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Using Case Study Research as an Active Learning Tool for Demonstrating the Ability to Function on Multidisciplinary Teams

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Abstract

Case study projects can be used as an active learning tool for expanding students' knowledge beyond classroom discussion. A required course taken by EE (Electrical Engineering) and CS (Computer Science) students at the University of Portland provides an excellent environment for assessing students' ability to function on multidisciplinary teams as specified in the ABET Engineering Accreditation Commission Student Outcome (d) an ability to function on multidisciplinary teams. This paper presents an experience of using a team-based case study project as an active learning tool in the EE and CS required course for assessing the attainment of this student outcome. The performance indicators clearly demonstrate that the ABET Engineering Accreditation Commission Student Outcome (d) is successfully attained.

I. Introduction

Since the ABET Engineering Criteria 2000 accreditation, efforts to satisfy Criterion 3(d) an ability to function on multidisciplinary teams have resulted in a large literature on the topics of team-based learning,[1] collaborative learning,[2] learning organization,[3] effective teams,[4,5] intra-team communication,[6] team skills,[7,8,9] implementing design projects,[10] assessing learning level,[11] and improving students' ability to function in teams.[12] To make sure students can satisfy this requirement, engineering programs try to provide team-oriented design projects through a student's college education starting from freshman year and culminating with a capstone design project in the senior year.

It is a challenging task to assess and demonstrate an intangible student outcome such as the ability to function on multidisciplinary teams. Teamwork in a design oriented project can be assessed by a team's tangible finished product and the team members' self-reporting surveys.[9,13,14,15] However, there is little discussion on how to assess teamwork performance in non-design oriented projects such as a case study on technical topics. This paper presents an experience of using a team-based case study project as an active learning tool for assessing students' ability to function on multidisciplinary teams.

The EE 333 Computer Organization course at the University of Portland is a required course for EE and CS students in the spring semester of their junior year. Since this course consists of multidisciplinary students, it is designated as a benchmark course to satisfy the ABET Engineering Accreditation Commission Student Outcome (d) an ability to function on multidisciplinary teams. To accomplish this goal, students form teams of two to work on team-based projects. Over the years, the team projects have been focused on hardware design. The content of hardware design projects forced EE students to contribute more on circuit design and CS students to contribute more on report preparation.

The textbook used in the EE 333 course covers in-depth MIPS CPU (Central Processing Unit) instruction set and central processing unit design techniques.[16] To expand students' learning beyond the MIPS architecture, a case study on the frontier of computing applications was assigned as a term project to teams of EE and CS students. Not only does it serve as an active learning tool, the team-based case study project also provides an opportunity for each team member to equally contribute to the project. This approach seems to better achieve the goal of demonstrating the attainment of ABET Engineering Accreditation Commission Student Outcome (d) an ability to function on multidisciplinary teams.

This paper details the experience of implementing this team-based case study project pedagogy. This section gives a summary of the motivation and the background of the approach. Section II discusses the team formation process, project scope, requirements, and tasks. Section III discusses the deliverables of the project and the team performance assessment tools. Section IV discusses the rationale of identifying the performance indicators used for assessing teamwork, details the grading rubrics for the performance indicators, summarizes the results of teamwork performance indicators, and analyzes the survey results. Section V discusses the active learning levels students have achieved and the team skills students have demonstrated. Section VI concludes that a case study research project can be used as an active learning tool to expand students' learning and also to demonstrate students' ability to function on multidisciplinary teams. Finally, Section VII offers suggestions for implementing case study projects.

II. Pedagogy—Using a Case Study Project As an Active Learning Tool in a Team Setting

The project is to conduct an in-depth technical research on the processors and system architecture employed in one of five emerging computing applications: big data, cloud computing, self-driving vehicles/unmanned aerial vehicles, desktop/network virtualization, and No. 1 supercomputers in the last three years of the top500supercomputer lists.

The Electrical Engineering program at the University of Portland offers two tracks of study focus, Electrical Track and Computer Track. Electrical Track focusses more on the electrical engineering fields such as Communications & Control, Electronics and Instrumentation, and Energy and Power. Computer Track focusses more on Digital Systems, Computer Hardware & Software, and Embedded Systems. Each student in the EE 333 class finds a teammate of their choice to form a team of two members who are in different majors/tracks (Electrical Track & CS, Computer Track & CS, and Electrical Track & Computer Track).

Each team chooses one of the five computing application categories. The project assignment is to submit a formal report documenting the team's researched details, to present a poster illustrating the team's research results, and to give a PowerPoint presentation debriefing each team's researched system and proposing a new innovative application for their researched system. Grading rubrics for the project report and poster are provided to the students. To further stimulate the students' motivation to create excellent posters, extra credit will be awarded to the best poster in each application category and also to the team proposed the most innovative new application. Students will anonymously vote for the best posters and the most innovative new application using a provided voting form.

A. Research on processor features

Based on a team's selected emerging computing application, this research task is to study the application's computer processor features whenever applicable such as types and numbers of CPU cores and functional units in a processor chip; instruction categories; pipelining design features; peak and averaged numbers of instructions dispatched and executed per clock cycle; internal bus design features; register allocation method; size and organization of data cache and code cache memories; cache memories (L1, L2, L3, multi-core caches) management; main memory to cache memory data transfer technique and bandwidth; methods to reduce branch instruction penalty; branch prediction capability; speculative instruction execution capability; out-of-order instruction execution capability; multi-thread execution features; scalable multi-core parallel-processing management; energy efficiency features; target markets; and a most impressive processor architectural feature.

B. Research on system architecture features

Based on a team's selected emerging computing application, this research task is to study the application's computer system features whenever applicable such as types and numbers of processor chips in the system; type and size of main memory in the system; types and numbers of clients supported; types and size of mass storage in the system; total system cost; types and numbers of applications can be run simultaneously by the system; system architecture category (SISD, SIMD, MIMD); type of MIMD system architecture (SMP, NUMA, Cluster); system peak and sustained performance; operating system; and types of user interface.

III. Team Performance Assessment Tools

The deliverables of the team-based research project are a project report, a project poster, and a PowerPoint presentation. The project report and project poster are used as the assessment tools to evaluate each team's performance. The project report is worth 15% and the project poster is worth 5% of the course grade. The purpose of PowerPoint presentation is to debrief each team's researched system and to propose a new innovative application.

The project report is a typed formal report which should thoroughly document the team's researched details for their selected computing application. The report should include a cover page, an introduction section introducing the overall system and processor architectural features, several sections discussing the researched details, a conclusion section, and a list of references. The discussions should address the topics specified in Section II. Students are encouraged to use headings and subheadings for creating a more organized report and to include pictures, figures, and tables for presenting more illustrative technical details. The report is due three days before the dead week.

Each team's project poster is implemented on a 22″x28″ poster board and is due four days before the dead week. Each poster must include a proposed new application for their researched system. Posters for the same computing application category are displayed as a group for easier comparison. The five groups of posters are displayed at different locations in a lab for one week so that students can take their time to review each poster group and select a best poster. Team members of a best poster will earn extra 3% of the course grade. Team members proposing the most innovative new application will earn extra 1.5% of the course grade.

IV. Assessment and Evaluation of Student Outcome (d)

As defined in ABET's Criteria for Accrediting Engineering Programs, 2014 – 2015 webpage:

> "Assessment is one or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes. Effective assessment uses relevant direct, indirect, quantitative and qualitative measures as appropriate to the outcome being measured."[17]

Based on the ABET 2010 webinar titled "Defining Student Outcomes", a student outcome can be assessed with performance indicators which are concrete actions students can perform to demonstrate students' ability to attain the outcome.[18]

With the goal of demonstrating the attainment of Student Outcome (d) an ability to function on multidisciplinary teams, the concrete actions students can perform in this case study project are to document the team's research results in a team report and a team poster. Each team's performance on project report and project poster can clearly demonstrate students' ability to work as a team to select an application type, to research a selected application, to analyze researched information, to identify relevant information, to collect useful results, to report the results, and finally, to present the results in a poster. Therefore, the performance indicators for this student outcome can be identified as the team's project report and project poster. These two performance indicators are also in line with the guidance of "evidence-based assessment of student work is key -- should be done by faculty" as shown in page 15 of the ABET webinar.[18] The attainment of Student Outcome (d) can then be assessed based on these two performance indicators: project report and project poster.

Each performance indicator can be assessed by the total score calculated from each category specified in the grading rubrics given to the students. The assessment of these two performance indicators is discussed below.

A. Using project report as a performance indicator

Each team needs to submit a formal report which thoroughly documents the team's research results for their selected emerging computing application. The project report is graded in seven categories: integration of knowledge (35%), topic focus (10%), depth of discussion (35%), cohesiveness (5%), spelling & grammar (5%), sources (5%), and citations (5%).[19] Both team members have the same score on the report except there is evidence showing one team member didn't equally contribute to the project.

To grade a project report, the instructor will first read through the report and make some remarks and then in the second pass, assign a score for each category. Reports containing in-depth elaborations will have higher scores in the integration of knowledge category; whereas reports containing many technical specification details or direct quotes without discussion and elaboration will have lower scores. The topic focus category can be graded by the consistency of contents throughout the report. The depth of discussion category closely reflects the integration of knowledge category so that reports showing good elaborations will have higher scores and reports with many hardware or software specification details will have lower scores.

Cohesiveness category can be graded based on how well the report contents flow. The spelling & grammar category can be graded based on common writing basics such as a figure caption should be under the figure and the table caption should be above the table; figure and table captions and their corresponding figures and tables should be on the same page; and paragraphs should have adequate lengths.

The sources category can be graded based on the cited references. The citations category can be graded based on how clearly the sources for figures, tables, and direct quotes are cited. Reports without citations will get zero point for this category.

B. Using project poster as the second performance indicator

Each team's poster is graded based on four categories: presentation of research (75%), visual presentation (15%), documentation of sources (5%), and spelling & grammar (5%).[20]

After the posters are submitted, the instructor will group the posters into five application categories: big data, cloud computing, self-driving vehicles/unmanned aerial vehicles, desktop/network virtualization, and No. 1 supercomputers. The posters in each group will be displayed in different locations in a lab for one week.

The instructor will grade a poster's presentation of research based on the presented information. Posters including essential information will have higher scores. Posters failed to show the authors, the project title, the proposed new innovative application will lose 5 points for each category. The poster's visual presentation is graded based on how well the information is presented. Posters with 3D arrangements, blinking LED lights, or colorful displays will have higher scores. Posters failed to show sources will have zero point in the documentation of sources category. The spelling & grammar category can be graded by checking for typos.

C. Results of performance indicators for assessing Student Outcome (d)

The 16 Electrical Track, 17 Computer Track, and 23 CS students in the EE 333 class in the fall 2013 semester formed 28 multidisciplinary teams of their own choice. Each team needed to submit their poster and to give a 2-minute PowerPoint presentation in class on an assigned due date. The project reports were due one day after the poster's due date.

The breakdowns of computing application categories chosen by students are: big data (1 team), cloud computing (5 teams), self-driving vehicles/unmanned aerial vehicles (6 teams), desktop/network virtualization (3 teams), and No. 1 supercomputers in the last three years of the top500 supercomputer lists (13 teams). The result for each category is summarized as follows.

1) Since big data just became a popular topic in 2013, there is very limited technical information on the Internet. But the team chose the big data category submitted an excellent project report and poster.
2) Cloud computing became a ubiquitous phrase since 2013. There is abundant information on the Internet and five teams chose this category.
3) Self-driving vehicles/unmanned aerial vehicles became an exciting topic after the Google car project was announced in 2010. Currently, several major car manufactures are racing to develop driverless cars. Unmanned aerial vehicles (UAV) also became popular recently with its potential applications; especially Amazon just announced their delivery service plan using drones (UAV). There were six teams chose this category.
4) Desktop virtualization is also a ubiquitous phrase and there is abundant marketing information on the Internet. Since most desktop virtualization is provided as a service, it is difficult to find a particular system with enough in-depth technical information. Three teams chose this category. Although network virtualization concept was introduced in 2009, there is very little implementation technical information on the Internet and no team chose this sub-category.
5) Supercomputers were chosen by 13 teams due to their abundant technical information and there were six No. 1 supercomputers to choose from.

The average report score was 95.5/100 (standard deviation 5.03, maximum 100, and minimum 81). There were two teams at 81 and 84 respectively and another two teams at 87. The other 24 teams were above 90.

The average poster score was 90.5/100 (standard deviation 4.37, maximum 95, and minimum 80). There were two teams at 80, three teams at 85, and one team at 88. The other 22 teams were above 90.

The most innovative new application was a virtual body system proposed by a team researched on desktop virtualization. The new application's idea is to allow a user to control a humanoid robot located anywhere in the world through a desktop virtualization server. The humanoid robot functions as the user's virtual body. Other competing new application proposals were big bang simulation, black hole simulation, and human spinal cord simulation for supercomputers and automatic pothole filling vehicles for self-driving cars.

The excellent results of both performance indicators for assessing Student Outcome (d) clearly demonstrate students' ability to function on multidisciplinary teams. It thus can be concluded that the ABET Engineering Accreditation Commission Student Outcome (d) has been successfully attained.

D. Survey to assess and evaluate the pedagogy

The EE 333 class was given an anonymous survey form containing six questions on the day of PowerPoint presentations. These survey questions were designed to obtain students' feedback on the project, project report, poster, a new proposed application, team experience, and effectiveness of teamwork. The survey results are shown in Table 1.

Table 1. Survey results for assessing and evaluating the pedagogy

Questions:	Strongly-agree	Agree	Neutral	Disagree	Strongly-disagree
1. The research project expands my understanding of real-world computer applications	12 (26.1%)	20 (43.5%)	8 (17.4%)	4 (8.7%)	2 (4.3%)
2. The project report provides a venue for documenting my research result	13 (28.3%)	26 (56.5%)	3 (6.5%)	2 (4.3%)	2 (4.3%)
3. The poster presentation provides a summary for my research project	10 (21.7%)	26 (56.5%)	4 (8.7%)	4 (8.7%)	2 (4.3%)
4. Proposing a new application enhances my understanding of the researched system	10 (21.7%)	16 (34.8%)	10 (21.7%)	6 (13%)	4 (8.7%)
5. This team project provides an experience in teamwork	16 (35.6%)	23 (51.1%)	5 (11.1%)		1 (2.2%)
6. The performance of the team project report and poster presentation reflects my ability to function in a team	14 (31.1%)	16 (35.6%)	10 (22.2%)	3 (6.7%)	2 (4.4%)

- Forty-one (41) students returned their survey forms at the end of the class period, five (5) students returned their survey forms in the following few days, and ten (10) students did not return their survey forms.
- One (1) survey form didn't answer Questions 5 and 6. Questions 2, 3, 4 are each totaled to 99.9% due to the rounding effect.
- Two (2) students strongly disagreed with Questions 1 through 4 which clearly indicating a disastrous team. A few students disagreed with Questions 1 to 6 indicating there were two struggling teams. It occasionally happened that some team members just couldn't get along with each other, even though they formed the teams by their own choice.
- The eight (8) and ten (10) students answered neutral to Questions 1 and 6 respectively might be still finishing up their project reports and were not sure how their project report would turn out. The survey was given one day before the project report was due.
- Ten (10) students answered neutral to Question 4 which is quite puzzling. It is an obvious and logical hypothesis that because conceiving a new idea demands a thorough understanding of a system, therefore the process of producing a new idea should have enhanced one's understanding of a system. A possible explanation could be these students were just overwhelmed by the complexity of their researched system and were having a difficult time comprehending the information of the system.
- Impressively, the result of Question 5 shows 86.7% students strongly agreed or agreed that this research project provided an experience in teamwork.

In summary, the positive survey results provide an indirect assessment for supporting the pedagogy of using a case study as an active learning tool as well as using the team project to demonstrate students' ability to function on multidisciplinary teams.

V. Assessment of Active Learning and Team Skills

Active learning is an effective way to enhance student learning. Active learning encompasses activities used for engaging students during a lecture and activities engaged by students outside the classroom so that students can learn by themselves without listening to lectures. During the first class of the semester, the EE 333 students were instructed to form teams of two multidisciplinary members. The students were also informed that all teams are expected to participate in team-based active-learning activities such as answering questions during lectures, working on homework assignments, engaging in a research project, presenting a project poster, and giving a PowerPoint presentation. The team project poster would count towards class participation worth of 5% of the course grade. Two team-based homework assignments were announced: 1) Writing and simulating a MIPS assembly program which is a software-oriented assignment; 2) Designing and simulating a 32-Bit ALU which is a hardware-oriented assignment. However, due to the time constraint, the ALU design assignment was cancelled.

A. Activities for assessing learning levels

The levels of cognitive learning achieved through this team-based research project can be assessed based on the six levels of Bloom's taxonomy: knowledge, comprehension, application, analysis, synthesis, and evaluation.[18,21] The achieved learning levels can be assessed by the research activities and the grading rubrics for the two performance indicators: project report and project poster. The activities for assessing achieved learning levels are shown in Table 2.

Table 2. Activities for assessing learning levels

Level	Research Activities	Report	Poster
1. Knowledge	Define a computer category		
2. Comprehension	Identify relevant systems Select relevant information		
3. Application	Propose a new application		
4. Analysis	Categorize systems into hardware and software components		
5. Synthesis	Propose a new application	Compose report contents	Create a poster
6. Evaluation		Summarize the findings	Summarize the results

The research activities can assess Levels 1 to 5 based on the required project tasks. Report writing and poster creation can assess Levels 5 and 6 based on their deliverables.

B. Assessment of achieved active learning

The achieved active learning can be assessed by the activities listed in Table 2. Since the project report and poster are the results of each team's research activities, the performance of project report, project poster, and PowerPoint presentation can directly assess the achieved active learning. As presented in Section IV.C, the average report score was 95.5/100 (standard deviation 5.03, maximum 100, and minimum 81). There were two teams at 81 and 84 respectively and another two teams at 87. The other 24 teams were above 90. The results demonstrated that the students have successfully achieved the learning levels as shown in Table 2. The average poster score was 90.5/100 (standard deviation 4.37, maximum 95, and minimum 80). There were two teams at 80, three teams at 85, and one team at 88. The other 22 teams were above 90. The results also demonstrated that the students have successfully achieved the learning levels as shown in Table 2.

Each team delivered an excellent PowerPoint presentation which was mainly to debrief their researched system and to propose a new application. The PowerPoint presentations were not graded and therefore were not included in Table 2.

C. Assessment of team skills

Effective team members need to possess three basic skills: communication and negotiation, analytic and creative skills, and organization.[22] Although each team consisted of only two members of different technical backgrounds, both team members took more than 16 credit hours of course load. The project was due at the busiest time of the semester; therefore, team members needed to communicate to each other about their available times and to negotiate the timelines of completing their tasks for the project. This process demonstrated each team member's communication and negotiation skills. There is diverse information on the Internet, the team members needed to be able to analyze and select the relevant information for their report. Integrating information on different aspects of a computer system into a high-quality report with in-depth discussion is a challenging task. Being able to complete the report and poster on time does demonstrate the team members' analytic, creative, and organization skills.

Based on the positive results produced by the direct assessment of the two performance indicators, it can be concluded that all team members have demonstrated these three important team skills. The positive results of survey Questions 5 and 6 also demonstrate students' overall positive experience on their team skills.

VI. Summary

Through a team-based case study research project, the EE and CS students taking the EE 333 Computer Organization course in fall 2013 had an equal opportunity to contribute to the project in their multidisciplinary teams. The excellent results of direct assessment using the project report and project poster as performance indicators clearly demonstrate students' ability to function on multidisciplinary teams. The encouraging results of indirect assessment collected from the survey also demonstrate that the students agree with the idea of using the project report and project poster as the teamwork performance indicators. In summary, the positive results of the direct and indirect assessments successfully demonstrate that team-based case study research project can be used as an active learning tool to expand students' learning and also to demonstrate students' ability to function on multidisciplinary teams.

VII. Future Work

This paper demonstrates that a case study on cutting-edge computing applications can greatly expand students' understanding beyond the classroom coverage. Based on the author's experience, it might be a good idea to increase the number of computing application categories and also to limit the number of teams for each application category. This will force students to promptly form their teams so that they can sign up the available slots. Limiting the number of teams for a computing category will eliminate the situation of too many teams taking on the same computing application category such as the same supercomputer system. Increasing the number of application categories will certainly expand the class's exposure to more different computing systems through poster and PowerPoint presentations.

Another approach is to partition a complicated processor or a sophisticated system into several areas so that students won't be overwhelmed by highly complicated technical details. For example, a highly complex ARM Cortex-A15 processor, an ARM Cortex-A9 based SoC (System-on-Chip), Texas Instruments Advanced Driver Assistance System TDA2x application processors, Intel Core i7 processor, and Intel Xeon E7 v2 processor can be partitioned into different functional categories and studied by different teams. A highly complicated supercomputer system can be partitioned into areas such as processors, interfacing between system components, operating system and user interface, and memory and storage management. Each of these partitioned areas includes hardware and software technical details.

As discussed in Section IV, the due dates of the poster and project report were a few days before the dead week which could cause high levels of anxiety on students. The author will try to move the project due date one or two weeks earlier next time so that students won't be overwhelmed by working on this project and also the assignments required by other courses. The timing of collecting survey might also affect students' feedback. The author ran out of time to give a second identical survey after the project reports and poster grades were returned. The hypothesis is students' sense of accomplishment and reflection might positively affect their mind-set while filling out the survey and might greatly reduce the neutral responses to the survey questions.

Although the presented performance indicators can be an effective teamwork assessment tool, however, the survey shown in Table 1 does not include peer evaluation questions. The survey questions also lack inquiry into the effectiveness of active learning. To provide more detailed indirect assessment of teamwork and team skills, specific peer evaluation questions regarding to each team member's contributions and team skills should be added. Survey questions regarding to the effectiveness of active learning for each learning level should also be added to future surveys. With well-rounded direct and indirect assessment tools, more useful assessment results can be produced for future improvement.

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