AC 2009-729: ENGINEERING DESIGN CASE IMPLEMENTATION: OBSERVATIONS, RESULTS, AND PERSPECTIVES

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Engineering Case Study Implementation: Observations, Results and Perspectives

Abstract

Waterloo Cases in Design Engineering (WCDE) at the University of Waterloo (UW) is a new program to enhance design education through the development and implementation of design cases from student co-op work term and capstone project reports.

This paper summarizes the results of an implementation of the same engineering design case given to three separate engineering classes during the same academic term. The engineering design case was written from a student capstone design project report, and was developed to highlight the engineering design process. The case was developed as a so called interrupted case, where the case was delivered in modules, reflecting steps in the design process. A teaching note was provided to each instructor and served as a recommended guideline for implementation.

Introduction

The Natural Sciences and Engineering Research Council (NSERC) and General Motors of Canada Limited (GMCL) support a program to enhance engineering design education at the University of Waterloo. Waterloo Cases in Design Engineering (WCDE) has been established to develop, implement and promote the use of engineering design cases across the Faculty of Engineering curriculum.

The unique feature of the WCDE program is that cases are developed from students' own work term reports. The University of Waterloo is a co-operative engineering school where students are required to gain practical experience between each academic term. Over 4000 work term reports are generated and submitted for academic credit each year. In addition, students are required to complete a final year engineering design project, to earn an accredited engineering degree. Both represent sustainable sources of engineering design experience for the development of design cases that can be developed and published for future educational use at UW or at other educational institutions.[1]

Cases have been used extensively and successfully in business, law, medicine and engineering to capture real situations and experiences and to deliver this knowledge into a classroom setting[2]. Proper implementation of cases in the form of the case method has been known to foster active learning through group and classroom discussion. *Intercommunication* between students and between instructor and student promotes enhanced problem finding and solving abilities, and can increase course effectiveness beyond that obtained by more traditional methods[3]. Cases also force students to use all four of Kolb's learning styles, including concrete experience, reflective observation, abstract conceptualization and active experimentation, whereas traditional methods only emphasize the last two styles[4].

Assessing the effectiveness of the case method in our own curriculum, with our own students and faculty would provide important information and insight we could use to continuously improve

our program implementation, and methods we use for assessment of student learning and understanding using cases. An opportunity to deliver the same design case to three separate engineering classes was available in a recent academic term, and a case was chosen that would highlight the engineering design process, a common topic for each of the three courses offered.

The purpose of this paper is to share our survey results and experience using one specific design case implemented in three (3) different mechanical engineering design courses.

Design Case Development

The case discussed in this paper, entitled *Foot Brace Design for Long Distance Running*, was generated from a 4th year design project report[5]. The case is an account of how the student author, suffered a serious knee injury during a soccer match. The injury severed the *peroneal nerve*, which is located within the knee joint, and resulted in a condition called *foot drop*. The long term consequence of this condition is that the author could not lift or evert (twist outward) his foot, making walking difficult, and running impractical. The case captures the design challenge of returning the author to an active lifestyle of running by creating a novel and useful foot brace. The case is structured as a so called *interrupted case*, where each module of the case reflects a different stage in the design process.

Module (-01) presented the case; it provided background information on foot drop and existing foot braces. Module (-02) provided the needs analysis and problem formulation, including design objectives, constraints, and criteria as determined by the original designer. Module (-03) covered conceptual design where several alternate designs were considered. A logical method of decision making was applied to select one design. Module (-04) provided some preliminary design and included design calculations, design details, options for material selection, and the final shape of the foot brace. Module (-05) documented the prototyping and evaluation of the foot brace.

A teaching note[6] was developed that contained the same introduction used in the case, teaching objectives and learning outcomes, a description of the central design challenge faced by the author (protagonist), recommended case implementation and a request to submit recommended improvements to the case and/or teaching note to the case developer. The prime teaching objective was to facilitate the study of the engineering design process. Additional objectives were to study state-of-the-art solutions and to recognize how each was deficient in addressing the need and to demonstrate how the conflict between adequate support and comfort was resolved.

The teaching note also recommended a preferred implementation that included individual reflection, group and classroom discussions between the case modules and implementation stages.

This interrupted case design was intended to have students move through Kolb's learning model[8] between each module, beginning with Concrete Experience (CE), the case (-01) module as the 'real' situation; Reflective Observation (RO), observation of the design challenge, both individual and group discussion; Abstract Conceptualization (AC), where students would form abstract concepts about the reflection, and finally Active Experimentation (AE), to test the generated formulation, in a group and class format. It was intended that this be practiced and

reinforced between each phase of the design process, i.e. during and between each module delivery cycle.

Implementation of the Case study

The case study was implemented in three different courses at UW; ME380, an undergraduate core course, ME423, an undergraduate elective course, and ME729 a graduate level course.

ME380, Mechanical Engineering Design Workshop, is a third year core course and it is intended to teach and reinforce the engineering design process. The students work in teams and have to design, analyze, construct and evaluate a mechanical device. Typically the devices are tested on a competition day, and marks are assigned for design quality and performance.

The case study was implemented over a several week period. Module (-01) was issued to the student teams to provide background information. The student teams were then required to do a needs assessment and formulate the design problem on their own time. A short report (two to five pages) was submitted the following week, which was followed by a short classroom discussion. This format was followed for each module.

Module (-02) summarized the needs assessment and problem formulation done by the original designer. The students were then required to generate several design concepts, select one design, and be able to support their decision. Module (-03) provided the conceptual designs and the selected design by the original designer. The student teams were then required to generate detailed design for their selected design. Finally, a short discussion was held on the prototyping of a foot brace.

ME423 Mechanical Design 2 is a 4^{th} year elective course focusing on machine design and machine elements, and includes a major design project component as part of the course. The design project scope is less than half of ME380, but requires students to move through the design method to design and verify a mechanical power transmission device. The case was used to remind the students of the steps in the design process prior to beginning the term project, and to permit student teams to work together in an initial exercise.

The case was implemented as the teaching note recommended, with the group work occurring between each module and during class. Each group was required to present their work. Only the case (-01) the needs assessment (-02) and the conceptual design (-03) modules were given in this class as the teaching objective was to remind the students of the early stages of the design process. It was intended to have them practice problem definition and formulation and conceptual design thinking specifically. The final design was presented (-05) only to provide closure to the case, to demonstrate the novel and successful approach demonstrated by a fellow student (in order to promote the student and our program), and to highlight how a design can evolve from the conceptual design phase to a working artifact.

ME729 Advance Machine Design is a relatively new graduate course, and is part of a new Master of Engineering Design Certificate program. It attracts working professionals and foreign-trained students who are interested in upgrading their engineering design skills. A class project

is part of this course offering as well but varies more significantly to encourage the definition of ill-defined problems. The case was used to provide an overview of the design process, with special emphasis on the problem definition phase. Therefore only the case (-01) and the needs assessment (-02) was delivered.

Survey Method

A survey was developed to capture feedback from the students on the case implementation. It was intended to be more general in nature, with the significant objectives of assessing student perspectives on engagement and understanding. The survey was partly based on earlier experience[8] assessing case implementation effectiveness to first year engineering students, and consisted of 17 questions. The questions are listed in an Appendix below. We were also very interested in how group and classroom discussions, activities that are not commonly planned for a traditional lecture method and setting, helped the students engage in their learning.

The foot-brace design case was intended to introduce and/or remind the students of the engineering design method, to reinforce terminology, and to practice non-technical and professional skills such as teamwork, communication, and time management. The case was delivered in the earlier part of each course, and the surveys were delivered in about the 10th week of term (each term is 14 weeks).

Observations and Results

The response to the case implementation was generally very favorable, with most students reporting that the case study reinforced their learning and understanding of the design process. However, students reported that the case study involved more work than expected. This is particularly reflected in ME380 due to the method of implementation.

The response rate overall was 43 of 91 students available for the survey. This percentage, 47%, was lower than desired, but found to be acceptable for this type of survey. The response rate for each course is summarized in Table 1.

	Surveys Received	Students Available	%
ME380	17	50	34
ME423	11	24	46
ME729	15	17	88
Total	43	91	47

Table 1: Survey Response Rate

The first survey question was intended to assess the students' understanding of the learning objective of the case and the results are shown in Figure 1. The teaching objectives as referenced above, were listed and the students' responses categorized according to each objective. The responses indicate that students understood the case to be designed to promote their

understanding of the engineering design process, the primary teaching objective. They recognized synthesis or design as a secondary objective.

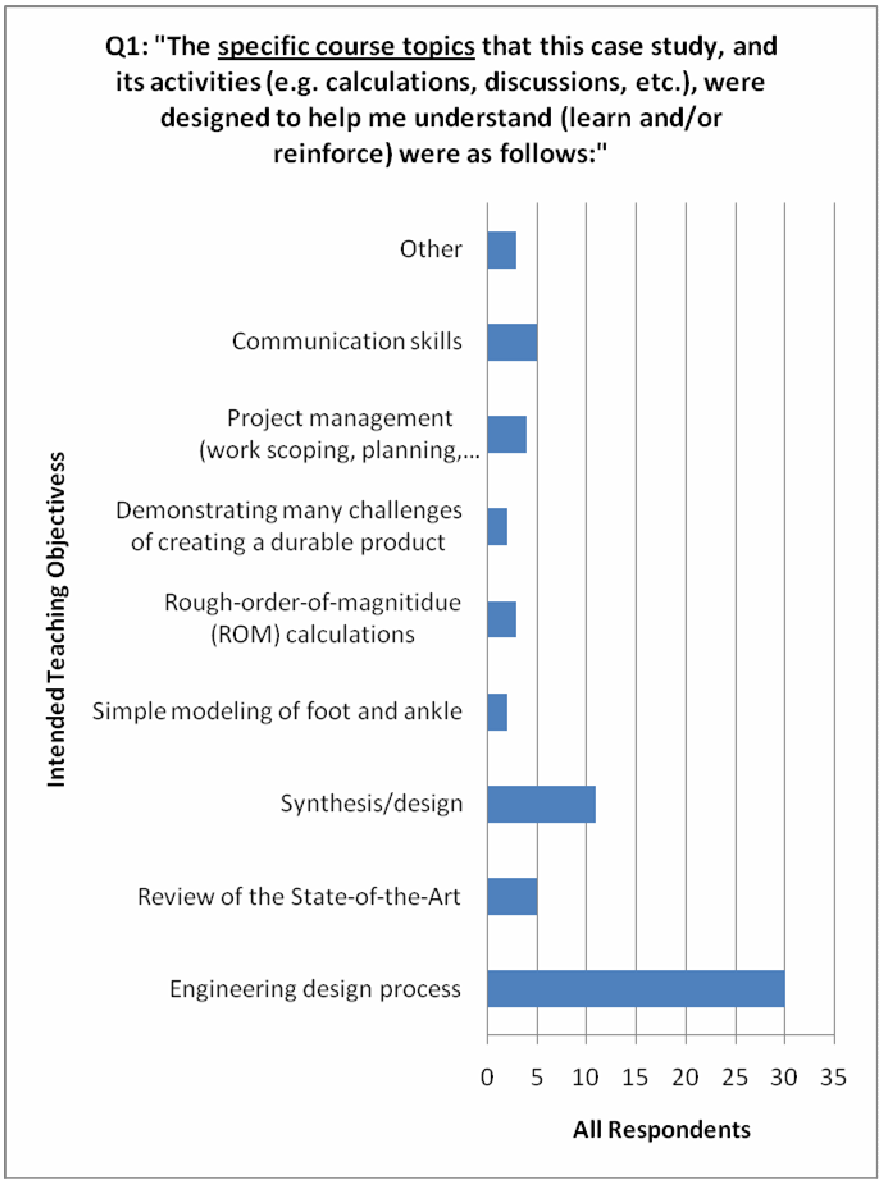

Figure 1: Response to survey Question 1

Additional results are presented in Figures 2 to 6. Results for each class and total responses are presented as shown in the graph legend. Bars plotted left to right correspond with legend items moving from top to bottom. Results are shown as percentages for all results only, with actual numbers responding in brackets beside the percentage labels.

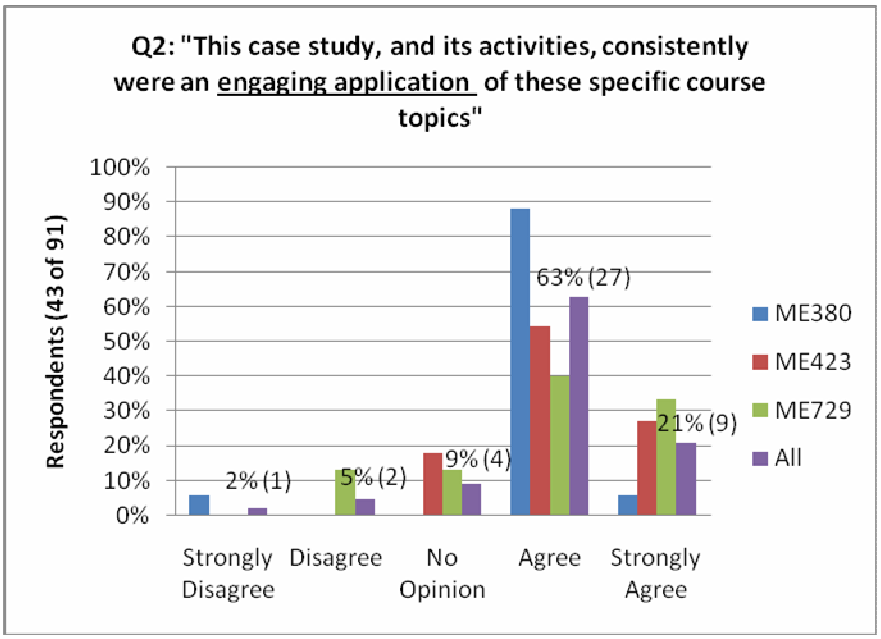

Figure 2: Response to survey Question 2

When students were asked whether the case promoted their interest and engagement, 84% agreed or strongly agreed as shown in Figure 2. One student responded that he/she especially liked the case because it summarized a real design activity by a student just like him/herself. This result is especially encouraging because we believe that an interested student facilitates learning, and more importantly promotes deeper understanding.

A similar but distinctly important question on whether they better appreciated the relevance of the engineering design process as a result of completing the case resulted in 79% of respondents either agreeing or strongly agreeing with 16% offering no opinion, and one student strongly disagreeing. The results are shown in Figure 3.

Question 5 asked whether the case study helped students understand the engineering design method. The results shown in Figure 4 reveal that three-quarters of respondents agreed or strongly agreed with this statement. Interestingly, a number of students disagreed or strongly disagreed. The distribution of response across the abscissa for ME423 could be attributed to some confusion regarding the phrase “specific course topics”. The foot brace design did not incorporate machine elements such as bearings, gears or clutches and brakes; the survey responses indicate the students may have thought that the content of the case did not specifically contribute to the understanding of these mechanical elements.

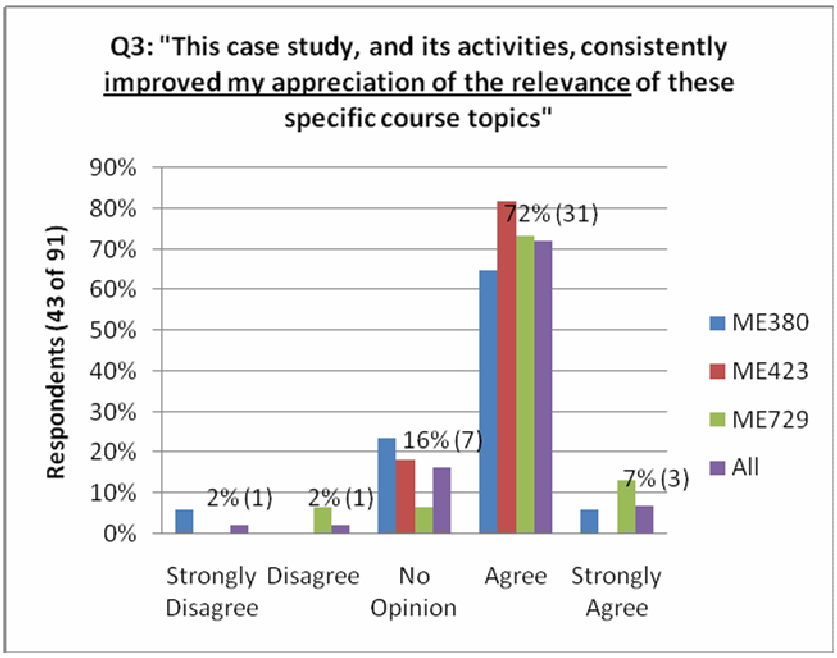

Figure 3 – Response to survey Question 3

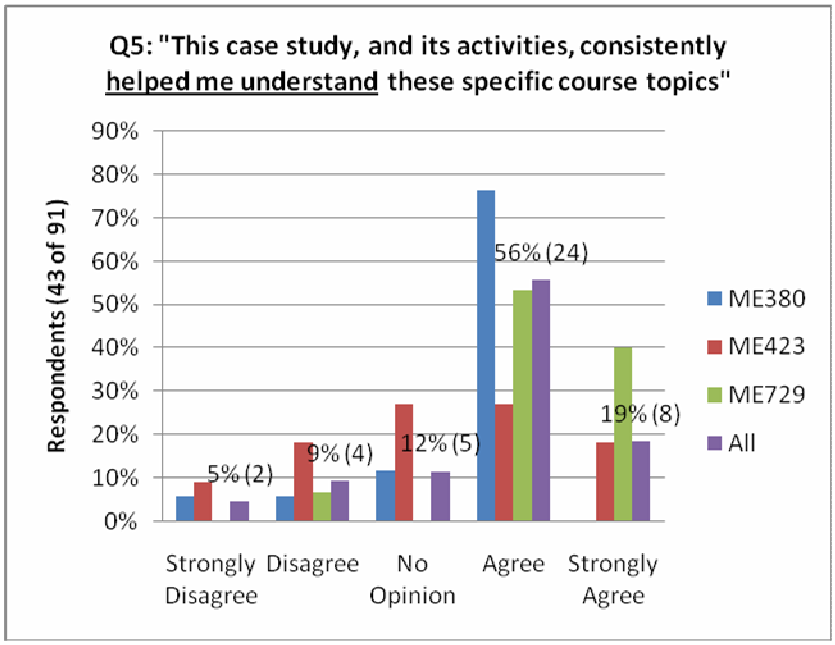

Figure 4 – Response to survey Question 5

Figures 5 and 6 show how students responded to questions regarding group and classroom discussion. A total of 85% of respondents agreed or strongly agreed that group discussions helped then understand, and that 82% of respondents agreed that classroom discussions helped them understand. Faculty instructor observations and perspectives vary on this point. For

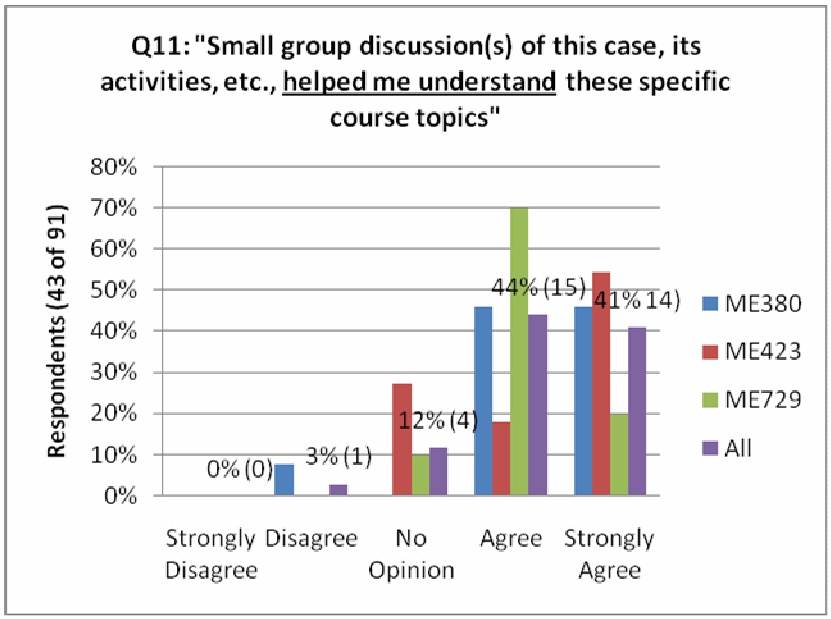

Figure 5 – Response to survey Question 11

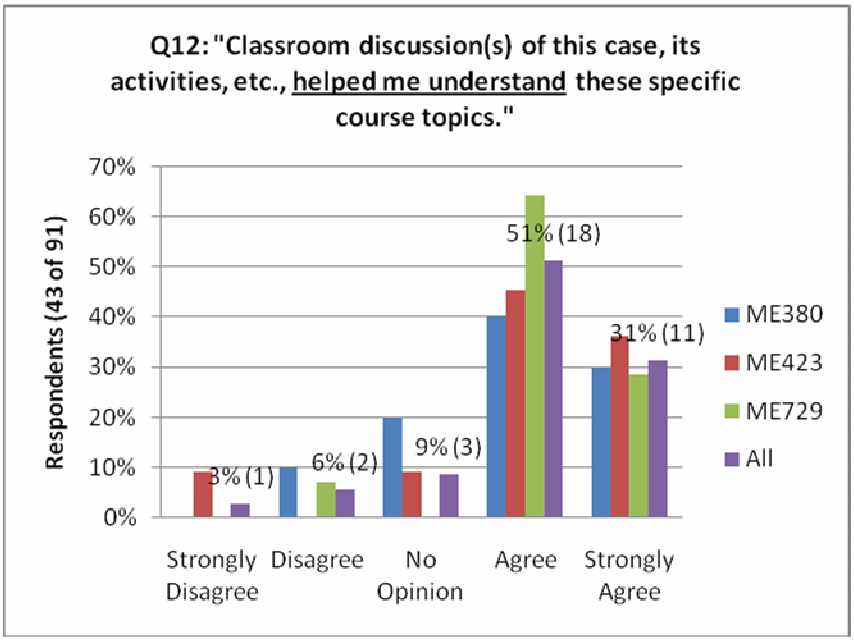

Figure 6 – Response to survey Question 12

ME380, a number of students were not available for the survey, specifically 50 of 90 students, and of those that were available only 17 submitted completed surveys. The instructor for this course observed relatively poor voluntary participation for classroom discussion, and found it necessary to stimulate discussion by calling on specific student teams and students. Generally

the results are favorable, and tend to support existing literature claims and business school teaching practices that group and classroom discussion promote understanding over traditional lecture-style-only methods. It is likely that these activities also accommodate for students' different learning styles as was referenced above.

Questions 14 to 17 were intended to obtain recommendations from the students on improving the case itself, and the implementation method. Students reported that they especially liked that the case was a real-life example, and that it promoted group discussion. They very clearly indicated that learning using the case was time-consuming and more work than they expected. Some reported that they would prefer the scope of the assignment to be better defined. This comment is not entirely surprising, as the design method involves both problem definition (finding) and problem solving, and uncertainty exists in the earlier stages of the process. We believe cases can help students learn to address this open-endedness better, over traditional methods of assigning well-defined problems.

Conclusions and Recommendations

The results obtained in this study are encouraging for our program. While the response rate was lower than expected, the results clearly indicate a favorable response to quite diverse implementations across all three courses. Students were engaged in their learning activity, and believed it helped them with their understanding.

This is a useful outcome for engineering educators because case source material is available in all engineering schools (i.e. capstone design project reports), and cases developed through our program are also available for use at other institutions. Case development and teaching courses are available at various universities, and our own initial *lessons-learned* experiences are summarized in a separate paper.[1]

Our limited experience in assessment suggests that surveys be shorter and perhaps more open-ended, and that we promote completion of the surveys to obtain a higher response rate. We are very interested in obtaining more detailed information in their responses, in an effort to *get behind* what motivated their answers, especially for *strongly agree* and *strongly disagree*.

Finally we find it necessary and important to continually survey such case implementations at every opportunity as we launch this rather daunting challenge of cultural change, and to adapt the case designs and implementation strategies effectively and efficiently.

Appendix – Survey Questions

Q1. "The specific course topics that this case study, and its activities (e.g. calculations, discussions, etc.), were designed to help me understand (learn and/or reinforce) were as follows:"

Q2. "This case study, and its activities, consistently were an engaging application of these specific course topics"

Q3. “This case study, and its activities, consistently improved my appreciation of the relevance of these specific course topics”

Q4. “This case study, and its activities, motivated me to be more interested in these specific course topics”

Q5. “This case study, and its activities, consistently helped me understand these specific course topics”

Q6. “The organization of this case study, and its activities, consistently helped me understand these specific course topics”

Q7. “The case study, and its activities, consistently provided sufficient background information and data for the activities (e.g. calculations, discussions, etc.)”

Q8. “The graphics or multimedia content of this case study, and its activities, consistently helped me to understand these specific course topics”

Q9. “Are there sections of this case study, and its activities, where your understanding of the case material could be enhanced by adding graphics and/or multimedia?

Q10. “In addition to reading this case study, what case-related activities (e.g. calculations, discussions, etc.) did your class carry out to help you understand these specific course topics?

Q11.”Small group discussion(s) of the case, its activities, etc., helped me understand these specific course topics”

Q12.”Classroom discussion(s) of this case, its activities, etc., helped me understand these specific course topics”

Q13. “What aspects of the case study, and its activities, did you especially like in terms of helping you understand these specific course topics?”

Q14.”What aspects of the case study, and its activities, did you especially dislike in terms of helping you understand these specific course topics?”

Q15.”What suggestions do you have for improving this case study, and its activities, in terms of helping you understand these specific course topics?”

Q16.” What are the advantages of using this case study, and its activities, over traditional lectures, in terms of helping you understand these specific course topics?”

Q17.”What suggestions do you have for improving this case study, and its activities, in terms of helping you understand these specific course topics?”

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