AC 2008-531: ASSESSING THE IMPACT OF FAILURE CASE STUDIES ON THE CIVIL ENGINEERING AND ENGINEERING MECHANICS CURRICULUM: PHASE II

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Assessing the Impact of Failure Case Studies on the Civil Engineering and Engineering Mechanics Curriculum: Phase II

Abstract

This paper is the second in a series documenting work to assess the impact of the introduction of failure case studies into engineering mechanics and civil engineering courses. Results from surveys and focus groups of both students and faculty are presented, along with recommendations for improving assessment instruments and processes. The students enjoyed the case studies and believed that they contributed to learning the course material. The case studies stimulated their interest. Most faculty who had participated in the one-day case study workshop and who responded to the survey had made at least some use of the cases in their courses. All fourteen respondents that had used case studies believed that the benefits justified the cost.

Introduction

Failure case studies may be used in engineering courses to address technical topics as well as non-technical topics, such as management, ethics, and professionalism. The authors have developed a number of failure case studies for classroom use. Pilot studies have been carried out over several semesters in order to assess the use of failure case studies in civil engineering and engineering mechanics courses. Prior results were presented at the 2007 ASEE annual meeting, and that paper provides much of the background behind the work.[1]

First, case study topics are linked to specific ABET general and civil engineering program criteria.[2] [3] Case study presentations and reading assignments have been developed to build student knowledge. Students are given specific homework and examination problems that require application of the case studies. ABET criterion 3 defines 11 program outcomes that all engineering programs must meet and document.

"Engineering programs must demonstrate that their students attain the following outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."[2]

Case studies are particularly useful for addressing the outcomes concerned with professional and ethical responsibility, global and societal context, life-long learning, and contemporary issues. The latter two outcomes may be addressed by discussing recent collapses, such as the Pittsburgh Convention Center or the Minneapolis I-35W Bridge. Further discussion of how failure case studies can address civil engineering program and Body of Knowledge (BOK) criteria is presented an another paper at the 2008 ASEE annual meeting[4].

Conducting the Surveys and Focus Groups

Student learning has been assessed through surveys as well as focus groups, led by researchers from the Cleveland State University College of Education and Human Services. The case studies were pilot tested in the spring of 2007 in two courses, Strength of Materials (sophomore, engineering mechanics, ESC 211) and Construction Planning and Estimating (senior, civil engineering, CVE 403). The case studies were presented to the students through PowerPoint lectures, and technical papers were provided beforehand. The use of case studies in the Strength of Materials course was modified in a subsequent offering, based on the findings of this study. This assessment is being repeated in the two courses in Spring 2008.

During the focus groups, the students were asked specifically about the technical lessons learned, as well as their response to the case studies. Case study questions were included on homework assignments and examinations. Survey questions linked student achievement to the a–k ABET outcomes.

The focus groups identified additional benefits to the use of case studies. The sophomore students observed that the cases helped build engineering identity, and provided historical understanding. The cases made the technical information relevant and linked theory to practice. Also, the students remembered a lot about the case studies, including names, dates, and technical details.

In addition, the faculty teaching these two courses were surveyed about the time commitment required to implement the case studies, and whether the benefits justify the investment. Since teaching and revising a course is a time-consuming endeavor, faculty will only incorporate failure case studies if that can be done fairly easily, and if the benefits can be shown to be substantial. Faculty at the home institution addressed the difficulty of implementation in the sophomore and senior courses surveyed.

Several dozen faculty from many different institutions have attended one-day failure case study workshops carried out between 2003 and 2007.[5] The past workshop participants were surveyed about their success in implementing case studies, and about the time commitment required and documented benefits.

Student Survey Results

Student survey responses from the two Spring 2007 courses are presented in tables 1 and 2. Table 1 suggests which outcomes may be considered to be strongly supported by the failure case studies. The scale ranged from 1 – strongly disagree to 5 – strongly agree.

Table 1: Student Survey Responses related to ABET Outcomes

	Strength of Materials ESC 211				Construction Planning and Estimating CVE 403			
The case studies contributed to:	Ave	SD	High	Low	Ave	SD	High	Low
my ability to apply knowledge of mathematics, science, and engineering;	4.33	0.71	5	3	4.00	0.53	5	3
my ability to design and conduct experiments, as well as to analyze and interpret data	3.67	0.71	5	3	3.75	0.46	4	3
my ability to design a system, component, or process to meet desired needs, using the principles of equilibrium;	3.78	0.67	5	3	3.75	0.89	5	3
my ability to function on multi-disciplinary teams	3.33	0.50	4	3	4.00	0.76	5	3
my ability to identify, formulate, and solve engineering problems;	3.78	0.83	5	3	4.25	0.46	5	4
my understanding of professional and ethical responsibility	4.33	1.12	5	2	4.75	0.46	5	4
my ability to communicate my problem solutions effectively;	3.56	0.88	5	2	3.88	0.35	4	3
the broad education necessary to understand the impact of engineering solutions in a global and social context	4.22	0.67	5	3	3.75	0.71	5	3
my recognition of the need for, and an ability to engage in life-long learning	3.67	0.71	5	3	4.25	1.04	5	2
my knowledge of contemporary issues	4.00	0.71	5	3	4.00	0.76	5	3
my ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.67	0.50	4	3	4.25	0.71	5	3

The students in both classes rated ability to apply knowledge of mathematics, science, and engineering; understanding of professional and ethical responsibility; and knowledge of contemporary issues at 4 or higher on average. The sophomore students also rated the broad

education necessary to understand the impact of engineering solutions in a global and social context above 4. The senior students rated ability to function on multi-disciplinary teams; ability to identify, formulate, and solve engineering problems; recognition of the need for, and an ability to engage in life-long learning; and ability to use the techniques, skills, and modern engineering tools necessary for engineering practice at 4 or higher.

All average results were 3.33 or higher. This suggests that the failure case studies can be important for enhancing learning of all ABET outcomes.

The students were also asked to rate the relative contributions of the textbook, lectures, homework, projects (if any), exams, and the case studies to their interest and understanding of the course material. Case studies were ranked at 4.33 (highest) and 3.88 (second highest) for interest by the sophomores and the seniors respectively, and at 4.0 for understanding (tied for third highest, highest). These show strong reinforcement of the specific course technical material.

Table 2: Student Survey Responses on Relative Contributions

How well did each of these elements contribute to your INTEREST in the course material?								
Textbook	2.89	1.17	5	1	3.14	0.90	4	2
Lectures	3.67	0.71	5	3	4.00	0.53	5	3
Homework	3.56	1.01	5	2	3.38	0.92	4	2
Projects	2.88	0.99	4	1	3.43	1.13	5	2
Exams	3.44	0.88	5	2	3.75	0.71	4	2
Cases	4.33	0.50	5	4	3.88	0.99	5	2
How well did each of these elements contribute to your UNDERSTANDING of the course material?								
Textbook	3.78	1.20	5	1	3.14	0.69	4	2
Lectures	4.00	1.00	5	2	3.50	0.93	5	2
Homework	4.11	1.05	5	2	3.75	0.89	5	2
Projects	2.56	1.01	4	1	3.29	0.95	4	2
Exams	4.22	0.67	5	3	3.88	0.99	5	2
Cases	4.00	1.00	5	2	4.00	0.93	5	2

The summary statistics indicate that students benefited most from case studies in the following ways:

1. Making the course more interesting.
2. Helping students broaden their understanding of the impact of engineering solutions in global and social contexts.
3. Making students aware of their professional and ethical responsibility.
4. Increasing students' ability to apply knowledge of engineering to real life situations.

Student Focus Group Comments

Researchers from the College of Education and Human Services discussed the use of the case studies in student focus groups without the instructors present, in both Spring and Fall 2007. Summary results are provided below. The focus groups will be repeated for Spring 2008, and these further results will be presented at the ASEE 2008 annual meeting.

Strength of Materials ESC 211 – Sophomores, Spring 2007

Q. 1. Students Remembered Details about the Case Studies

The students remembered a lot about the case studies, names, dates, and *technical* details about the failures. They had read at least some of the information package, in part to prepare for an examination.

Q. 2. Students found the case studies useful for several reasons:

1. Failure Case studies are motivating
   - They made the information relevant, and linked theory (technical aspects) to practice.
   - They made the information "real"

2. Case studies help build an engineering identity
   - Shows how important engineers are (if a doctor makes a mistake he/she only kill one at a time – a mistake by an engineer can kill thousands)
   - It is useful to know the history of the field, with major failures as part of the history.

Q. 3. Problems were Minor

- A guest speaker's introduction was too fast and did not include enough elaboration
- Would like failure cases related to each of the major topics (the 2 cases examined were rather similar)
- Would like more integration through the course.

Q. 4. Suggestions

- In addition to using "big" cases, also use "mini" cases or small cases to illustrate points.

Strength of Materials ESC 211 – Sophomores, Fall 2007

Q. 1. Students Remembered Details about the Case Studies

Students were able to remember specific cases such as the Quebec Bridge including dates, and *technical* details about the failures. Students indicated that the case studies were first introduced in September. They noted with concern that the failures were mainly due to human error such as complains being ignored, the engineer not being

present on site during critical times, and in one case where one student felt the engineer was too old to fulfill his obligations.

Q. 2. Students found the case studies useful for several reasons:

1. Application
   - Learning something real and applied, and making a connection with real practical situations.
   - They made the information " real"

2. Case studies help an engineer realize the importance of accountability and responsibility. They make one think of high risk situations and therefore to be more careful. One needs to really check things by himself/herself and not rely on other people. If you have to use other people, you need to make sure they have sufficient experience.

3. Realize the importance of communication

4. Homework following the case studies was much easier than most homework.

Q. 3. Problems

No problem was mentioned in the presentation of case studies.

Q. 4. Suggestions

- Integration of case studies throughout the course – to spread the case studies around.
- Would be interested in success stories as well.
- Expansion of coverage:
  - A wider variety of failure case studies
  - More assignments on failure case studies
  - Greater depth in each case studied, including computation related to these failure cases

Construction Planning and Estimating CVE 403 – Seniors, Spring 2007

Q. 1. Students Remembered Details about the Case Studies

- Remembered 4 major case studies, who presented them (outside speaker presented 2 of them) and that there were some supplementary materials
- Remembered a mixture of technical details as well a role of *team, communication, etc.*

Q. 2. Students found case studies useful

- Real problems that engineers have to know – not just equations or books, but communication etc.

- Interesting
- Maybe will help students avoid mistakes in the future

Q. 3. Issues or Problems

- More class interaction about case studies.
- More interaction and time for Q & A in presentation
- Small group discussion about the cases – maybe present problems and let students figure our possible solutions (this would work well for problems in communication)

Q. 4. Suggestions

- Include some video cases (or at least some video content)
- Maybe include cross cultural communication content (related to one case study)
- Maybe a case on use of technology and communication across time zones.

CSU Faculty Comments

The CSU faculty teaching these two courses reviewed the results with researchers from the College of Education and Human Services. These conversations will continue throughout the three year project, addressing issues such as:

1. Was the use of case studies helpful in this course?
2. Did the use of case studies raise issues or cause problems in this course?
3. What suggestions to you have for modifying the use of case studies in this course?

On the basis of these conversations and the student survey results, the delivery of the case studies will be adjusted as necessary.

Workshop Faculty Participants

Faculty workshop participants from the 2003 through 2006 workshops were surveyed by email in January 2008. The workshop participants were primarily from U.S. civil engineering programs, but also included faculty in architectural, construction, and other engineering programs, and faculty from Canada and Ireland. The workshop materials included copies of case study technical papers along with a CD of PowerPoint presentations on individual case studies.

Survey questions and some of the responses are provided below. Eighteen surveys were returned, but only 14 of the respondents were using case studies. Since the email was sent to 54 past participants, it is likely that the surveys returned over-represented those faculty that are currently making use of case studies.

1. How much have you used case studies in your courses since the workshop?

   Not at all (go to question 2) – 4 responses

Some (go to question 3) – 11 responses

A lot (go to question 3) – 3 responses

2. If not, why not? Then send back the survey.

   Typical response – "The courses that I have taught since the workshop do not accommodate the Case Study material well, either due to the subject matter or because the required content does not leave enough time to include the case studies. I do plan to work case studies into a future undergraduate course on structural systems, and a graduate course on durability of concrete structures."

3. How many courses have you used case studies in? Please provide total number, undergraduate/graduate breakdown, and course names. Typical response was one to three undergraduate and/or one or two graduate courses per year, per faculty respondent.

   Typical course titles:
   - Undergraduate: Architectural Structures I, Civil Engineering Materials, Construction Materials, Freshman Seminar, Introduction to Structural Design, Soil Mechanics and Lab, Structural Analysis, Structural Steel Design Laboratory, Small Scale Structures for Architects, Large Scale Structures for Architects, Reinforced Concrete Design Laboratory, Advanced Reinforced Concrete Design, Design Studio, Geology and Soil Mechanics
   - Graduate or UG/Grad: Building Performance Failures and Forensic Techniques, Nondestructive Testing, Forensic Engineering, Seepage – Flow Through Porous Media, Consolidation and Settlement, Geosynthetics, Shear Strength and Slope Stability, Shallow Foundation Design, Foundation Engineering, Rock Mechanics, Structural Dynamics, Prestressed Concrete, Elastic Stability

4. How many students were in those courses (approximately)? Please provide undergraduate/graduate breakdown.

   Responses varied – undergraduate totals per year were typically 15 or 20, with one response as high of 130. Graduate totals were 5 to 10 students per year.

5. Are you using failure case studies in your courses more, less, or about the same since the workshop?

   More – 9, Less – 0, about the same – 5

6. What barriers have you had to overcome to use case studies in your courses?

   - Lack of time to cover course content, time constraints (most common answer)
   - None (second most common answer)
   - Hard to find original investigation reports and high quality photographs
   - Need to update material for recent failures

7. On a scale of 1 – not difficult to 5 – very difficult, how difficult has it been to include case studies in your courses?

   Average 2.07, standard deviation 1.33, high value 5, low value 1

8. On a scale of 1 – not helpful to 5 – very helpful, how useful were the materials provided at the workshop for overcoming those barriers and difficulties?

   Average 3.83, standard deviation 1.40, high value 5, low value 1

9. On a scale of 1 – not much time to 5 – too much time, how would you rate your time commitment required by using case studies in your courses?

   Average 2.54, standard deviation 0.88, high value 4, low value 1

10. On a scale of 1 – not much benefit to 5 – substantial benefit, how would you rate the usefulness to your students of using case studies in your courses?

    Average 4.21, standard deviation 0.70, high value 5, low value 3

11. Overall, do you believe the benefits justify the costs? Yes/No

    Yes, 14 answers (imagine 14 faculty being unanimous about anything)

12. If possible, provide specific "success stories" from using case studies in your courses.

"Most recently, I have had success in assigning case studies to each student, then grouping them based on type of failure, building type etc. (ie Fires, Collapse During Construction etc.) to have them explore patterns or common lessons that have not really been learned by industry since they seem to occur over and over again. That way each class gets exposed to 20 – 30 case histories and the group lessons. Each group presents to the class at the end and writes a paper."

"The course evaluations demonstrate that the students like practical examples. Feedback from graduates also indicates that the courses were considered to be of more interest when they could see principles being employed or violated and the consequences thereof."

"Better reception of and great interest in structural failures, especially the MN bridge failure."

"Engineers are not just to be involved in design. More and more are now being asked to do renovations, and these case studies in failure, or in conditions leading to failures, are invaluable."

"Student evaluations of modules often request more case histories as they can engage with the material presented and find it provides the context for the theoretical aspects of the module."

13. In hindsight, can you suggest any improvements to the format of our annual failure case study workshop?

    Requests were mainly for more cases and more details, updates, one request for simpler stories that could be presented in about 5 minutes, more environmental case studies. Most said that the workshop was fine, as is.

14. Have you done any sort of assessment of the results of incorporating case studies? Yes/No

    Yes – 2, No – 5, marginal – 1

15. Have you used case studies to attempt to satisfy any ABET a – k or BOK objectives? If so, which ones?

    2 Yes – used to satisfy ethics requirement, No – 9

16. Would you be willing to participate in other discussions – by email, phone, or live – on your experiences in using case studies in courses? Yes/No

    Most yes

Summary and Conclusions

The assessment instruments and processes developed during the project are still in a preliminary stage, but are obviously already yielding some useful results. The desired end result would be to distribute the assessment instruments and processes to the faculty workshop participants for broader implementation. At least one of the faculty responding to the survey asked for assessment materials.

The students enjoyed the case studies and believed that they contributed to learning the course material. The case studies stimulated their interest.

Most faculty who had participated in the one-day case study workshop and who responded to the survey had made at least some use of the cases in their courses. Although the range of responses was wide, responses indicated:

- It was not particularly difficult to include case studies in courses
- The workshop materials were helpful
- A significant time commitment was often needed to incorporate case studies
- Usefulness to students was high

All fourteen respondents that had used case studies believed that the benefits justified the cost. A number of them requested additional case study materials. A book of failure case studies in the civil engineering and engineering mechanics curriculum will be published by ASCE Press later this year.[6]

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