-automatic and manual modes. Where in some modes requires user intervention. Also requires the machine components to feedback(input) to the controller(Water levels reached, thus changing signal values). Printers would have a high level of complexity, as it has multiple devices/components that acts as inputs(scanner, USB, etc) and outputs(Printer head, ink cartridge, etc), requires a complex amount of logic configuration/programming. I would probably use the Printer for my Case Study Paper. (Student 3)

Compare this with this same student's application section in the Case Study Paper:

> Inkjet printer uses one of the most popular printing technologies today, and the relatively low cost and multi-purpose printing abilities makes inkjet printers a good choice for small businesses and offices. Inkjet printers uses quick-drying, water-based ink and a print head with an assembly of small nozzles that spray ink onto the surface of the paper. The print head is driven by a belt-fed motor that moves the print head across the paper. Inkjet printers are usually low cost and scale slightly upwards based on print quality, extra features and the ability to print on larger formats. (Student 3)

Notice that this student's week one RJ is longer than the Case Study Paper as it consists of three suggestions for microcontroller applications. The application section write-up of the Case Study

Paper is quite different from the RJ yet the main components are mentioned again in more detail in the Case Study Paper.

Other students in the "related" category have not thought deeply about the details when writing their RJs, and expanded their ideas with details in their Case Study Papers. An example of this is Student 22's submission for his/her week one RJ:

> Simple - Running lights....like the ones used on hari raya or christmas. Mid Complex - Remote control car. Complex – Arduino I would use remote control car for my case study cause there's a lot to write about. (Student 22)

Compare it with this student's application section in the Case Study Paper:

> This is an autonomous Vehicle that follows a certain type of marking on the floor. It uses sensors that detect the marking and controllers the motors and the wheel accordingly directing the vehicle along the desired route. (Student 22)

This student only mentioned that she/he would write about the remote control car in his week one RJ. Notice that the application section write-up is not very detailed either, though it does provide the reader with a much better idea of what type of remote control car she/he wrote about in the Case Study Paper.

Table 8 revealed 16.67% of the week one RJs and 40% of the week two RJs are identical to a section in the Case Study Paper. Week one RJs were copied into the application section of the Case Study Paper while week two RJs were copied into the system functionality description section of the Case Study Paper. This group of students spent more time in writing their RJs, with the intention of writing the complete section of the final paper submission.

A smaller percentage (13.33%) of the RJs for weeks one and two come from the almost identical category. The majority of the contents in these students' Case Study Papers were copied directly from the RJs, with some effort put into editing and adding a few sentences.

Since week one RJ questions asked students to propose three possible applications of microcontroller while the Case Study Paper only needed one proposal, 13.33% of the students made an effort to copy a subset of their week one's RJ in to the application section of their Case Study Paper. An example of an RJ in the identical subset category is Student 4's week one RJ:

> Some common applications, machines or systems I encounter that possibly use a microcontroller are mobile phones, cars, washing machines, cameras and security alarms. In my opinion, mobile phones communication with microcontroller using Bluetooth is

> simple. Data can be transmitted and received wirelessly between the devices through host controller interface. Security alarms have mid-complexity. Security systems for doors use microcontrollers. Digital input can be read from infrared receiver. Data can be sent to LCD and computer using serial port. Washing machines are complex. Microcontroller receives analog inputs that can sense water level, laundry load and volume. Data can be stored for customizing programs. Microcontroller adjusts water and cuts power automatically. It can also detect failures. Clocks and timers can implement sleep mode and add delays in operations. A buzzer is also present and it generates different alert tones. Out of these three, I would possibly use washing machine for my Case Study Paper. (Student 4)

Compare it with this student's application section in the Case Study Paper:

> Microcontroller receives analog inputs that can sense water level, laundry load and volume. Data can be stored for customizing programs. Microcontroller adjusts water and cuts power automatically. It can also detect failures. Clocks and timers can implement sleep mode and add delays in operations. A buzzer is also present and it generates different alert tones. (Student 4)

Careful inspection reveals that the application section write-up in the Case Study Paper is a subset of what this student wrote in the RJ for week one.

Only a very small percentage of the RJs the students wrote are not related to their Case Study Papers. Students in this group responded to the RJ questions, using other microcontroller applications, and later changed their applications to something else. An example is Student 20, who wrote about an activity monitor, a blood pressure monitor, and a lighting system board in week one's RJ:

> An activity monitor that is used in a hospital, Blood pressure monitor that is used in a hospital and lastly, a lighting system board. I would range the activity monitor to be the simplest, blood pressure monitor would be mid-complexity and lastly the lighting system board would be the most complex out of all the 3 application. I would probably use the lighting system board as my Case Study Paper because firstly it weights a large amount of marks in my CA. Furthermore, there are more micro controller functions in a lighting system board and also i thinks that it would be a really interesting topic to do on my case studies paper. (Student 20)

This same student switched to write about cameras in his/her Case Study Paper.

The RJs correlation to the Case Study Paper can be further analyzed by grouping students whose Case Study Paper and RJs had the same level of overlap and computing the average of the Case Study Paper rubric scores for each category. The students would fall into one of the six mutually exclusive categories.

- Category One: Students with both weeks one and two RJs identical, almost identical, or identical subset to the application and system functionality description sections of their Case Study Paper respectively.
- Category Two: Students with both weeks one and two RJs related to the application and system functionality description sections of their Case Study Paper respectively.
- Category Three: Students with week one RJ related to the application section of their Case Study Paper, and week two RJ identical, almost identical, or identical subset to the system functionality description section of their Case Study Paper.
- Category Four: Students with week one RJ identical, almost identical, or identical subset to the application section of their Case Study Paper, and week two RJ related to the system functionality description section of their Case Study Paper.
- Category Five: Students with week one not related to their Case Study Paper, and week two RJ related to the system functionality description section of their Case Study Paper.
- Category Six: Students with both weeks one and two RJ not related to their Case Study Paper.

Table 9 shows the list of all 30 students and the category they are in.

		Week One RJ	Week Two RJ	Category
Student ID	Student 1	Almost Identical	Almost Identical	1
	Student 2	Related	Related	2
	Student 3	Related	Identical	3
	Student 4	Identical Subset	Identical	1
	Student 5	Identical	Identical	1
	Student 6	Related	Related	2
	Student 7	Related	Related	2
	Student 8	Almost Identical	Almost Identical	1
	Student 9	Related	Related	2
	Student 10	Related	Related	2
	Student 11	Related	Related	2
	Student 12	Related	Related	2
	Student 13	Related	Related	2
	Student 14	Identical	Identical	1
	Student 15	Identical	Identical	1
	Student 16	Related	Identical	3
	Student 17	Identical Subset	Identical	1
	Student 18	Related	Related	2
	Student 20	Not Related	Not Related	6
	Student 21	Not Related	Related	5
	Student 22	Related	Related	2
	Student 24	Related	Almost Identical	3
	Student 25	Related	Almost Identical	3
	Student 26	Almost Identical	Identical	1
	Student 27	Almost Identical	Related	4
	Student 28	Identical	Identical	1
	Student 29	Identical	Identical	1
	Student 30	Not Related	Related	5
	Student 31	Identical Subset	Identical	1
	Student 32	Identical Subset	Identical	1

Table 9: RJs Correlation to Case Study Papers Categories

Table 10 shows the Case Study Paper rubric score for each of the student in Category One. Twelve students fall into this category. The student with the highest rubric score (Student 26) is in this category, as is the student with the lowest rubric score (Student 28), which is puzzling. The category average score is 3.11, the same as the overall rubric score mean. Category average is the average rubric score of the students in the same category.

		CSP Rubric Score
Student ID	Student 1	2.17
	Student 4	3.00
	Student 5	2.50
	Student 8	3.83
	Student 14	3.83
	Student 15	2.50
	Student 17	3.00
	Student 26	4.00
	Student 28	1.83
	Student 29	3.33
	Student 31	3.83
	Student 32	3.50
	Category Average	3.11

Table 10: Category One Students' CSP Rubric Score

Table 11 shows the Case Study Paper rubric score for each of the students in Category Two. Ten students fall into this category. The category average score is 2.93, lower than Category One average score.

		CSP Rubric Score
Student ID	Student 2	2.83
	Student 6	3.33
	Student 7	2.83
	Student 9	2.67
	Student 10	3.33
	Student 11	2.17
	Student 12	3.00
	Student 13	2.83
	Student 18	3.50
	Student 22	2.83
	Category Average	2.93

Table 11: Category Two Students' CSP Rubric Score

Table 12 shows the Case Study Paper rubric score for each of the student in Category Three. Four students fall into this category. The category average score is 3.08.

		CSP Rubric Score
Student ID	Student 3	3.00
	Student 16	2.50
	Student 24	3.33
	Student 25	3.50
	Category Average	3.08

Table 12: Category Three Students' CSP Rubric Score

Table 13 shows the Case Study Paper rubric score for the only student in Category Four. This student's rubric score is 3.67.

		CSP Rubric Score
Student ID	Student 27	3.67
	Category Average	3.67

Table 13: Category Four Student's CSP Rubric Score

Table 14 shows the Case Study Paper rubric score for each of the student in Category Five. Only two students fall into this category. Both students have a rubric score of 3.67, and hence the category average score is also 3.67.

		CSP Rubric Score
Student ID	Student 21	3.67
	Student 30	3.67
	Category Average	3.67

Table 14: Category Five Students' CSP Rubric Score

Table 15 shows the Case Study Paper rubric score for the only student in Category Six. This student's rubric score is 3.33.

		CSP Rubric Score
Student ID	Student 20	3.33
	Category Average	3.33

Table 15: Category Six Student's CSP Rubric Score

Chapter 6: Discussion

The results presented in the previous chapter are discussed in this chapter. Specifically, the discussion covers the scoring rubrics results, the content analysis, and the comparison between the RJs and the Case Study Papers. Additional observations made during the analysis of the Case Study Papers are also discussed in this chapter.

6.1: Scoring Rubrics Discussion

Referring to Table 5 (p. 48) in Chapter 5, the overall scoring mean for the Case Study Paper is 3.11. A comparison can be made with the average CA (Continual Assessment) grade for a single lesson in School of Engineering. Recall that CA grade can be A (4), B (3), C (2), D (1), or F (0). This closely matches the scoring rubrics used for this study. In a typical lesson, the average score for the CA is usually about 2.5, with most students scoring either B or C grades.[6] A mean of 3.11 for Case Study Paper suggests that students did better for the Case Study Paper compared to their usual assessments.

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. The rest of this section is dedicated to the discussion on the results of rubrics scoring of the individual categories.

6.1.1: Components of Case Study Paper Rubric Category

Figure 6 (p. 50) in Chapter 5 indicated that most students performed well in the components category of the scoring rubrics. Only two students have missing components in their Case Study Paper. We assume the main reason students performed well in this category is that most of them followed the format of the sample paper used as scaffold. This indicates that students are good in following a certain format to include required components when proper scaffolding is provided.

[6] Data are only available internally within the polytechnic and the rights to publish it is withheld by the registrar of the polytechnic.

6.1.2: Amount of Information Category

The students in School of Engineering are generally not very proficient in writing in English. Writing at least 100 words in each section of the Case Study Paper, as observed, is a challenge to many. Referring to Figure 7 (p. 51) in Chapter 5, the category mean score is three, with 63.33% scoring at or above this category mean. This indicates that the students wrote an average of between 80-99 words for each section of the paper. The application section of a typical mid-complexity microcontroller application should be about 100 words, while the system functionality description can contain much more than 100 words. The sample paper used as reference for students contained 109 words in its application section and 237 words in its system functionality description section. This finding appears to support the earlier remark that the students find it difficult to write in English.

6.1.3: Quality of Information Category

As can be observed from Figure 8 (p. 52) in Chapter 5, the students performed excellently in this category, with 80% of the students scoring above the category mean of 3.67. As with the components category, the students performed well in this category because most of them have followed the format from the sample paper used as scaffold. The sample paper included details and photos of each of the I/O (Input/Output) used in the application example. While the sample paper's format is only a guide, most students used the same format for their Case Study Paper. Each description of an I/O (Input/Output) is considered as one supporting detail, and usually there are a handful of I/Os (Input/Output) in a microcontroller application.

6.1.4: Explanation of Application Category

As can be seen from Figure 9 (p. 53) in Chapter 5, the students did not perform well in explaining their applications in their Case Study Paper. Many of the explanations are at the user level and lack technical depth. Only seven students (23.33%) provided deeper technical explanations of their system. One of the reasons for the lack of technical depth in could be the instructors did not communicate fully with the students about the technical depth they wanted in the Case Study Paper. Another reason could be the students' lack of training and exposure; they are, after all, second year students in their first semester of the year. They have only completed about four to five engineering related modules in their first year of study.

6.1.5: Diagrams and Illustrations Category

While all students provided at least one diagram, many did not explain the diagrams clearly. Referring to Figure 10 (p. 54) in Chapter 5, 73.33% of the students provided accurate block diagrams (score of two and above), but only 40% provided a clear explanation of the block diagrams that add to a reader's understanding (score of three and above). 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 week two and week three RJ, respectively. Most students probably did not visualize a block diagram in week two when explaining how their proposed application functions in the same week. And in week three, these students probably did not refer back to their RJ in week two while drawing the block diagram for their system. In week 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 is probably not done either.

6.1.6: Application of Transfer Category

Referring to Figure 11 (p. 55) in Chapter 5, it is observed that students did very well in this category, with a mean score of 3.6. More than 90% of the students demonstrated at least two clear applications of knowledge or skills from previous learning, either from the Microcontroller Systems module, or from other modules. Evidence of this transfer of knowledge includes using and explaining electronic hardware components, using a flowchart to explain the application, and describing simple LED usage and control. In the I/O section of the 30 analyzed submissions, it is common to find electronic components (e.g., LED, various types of switches, potentiometer, relay, transistor) being listed and their functionality explained. These electronics components and their use are taught in other modules. Also some of the students included an optional flowchart to explain the software flow as they understood it. Flowcharts are primarily used to describe the sequential and logical flow of software codes and used as a common tool for software developers. Students learnt how to use flowcharts in a software module in their first year of study. Similarly, the use and control of LED(s) is commonly mentioned in the Case Study Paper submissions. Students learnt how to control LEDs using a microcontroller in lesson one and two of the Microcontroller Systems module.

Should this be numbered as a separate subsection? The high average scores for "quality of information" and "application of transfer" rubric categories suggested that students know much about electronic components (application of transfer) and are able to describe what these components are used for (quality of information) in an application. The electronic components and their description of usage are like pieces of a jigsaw puzzle. Students seems to lack the skill to present the whole picture of the jigsaw puzzle whether by describing the system in words or through diagrams. This is revealed in the lower average scores for Explanation of Application as well as Diagrams and Illustrations rubric categories. Recall that the students in this study are second year, first term students. The findings suggested that prior teachings in year one and first few weeks of the current term have been effective in introducing various electronic components and their uses. The findings also suggested that more work have to be done in the students' second and third year curriculum to expose the students to systems thinking so they can see the complete picture of an application.

6.2: Content Analysis Discussion

Findings from Chapter 5 (p. 55) revealed two major categories of applications described by students: Household Equipment and Entertainment Devices. Fifty percent of the students used Household Equipment as their application, while another 30% used Entertainment Devices as application. This suggests that it is easy for students to relate to equipment found in the common home or systems used for entertainment as examples of microcontroller applications. This is probably because students are familiar with the entertainment systems and home equipment that surrounds them. Only 6.67% of the students proposed applications in the category of Office Equipment. This suggests that majority of the students lack familiarity with equipment in the office that uses microcontroller systems. 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. We know this practice helps to further learning.

Findings from Chapter 5 (p. 57) indicated that 29 out of 30 students described at least one electronic component in their papers. This indicates that most students are able to apply prior knowledge and skills from the Microcontroller Systems module and from other modules. This reinforces the findings from Application of Transfer in the rubrics analysis.

While 27 of the analyzed applications (p. 58) should include LED(s), only 14 students mentioned and described it. LEDs is one of the simplest and most fundamental electronic components. The usage of LEDs is covered in year one of study, and revisited in lessons one and two of Microcontroller Systems module. Another electronic output component, the buzzer or speaker, was described in all 10 applications that needed a buzzer or speaker (p. 58). The buzzer was covered only in lesson four of Microcontroller Systems module, which is the week the Case Study Papers are due for submission. By comparison, only slightly more than 50% of the students were able to recognize that their applications included LED(s), while 100% of the students were able to recognize that their applications included the buzzer or speaker. One possible explanation of this outcome is that students pay more attention to auditory feedback than visual feedback in a microcontroller application. Another possible reason is that students might have described what they felt are the more important components of the application and omitted the LED(s). Yet another explanation is that buzzers are covered in the same lesson that the Case Study Paper is due. These findings suggest a review of Microcontroller Systems lessons one and two on usage of LEDs would be helpful.

Findings from Chapter 5 (p. 58) reveal that while all papers should include buttons, switches, or keypads, 23 students mentioned and described these components. Buttons and switches are covered in a year one module, and revisited in lesson five of Microcontroller Systems module, one week after the Case Study Papers have been submitted. Keypads are not covered in the curriculum and students that know to include a keypad are self-taught. Since the Microcontroller Systems module has yet to cover buttons and switches when the students are working on their Case Study Papers, this indicates application of knowledge and skills from other prior modules, or that some students are particularly observant about the systems that surround them.

Eighty percent of the applications that should include sensor(s) have described them. This is an interesting finding. There are various types of sensors, and even sensors of the same type have different specifications. Creating an exhaustive list of sensors would be almost impossible. Modules cover specific sensors only when needed. Many of the sensors described by the students are not covered in their curriculum. The findings suggest that students are aware, as well, of the type of sensors used in various microcontroller applications, even when it is not covered in any of their modules. This is probably knowledge gained from the internet or from their observations. This suggests that students can construct new knowledge (sensors not taught in class) based on old knowledge (their current knowledge of sensors taught in class).

The description of the electric motors in 10 out of 19 motor-related applications is also evidence of application of transfer of knowledge from another prior module. Engineering students in the polytechnic learnt the basics of motors in their first year of study. Microcontroller Systems does not cover motors in its curriculum. This finding suggested about 50% of the students still cannot identify the use of motors in some applications, which hints a review of the prior module that teaches motors is needed.

Another interesting discovery from analyzing the papers is that 50% of the students explained the significance of their proposed applications. These students are aware of the importance of microcontrollers and how they benefit mankind. Such awareness can generate motivations for students taking the Microcontroller Systems module. This finding does not suggest that the other 50% of the students are not aware of the importance of their applications, but that they did not include that as it is not a requirement for the Case Study Paper.

6.3: Discussion on Case Study Paper to RJs Comparison

The RJ comparison analysis results in the Chapter 5 revealed two major styles of preparation for the Case Study Paper:

- Students who used their RJs as a scratch pad for their ideas and information, and later used them to write their Case Study Paper
- Students who wrote their RJs as a complete section of their Case Study Paper

The concern about students who use the RJs as a scratch pad is that they may not be thinking carefully when writing the RJs, which might or might not propagate to a poorly written Case Study Paper. With the evidence shown in Chapter 5 (student 22's week one RJ), some students might just mention an application idea in their RJ and not think too much about it until later. For motivated students, this would not be a concern for when they have to write the Case Study Paper, they would think more about their idea and develop the details of their application. After all, creativity takes time. There are students who prefer to have more space and time to think before writing. For students who are not motivated, however, using the RJs as a scratch pad might lead to a poorly written Case Study Paper due to lack of time and thoughts put into the paper.

For students who wrote their RJs for a complete section of their Case Study Paper, the concern is they did not review their own work prior to submission in week four. All that was done was to simply cut and paste the RJs into their Case Study Paper for submission. The evidence in this

group of students indicated the absence of effort in reviewing the Case Study Paper prior to submission. On the other hand, if a student carefully wrote and reviewed an RJ with a section of the Case Study Paper in mind, then there is nothing wrong with the RJ being identical to a section of the Case Study Paper. This can be a more efficient style of delivering the Case Study Paper. This difference in preparation style could be discussed in class, and the instructor could alert the students to the advantages and drawbacks of each way of approaching the Case Study Paper.

Table 16 summarizes the results from Chapter 5 Tables 9-14 correlating the categorization of RJs to the overall rubric scores on the Case Study Paper and number of students for each category. For each category, the rubric scores of all students in the category are added together and the average computed.

	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

Table 16: Summary of Six Categories Average CSP Rubric Score

While the categories with two or less students have higher average rubric scores than other categories, these scores are not representative averages and hence should not be used for comparison with the averages of other categories. Ideally, each category should have at least 30 students so that central limit theorem applies. The limitation here is that with only 30 students in total, splitting them into categories means there are less than 30 students per category. The number of students in Category One and Category Two is 12 and 10 respectively. While the numbers are still too small to represent the student population, it can be used with limitation for comparison. Category One has a slightly higher average rubric score compared to Category Two. This means that students whose RJs in both weeks one and two were identical, almost identical, or identical subsets to the sections in those students' Case Study Paper performed better than students whose RJs were only related to the sections of their Case Study Paper. This suggests that the strategy of using what had been written in RJs to write complete sections of the Case Study Paper is an effective one. It also suggests that stronger students write better RJs and then write better Case Study Papers.

6.4: Discussion on Additional Findings

While reading through the Case Study Papers and RJs of the 30 students, it is noted that some students made grammatical errors, suggesting poor command in English. Evidence of this problem can be seen in the extracts of students' work in Chapter 5: Student 3 (p. 62), Student 6 (p. 60), Student 10 (p. 58), Student 20 (p. 64), Student 21 (p. 59), Student 22 (p. 58 and p. 63) and Student 31 (p. 60). All quotations from students in this thesis are their original work, and have not been corrected for grammar or punctuation. This discovery is not a concern as the focus of the paper is on technical competency, hence the reason that grammar is not included in the scoring rubrics. A measure of the students' command in English does not help to identify any new findings that can improve future implementations of the Case Study Paper. However, writing the daily RJ can be seen as a channel to help students improve their written fluency in English. This Case Study Paper serves to provide yet another channel for students to improve their written English proficiency.

Another observation from the submissions is that a system boundary is missing when students described their microcontroller application. Without defining a system boundary for a system, it is more difficult to describe a system clearly. With a clearly defined system boundary, it is easier to explain how a system works within that boundary and how it interacts with modules beyond the boundary. Students are not taught how to define a system boundary, hence the lack of skill in defining a system boundary is not the fault of the students.

6.5: Limitations of the Study

While the study provides new insights into the use of the case study method for the school, there are some unavoidable limitations of this study.

First, as this is an individual thesis work, the PI 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 random students from the cohort of students taking the Microcontroller Systems module. While a minimum of 30 satisfies the central limit theorem for quantitative analysis, there are some analyses in this study where students were sorted into smaller groups and hence the findings are less representative of the cohort.

Lastly, the Microcontroller Systems examinations results of the cohort of students who wrote the Case Study Paper should ideally 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 has helped students improved their performance in the module. However, prior Microcontroller Systems 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. While the MSA results can be compared between students who did the Case Study Paper with the 28 students who did not submitted the Case Study Paper, these 28 students are not randomly selected and hence the comparison would not be meaningful (there are 192 students taking the module and only 164 submitted the Case Study Paper).

This page intentionally left blank

Chapter 7: Recommendations and Conclusion

7.1: 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:

- A requirement should be added 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) need to 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 Engineering Design module.
- 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 week 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.

- The Microcontroller Systems module (or some other module) should teach students how to define the system boundary.

7.2: Conclusion

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. 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.

References

(2016, Jan). Retrieved Jun 13, 2016, from Republic Polytechnic JAE 2016 Last Aggregate Scores: http://www.rp.edu.sg/Admissions_Information/Last_Aggregate_Scores.aspx

A Guide to Polytechnic Education. (2016). Retrieved May 31, 2016, from Joint Portal of the Polytechnics in Singapore: http://www.polytechnic.edu.sg/introduction/what-is-polytechnic-education

Angelo, T. A., & Cross, K. P. (1993). Minute Paper. In *Classroom Assessment Techniques: a Handbook for College Teachers* (pp. 148-153). San Francisco: Jossey-Bass Publishers.

Ashakiran, S., & Deepthi, R. (2013). One-Minute Paper: A thinking centered assessment tool. *Internet Journal of Medical Update, 8*(2), 3-9.

Assessing Outcomes and Improving Achievement: Tips and Tools for Using Rubrics. (2010). Washington, DC, USA: AAC&U.

Bain, J., Ballantyne, R., Packer, J., & Mills, C. (1999). Using journal writing to enhance student teachers' reflectivity during field experience placements. *Teachers and Teaching: Theory and Practice, 5*(1), 51-74.

Benson, B. K. (1997, Nov). Scaffolding: Coming to Terms. *English Journal, High school edition, 86*(7), 126-127.

Blank, S. C. (1985). *Effectiveness Of Role Playing, Case Studies, and Simulation Games in Teaching Agricultural Economics.*

Boud, D., Keogh, R., & Walker, D. (1985). *Reflection: Turning Experience into Learning.*

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experience, and School.* Washington, D.C: NATIONAL ACADEMY PRESS.

Education in Singapore. (2007, March 16). Retrieved May 31, 2016, from Wikipedia: https://en.wikipedia.org/wiki/Education_in_Singapore#Polytechnics

Garvin, D. A. (Sept-Oct 2003). Making The Case: Professional Education for the World of Practice. *Harvard Magazine, 106*(1), 56-65.

Gleaves, A., Walker, C., & Grey, J. (2008). Using digital and paper diaries for assessment and learning purposes in higher education: a case of critical reflection or constrained compliance? *Assessment & Evaluation in Higher Education, 33*(3).

Harwood, W. (1996). The one-minute paper. *Journal of Chemical Education, 73*(3), 229.

King, D. B. (2011). Using Clickers To Identify the Muddiest Points in Large Chemistry Classes. *Journal of Chemical Education, 88*(11), 1485-1488.

Ladd, D. (1978). Notes on Use of the Case Method. *Intercollegiate Case Clearing.*

Lew, D., & Schmidt, H. (2011A). Writing to learn: can reflection journals be used to promote self-reflection and learning? *Higher Education Research & Development, 30*(4).

Lew, M., & Henk, S. (2006). *Reflection upon learning between theory and practice: A focus-group study of tutors' and students' perceptions.* Rotterdam: The Netherlands: Erasmus University.

Lew, M., & Schmidt, H. (2011). Self-reflection and academic performance: is there a relationship? *Advances in Health Sciences Education, 16*(4), 529-545.

Lionni, L. (1970). *Fish Is Fish.* New York: Scholastic Press.

Martin, M. (1999). *Classroom Assessment Techniques Designed for Technology.* Middle Tennessee State University.

Moon, J. A. (2004). *A Handbook of Reflective and Experiential Learning: Theory and Practice.*

Moskal, B. M. (2000). Scoring Rubrics: What, When and How? *Practical Assessment, Research & Evaluation, 7*(3).

Moskal, B. M., & Leydens, J. A. (2000). Scoring Rubric Development: Validity and Reliability. *Practical Assessment, Research & Evaluation, 7*(10).

O'Glady, G., & Alwis, W. (2002). One Day, One Problem: PBL at the Republic Polytechnic. *4th Asia Pacific Conference in PBL.* Hatyai, Thailand.

O'Rouke, R. (1998). The Learning Journal: from chaos to coherence. *Assessment & Evaluation in Higher Education, 23*(4), 403-413.

Pilato, B., & Ulrich, M. M. (2014). Is The Case Study Method an Effective Pedagogical Method for Students to Learn the Fundamentals of Financial Accounting? *American Society of Business and Behavioral Sciences, 21*(1).

Post-Secondary Education. (2016, May 16). Retrieved May 31, 2016, from Ministry of Education, Singapore: https://www.moe.gov.sg/education/post-secondary#polytechnics

Republic Polytechnic: Introduction and Background. (2016, May). Retrieved May 31, 2016, from Republic Polytechnic: www.rp.edu.sg/Introduction_and_Background.aspx

RP Academic Information. (2016). Retrieved May 31, 2016, from Republic Polytechnic: http://www.rp.edu.sg/01.Academic_Information.aspx

RP SEG DEEE Information. (2016). Retrieved Februrary 18, 2016, from http://www.rp.edu.sg/Diploma_in_Electrical_and_Electronic_Engineering_%28R50%29.aspx

Ryan, G. W., & Bernard, H. R. (2003, Feb). Techniques to Identify Themes. *Field Methods, 15*(1), 85-109. doi:10.1177/1525822X02239569

Schön , D. A. (1983). *The reflective practitioner: How professionals think in action.*

Selfe, C., Petersen, B., & Nahrgang, C. (1986). Journal writing in mathematics. *Writing across the disciplines*, 192-207.

Sewell, J., Frith, K. H., & Colvin, M. M. (2010). Online Assessment Strategies: A Primer. *Journal of Online Learning and Teaching, 6*(1), 297.

Sumsion, J., & Fleet, A. (1996). Reflection: Can we assess it? Should we assess it? *Assessment & Evaluation in Higher Education, 21*(2), 121-130.

Tedds, L., & Brady, M. (2009). *Content and Discourse Analysis*. (PBworks) Retrieved 04 18, 2016, from http://admn502awiki.pbworks.com/w/page-revisions/10041942/Content%20and%20Discourse%20Analysis

Tham, Y. (2008). *E206 Microcontroller Systems Synopsis*. Retrieved May 31, 2016, from Republic Polytechnic: http://www.rp.edu.sg/Module_Synopses/E206_Microcontroller_Systems.aspx

Wong, F., Kember, D., Chung, L., & Yan, L. (1995). Assessing the level of student reflection from reflective journals. *Journal of Advanced Nursing, 22*(1), 48-57.

Woodward, H. (1998). Reflective journals and portfolios: Learning through assessment. *Assessment & Evaluation in Higher Education, 23*(4), 415-423.

Appendix A: Participants Consent Form

Title of Project: Enhancing Student Learning Through Use of Case Study Paper
Principal Investigators (PI): Eugene Tham

Print Participant's Name:.....
Recall that in E206 Microcontroller Systems you and your peers in the cohort are required to submit a Case Study Paper. Congratulations first, on your submission of the paper, even though it might not be a comfortable assignment to do. The purpose of this study to study if students' learning are enhanced and improved with inclusion of the Case Study Paper. We have randomly selected some students to have their papers analyzed for this purpose, and you are one of the selected few. Rest assured that this study is independent of your grade for the paper.

This study is in collaborations with the Teaching and Learning Laboratories (TLL) in Massachusetts Institute of Technology (MIT). MIT is one of the top universities in the world. The study is overseen by Professor Lori Breslow, the founding director of the TLL in MIT and an internationally recognized expert in higher education,

As a participant in this study, your RJs for E206 Microcontroller Systems for week one to week three and your Case Study Paper submission would be analyzed and studied qualitatively. There is no additional effort, time, nor commitment required from you for this study. Your identity would be masked. You would not be identified and the results of the study would not affect your grades for the module.

Please note the following information:

- *The information you give us is completely confidential, and your name and student ID masked off from your RJs and Case Study Paper for the study.*
- *You may refuse participation or withdraw from the study at any time.*
- *We understand how important it is that this information is kept private and confidential. We will ask participants to respect each other's confidentiality.*
- *If you have any questions now or after you have completed the focus group discussion, you can always contact the Principal Investigator (PI) Mr Eugene Tham or the Co-Principal Investigator (Co-PI) Mr Kwek Chin Wee*

Name:	*Eugene Tham*	*Kwek Chin Wee*
Contact number:	*+1 857 316 7492 (USA only)*	*66971135*
Email address	*eugene_t@mit.edu*	*kwek_chin_wee@rp.edu.sg*

Please complete and sign the consent form attached to this information sheet. Please check the appropriate space for the questions below. Your signature and agreement on this form will indicate your consent for participation in the study. Please retain a copy for your records. Thank you!

Participant Consent Form

(Delete as appropriate)

➢ I confirm that I have read and understood the information sheet for the above study and what my contribution will be.	**Yes**	**No**
➢ I have been given the opportunity to ask questions.	**Yes**	**No**
➢ I understand that my identity would be kept confidential for the study.	**Yes**	**No**
➢ I consent to the researcher using my weeks one to three RJs and my Case Study Paper as part of his research data.	**Yes**	**No**
➢ I understand that the participation/non-participation in this study will not affect my continual assessment and final module grade for E206.	**Yes**	**No**
➢ I understand that my participation is voluntary and that I can withdraw from the research at any time.	**Yes**	**No**
➢ I agree to take part in the above study.	**Yes**	**No**

Participant: By signing below, you indicate that you have read the information written above and have indicated your choices for the research study above.

_____	_____	_____	_____
Signature of Participant	Date	Time	Printed Name

Appendix B: Case Study Paper Topic Released to Students

E206 – Microcontroller Systems
Case Study Paper

Topic
You are to deliver a Case Study Paper on an application of microcontroller(s) you have encountered in your daily life. This would be an individual written assignment with guidance from your lecturer weekly.

The Case Study Paper should include:
- Your idea of the application
- Description and functionality of the system
- Input(s) and Output(s) list and functionality
- Your idea of the block diagram of the system
- Your idea of the program flowchart for the system (can be simplified)

Submission Requirement
The assignment should be submitted electronically, with a minimum of two A4-pages long including block diagrams. You should use font size 11 and 1.5 lines spacing.

Submission Deadline
Submission of the Case Study Paper would be during week's four lesson.

Guidance
There would be in-class guidance from weeks one to four of the module to help you prepare your Case Study Paper. The final segment of each lesson in weeks one to three would be reserved for this purpose and your RJ for these weeks would be aligned to help you with your Case Study Paper. The last segment of week four's lesson would cater time for you to put everything together and final consultation with your lecturer.

Grading
Assessment of the answers to RJ questions for week one to three and Case Study Paper submission will be based entirely on the quality of work submitted. This will in turn affect your continuous assessment (CA) grade for each week.

CA grade will be downgraded by one full grade if no RJ is submitted for week one to three. CA grade will be downgraded by two full grades if no Case Study Paper is submitted at the end of class on week four.

Plagiarism
While you are allowed to discuss your Case Study Paper with your peers, this would be an individual assignment. Copying each other's work or copying work from books/internet would be

considered as plagiarism and a zero grade would be awarded. Please be original in your work. References from internet/books should to be quoted. You can consult your lecturer on how to include quotations and citations.

Appendix C: Case Study Paper Presentation Week One

REPUBLIC POLYTECHNIC

Case Study Paper

E206 – Microcontroller Systems

SCHOOL OF ENGINEERING

Case Study Paper

You are to deliver a case study paper on an application of microcontroller(s) you have encountered in your daily life. This would be an individual written assignment with guidance from your lecturer weekly.

The case study paper should include:

- Your idea of the application
- Description and functionality of the system
- Input(s) and Output(s) list and functionality
- Your idea of the block diagram of the system
- Your idea of the program flowchart for the system (can be simplified)

Case Study Paper

Submission Requirement

The assignment should be submitted electronically, with a minimum of two A4-pages long including block diagrams. You should use font size 11 and 1.5 lines spacing.

Submission Deadline

Submission of the Case Study Paper would be during week's 4 lesson.

Guidance

Weeks 1-3

- The final segment of each lesson in weeks 1-3 would be reserved for this purpose and your RJ for these weeks would be aligned to help you with your Case Study Paper. Note that the RJs for these weeks are not the usual take home RJ (except week 4). Your lecturer would be in class to provide guidance to you.

Week 4

- The last segment of week 4's lesson would cater time for you to put everything together and final consultation with your lecturer.

Grading

Assessment of the answers to RJ questions for week 1 to 3 and CSP submission will be based entirely on the quality of work submitted. This will in turn affect your continuous assessment (CA) grade for each week.

CA grade will be downgraded by 1 full grade if no RJ is submitted for week 1 to 3. CA grade will be downgraded by 2 full grades if no CSP is submitted at the end of class on week 4.

Plagiarism

- this is an individual assignment
- Copying each other's work or copying work from books/internet would be considered as plagiarism and a **zero grade** would be awarded
- References from internet/books should to be quoted

This Week's RJ

- What are some of the common applications, machines or systems you encounter that possibly use a microcontroller? List at least three such applications/machines/systems, ranging from simple, mid-complexity, and complex (it is ok to use your own judgment to decide on the level of complexity). Which one would you possibly use for your case study paper?

In-Class Example (Do not use this example)

Application: Anti-Burglar Home Monitoring System

- This simple system protects the regular home from intruder(s) when the homeowner is not a home or sleeping. While many such systems are available commercially, this particular system is low-cost and requires moderately low power to operate. A low cost design would alleviate homeowners from purchasing high-cost advanced home-security systems that many cannot afford. The system makes use of commercially available input sensors, output displays, and microcontroller board. Any movement detected in the home, windows or main door opened without deactivating the anti-burglar system, would trigger SMSes and MMSes (for images) to be send to the homeowner's mobile phone, warning the homeowner that there has been a home intrusion.
- Complexity Level: Simple

Appendix D: Case Study Paper Sample

Application: Anti-Burglar Home Monitoring System

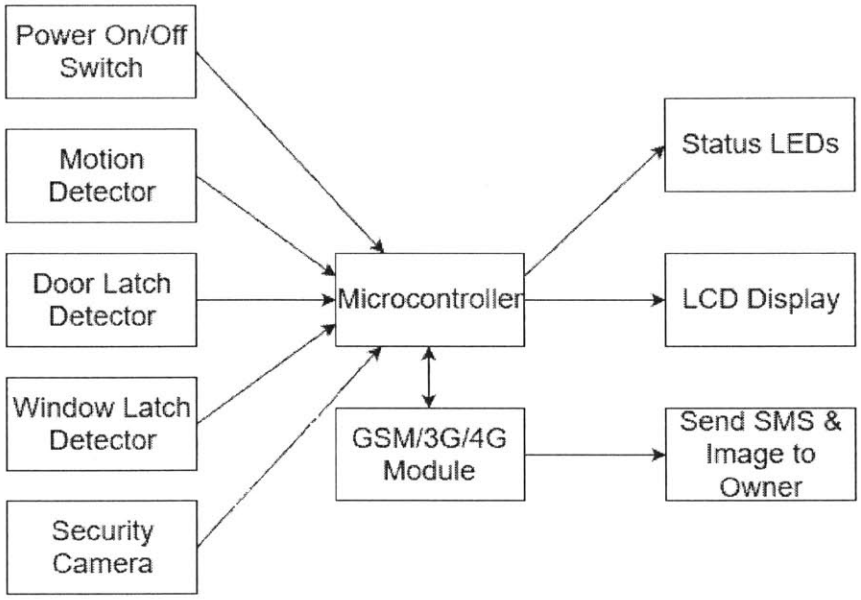
This simple system protects the regular home from intruder(s) when the homeowner is not a home or sleeping. While many such systems are available commercially, this particular system is low-cost and requires moderately low power to operate. A low cost design would alleviate homeowners from purchasing high-cost advanced home-security systems that many cannot afford. The system makes use of commercially available input sensors, output displays, and microcontroller board. Any movement detected in the home, windows or main door opened without deactivating the anti-burglar system, would trigger SMSes and MMSes (for images) to be send to the homeowner's mobile phone, warning the homeowner that there has been a home intrusion.

System Functionality Description

The Core of the device is a simple microcontroller module and a GSM/3G/4G module that are connected to each other. A GSM/3G/4G SIM card from a Telco need to be inserted into the GSM/3G/4G module for the system to be able to operate as intended. A power on/off switch turns on or off the system through the microcontroller module. When the power is turned on, the GSM/3G/4G module system initialization takes place. After a short wait, the GSM/3G/4G module completes its initialization and informs the microcontroller. Status of the system are indicated in the LEDs, with green LED indicating power on, red LED indicating intrusion. The LCD display shows more detailed status of the system like initialization, system ready and specific intrusion. The motion sensor detects motion and triggers an intrusion when motion is detected. The main door latch detector and the window latch detectors are simple contact switches that detects the door or window(s) being open and triggers an intrusion.

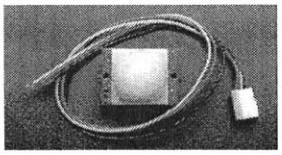
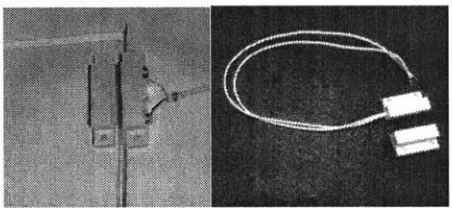
When an intrusion happens, the security cameras take pictures of the location they are installed. The microcontroller module instructs the GSM/3G/4G module to send SMS messages to the homeowner's phone number to inform the homeowner of intrusion. MMS images of the scene of crime are also sent to the homeowner's phone number. Local LCD display and LEDs would indicate intrusion as well. System intrusion status can be reset by turning off and on the system.

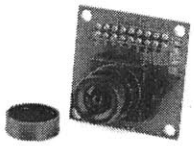
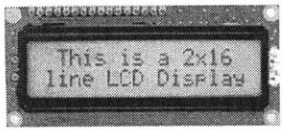
Block Diagram



I/O List and Functions

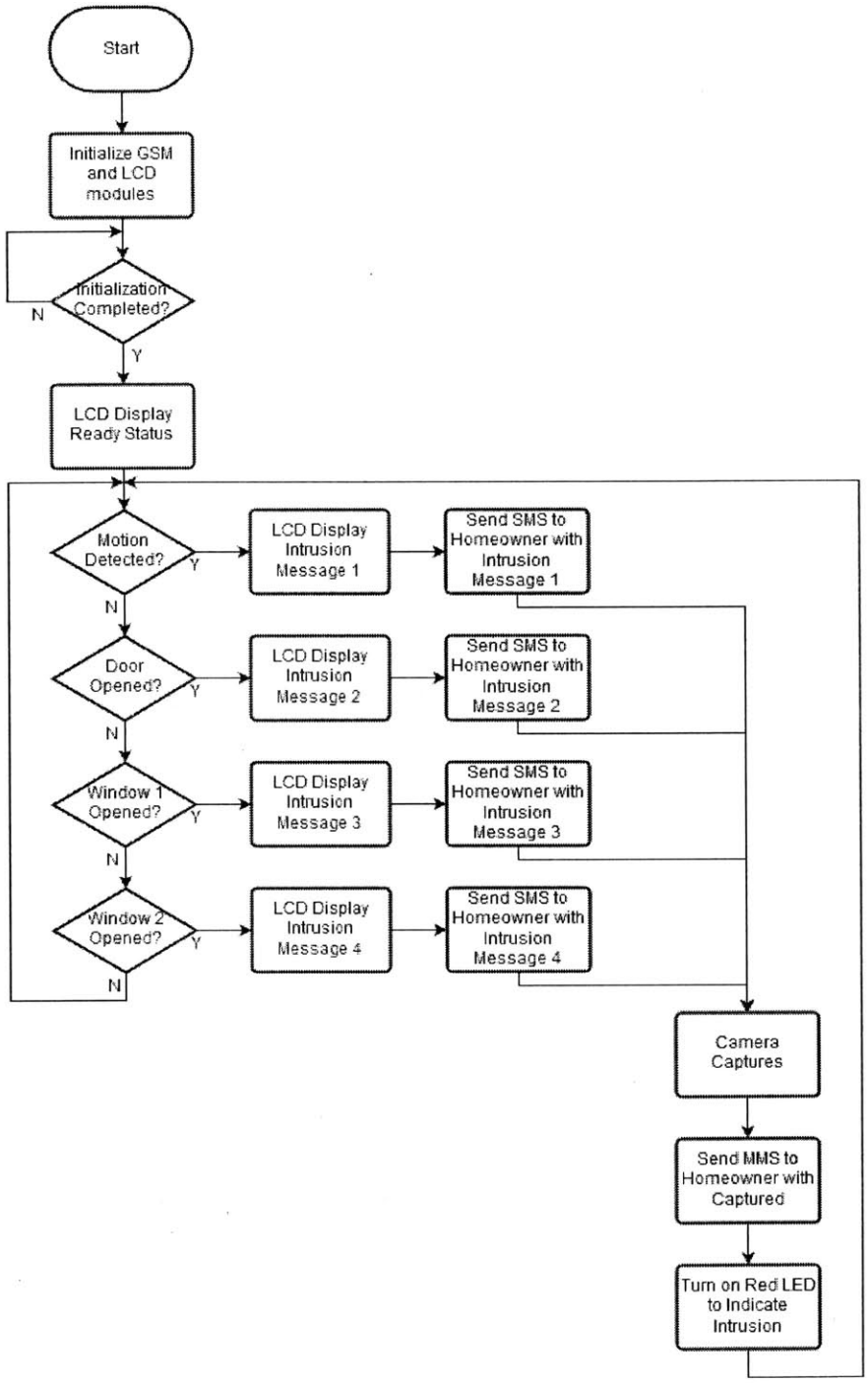
Name	I/O Type	Functionality
Power On/Off Switch	Input	Turns on/off the anti-burglar system. Can be implemented with a simple toggle or rocker switch. Closing the switch allows power supply to pass through and turning on the system. Opening the switch cuts off the power supply to the system and hence turning it off.
Motion Detector	Input	Used to detect motion. A simple detector would be the commercially available PIR motion sensor. Inputs to this sensor is 5V and GND. The sensor outputs 0V when there is no motion detected, outputs a 5V when there is motion detected. The microcontroller that this sensor is connected to can

		make use of the output from the PIR motion sensor to determine if motion have been detected. 
Door Latch Detector	Input	Used to detect when the door is open while the anti-burglar system is operating. This detector is commercially available in both wired and wireless form. A simple wired version of the detector operates just like a normal switch: when both ends of the magnetic sensor is close to each other, the switch is in "closed" position. When the ends of the magnetic sensor is away from each other, the switch is in "opened" position. The switch is connected to the system's microcontroller which would make use of its "opened" and "closed" positions to determine if there is an intrusion. 
Window Latch Detector	Input	Same hardware and functionality as the door latch detector. More than one can be used to secure multiple windows, subjected to input pin limits of the microcontroller board.
Security Camera	Input	Used primarily to capture photo images when intrusion is triggered. Can be purchased commercially at low cost.

		
Status LEDs	Output	Green LED to indicate power on. Red LED to indicate intrusion.
LCD Display	Output	Used to display system status information: Initialization, GSM/3G/4G module error, System Ready, Intrusion, which sensor detected the intrusion. Various models are available commercially. An easy to use model would be the I2C controlled type. 

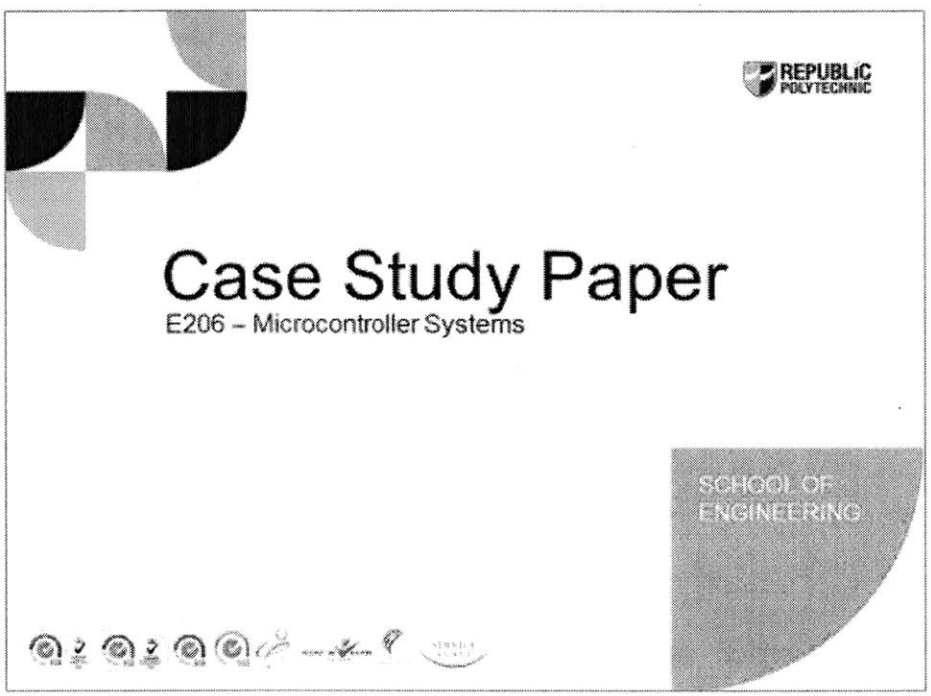
Nominal Operation Flowchart

The flowchart below shows the simplified nominal operation (system is turned on, and GSM/3G/4G module is functioning). This Flowchart shows two windows and one main door in the system. The system can be scaled up to include more windows and doors detection.



This page intentionally left blank

Appendix E: Case Study Paper Presentation Week Two



This Week's RJ

- Recall the application/machine/system you chosen for your case study paper in your previous RJ. Describe the functionality of the system.

In-Class Example (Do not use this example)

Application: Anti-Burglar Home Monitoring System

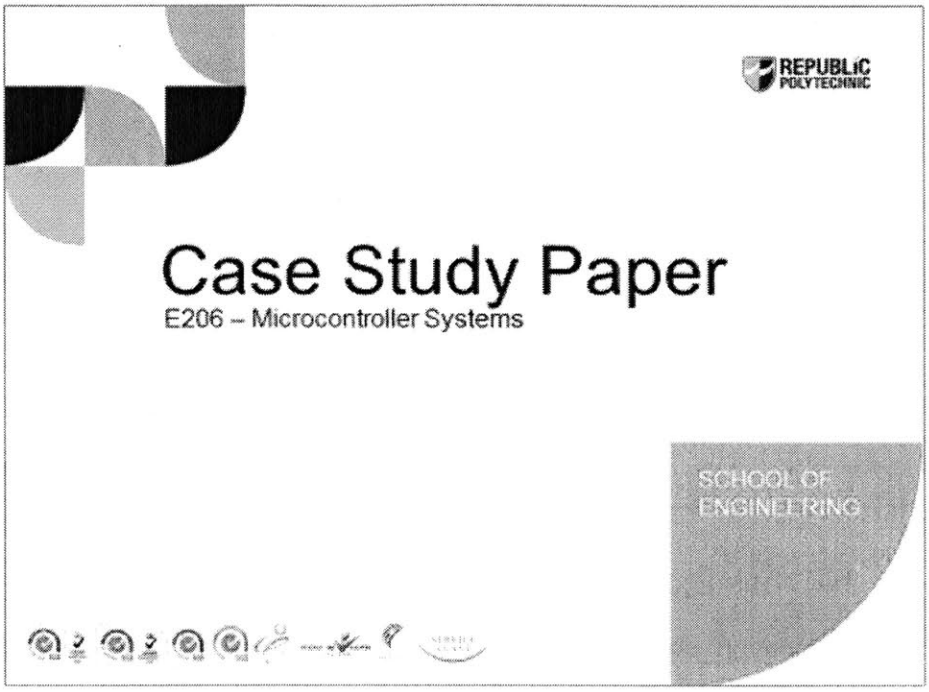
The Core of the device is a simple microcontroller module and a GSM/3G/4G module that are connected to each other. A GSM/3G/4G SIM card from a Telco need to be inserted into the GSM/3G/4G module for the system to be able to operate as intended. A power on/off switch turns on or off the system through the microcontroller module. When the power is turned on, the GSM/3G/4G module system initialization takes place. After a short wait, the GSM/3G/4G module completes its initialization and informs the microcontroller. Status of the system are indicated in the LEDs, with green LED indicating power on, red LED indicating intrusion. The LCD display shows more detailed status of the system like initialization, system ready and specific intrusion. The motion sensor detects motion and triggers an intrusion when motion is detected. The main door latch detector and the window latch detectors are simple contact switches that detects the door or window(s) being open and triggers an intrusion.

In-Class Example (Do not use this example)

Application: Anti-Burglar Home Monitoring System

When an intrusion happens, the security cameras take pictures of the location they are installed. The microcontroller module instructs the GSM/3G/4G module to send SMS messages to the homeowner's phone number to inform the homeowner of intrusion. MMS images of the scene of crime are also sent to the homeowner's phone number. Local LCD display and LEDs would indicate intrusion as well. System intrusion status can be reset by turning off and on the system.

Appendix F: Case Study Paper Presentation Week Three

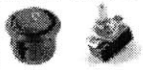


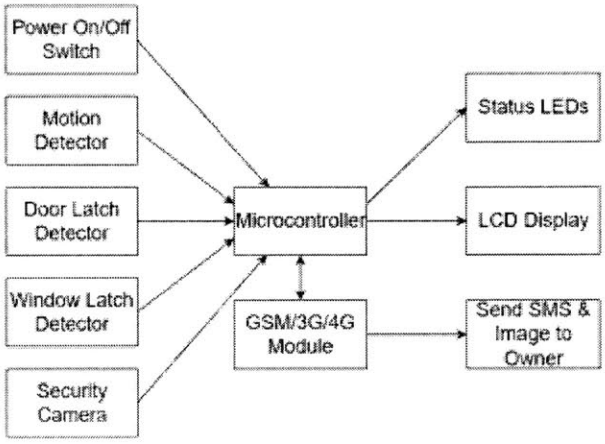
This Week's RJ

- Recall the application/machine/system you chosen for your case study paper in your previous RJs. What are the inputs and outputs (I/O) of the system? Draw a simplified I/O module block diagram and describe the functionality of each I/O.

In-Class Example (Do not use this example)

Application: Anti-Burglar Home Monitoring System

Name	I/O Type	Functionality
Power On/Off Switch	Input	Turns on/off the anti-burglar system. Can be implemented with a simple toggle or rocker switch. Closing the switch allows power supply to pass through and turning on the system. Opening the switch cuts off the power supply to the system and hence turning it off. 
Motion Detector	Input	Used to detect motion. A simple detector would be the commercially available PIR motion sensor. Inputs to this sensor is 5V and GND. The sensor outputs 0V when there is no motion detected, outputs a 5V when there is motion detected. The microcontroller that this sensor is connected to can make use of the output from the PIR motion sensor to determine if motion have been detected.

In-Class Example (Do not use this example)

Application: Anti-Burglar Home Monitoring System