AC 2007-761: ASSESSING THE IMPACT OF CASE STUDIES ON THE CIVIL ENGINEERING AND ENGINEERING MECHANICS CURRICULUM

Norb Delatte, Cleveland State University

Rosemary Sutton, Cleveland State University

William Beasley, Cleveland State University

Joshua Bagaka's, Cleveland State University

Assessing the Impact of Case Studies on the Civil Engineering and Engineering Mechanics Curriculum

Abstract

Engineers design. Engineering design uses mathematics and other principles, combined with judgment, to prevent failures. The lessons learned from failures have often led directly to changes to engineering codes and procedures. There is much that engineering students and engineers can learn from failures, and failures play an important role in engineering design. Therefore, there is a recognized need for failure awareness in the undergraduate engineering curriculum. This need has been documented in a number of papers and at a number of conferences over the past 15 years. This project is a specific response to that need, and will provide much needed access to thoroughly developed examples, and a heightened appreciation of the role failure analysis knowledge can play in higher education and public safety.

The expected outcomes of this project will be educational materials on failure case studies for use in civil engineering and engineering mechanics courses, in print and CD-ROM format, and a series of three one-day workshops to disseminate those materials to engineering faculty members across the U.S., as well as a tested assessment package. The objectives of the project will be greater breadth of knowledge, greater depth of knowledge, and improved learning with a reasonable benefit/cost ratio for faculty.

Although the majority of the work will be carried out at Cleveland State University, faculty members and practicing engineers from across the country will participate in the development of these materials and the workshop, through the various committees of the American Society of Civil Engineers (ASCE) Technical Council on Forensic Engineering (TCFE). Researchers from CSU College of Education will assist in assessing the impact of this project.

Case studies require students to synthesize the facts and engineering principles they have learned, and combine them with their broader education in the arts, humanities, and sciences. These intellectual merits have been demonstrated so far with the students who have developed case studies under the proof-of-concept phase of this work. Case studies tie together technical aspects, ethical issues, and procedural issues, and require students to undertake higher order thinking in order to synthesize the relevant concepts. The case study products of this research will help civil engineering educators improve their teaching of specific technical topics within the discipline. In addition, the cases integrate ethics and procedural/professional issues into the courses.

The broader impacts of the proposed activity will be the implementation of a set of fully developed case studies for civil engineering education. Based on survey returns from the participants selected for the pilot workshop, each of the 60 faculty can expect to directly influence an average of 3.2 courses and 215 students in the two years following workshop attendance. Thus, the broader impact will be approximately 190 courses and 13,000 students across the U.S. Furthermore, students will participate in this program developing case studies under the supervision of the faculty investigators.

Introduction

Engineers design. Engineering design uses mathematics and other principles, combined with judgment, to prevent failures. The lessons learned from failures have often led directly to changes to engineering codes and procedures. For example, seismic design codes are routinely modified after an earthquake event. Students are more likely to appreciate advances in design and analytical procedures if they are placed in a historical context.

Many authors over the past two decades have pointed out the need to integrate lessons learned from failure case studies in civil engineering education[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]. A complete discussion is provided in an ASCE 150th Anniversary State of the Art paper by Delatte and Rens[11].

A separate failure analysis course can offer great depth in the topic, but this type of offering is likely to remain limited. Even at colleges and universities where courses are offered in this area, few undergraduates are likely to be able to take them. While some might argue for a required stand-alone course in failure analysis for all undergraduate civil engineering students, the argument is hard to sell due to the trend of institutions reducing credit hour requirements.

A more promising approach is to integrate failure case studies into courses throughout the curriculum. Many professors have done this on an informal basis for years. The first author used this approach at the United States Military Academy (USMA) while teaching two courses in engineering mechanics: Statics and Dynamics and Mechanics of Materials. Subsequently, case studies have been integrated into courses at the University of Alabama at Birmingham (UAB) and Cleveland State University (CSU).

Some of the ways to use case studies and a suggested format were reviewed in Delatte and Rens[11]. These include:

- Introductions to topics – use the case to illustrate why a particular failure mode is important. Often the importance of a particular mode of failure only became widely known after a failure – examples include the wind-induced oscillations of the Tacoma Narrows Bridge and the failure of Air Force warehouses in the mid-1950's that pointed out the need for shear reinforcement in reinforced concrete beams.
- Class discussions – link technical issues to ethical and professional considerations. Add discussions of standard of care, responsibility, and communications to coverage of technical topics.
- Example problems and homework assignments – calculate the forces acting on structural members and compare them to design criteria and accepted practice. This can have the added benefit of requiring students to compare design assumptions to actual behavior in the field under service loads and overloads.
- Group and individual projects – have students research the cases in depth and report back on them. This will also help built a database of cases for use in future classes. Students gain valuable research, synthesis, and communication skills.

This work is strongly student focused. Many of the key technical principles that civil engineering students should learn can be illustrated through case studies. For example, the first author has discussed the Hyatt Regency walkway collapse, the Tacoma Narrows Bridge failure, and other well-known cases with students in Statics, Mechanics of Materials, and other courses. These cases help students:

- Grasp difficult technical concepts and begin to acquire an "intuitive feel" for the behavior of systems and structures,
- Understand how engineering science changes over time as structural performance is observed and lessons are learned,
- Analyze the impacts of engineering decisions on society, and
- Appreciate the importance of ethical considerations in the engineering decision making process.

This project will build on work over the past eight years at the United States Military Academy, at the University of Alabama at Birmingham (UAB), and at Cleveland State University (CSU) to develop resources for educators to incorporate case studies into engineering education. Some of this work has been funded by the American Society of Civil Engineers and the CSU University Center for Teaching and Learning, in addition to the NSF.

The main obstacle to integrating case studies and lessons learned from failures into existing courses is that many faculty do not have the time or background to research and prepare case studies. Although there are many references available they are difficult to translate into classroom lectures without considerable added effort on the part of the instructor. The work so far has addressed this need through the development of innovative course materials to support a master plan linking courses, learning objectives, and case studies. The main task remaining is to implement to use of case studies across the civil engineering and engineering mechanics curriculum, and to assess the impact.

In this proposed research effort, the case study materials will be disseminated through three workshops for engineering faculty. The case studies will be implemented throughout the civil engineering undergraduate curriculum at CSU, and CSU College of Education and Human Services researchers will cooperate with the authors to develop and test assessment materials. Assessment will be added into the program of faculty workshops.

In summary, there is a need for failure awareness in the undergraduate engineering curriculum. Engineering students can learn a lot from failures, and failures play an important role in engineering design. This need has been expressed in a number of papers and at a number of conferences over the past two decades. This proposed research is a specific response to that need and will provide (1) much needed access to examples, and (2) a heightened appreciation of the role failure analysis knowledge can play in higher education and public safety.

This work will promote the goal of stimulating, disseminating, and institutionalizing innovative developments in use of case studies in engineering education through production of knowledge and improvement of practice. The case studies and assessment instruments will contribute to the STEM education knowledge base. The researchers have already begun developing a community of scholars within engineering education, and the proposed work would further the development of that community.

The project builds on the prior work of the NSF proof-of-concept project and ASCE Technical Council on Forensic Engineering (TCFE) Education Committee activities, and contributes to the knowledge base of undergraduate engineering education and practice. An important focus of the project is the integration of research and education, with the goal of enhancing student abilities to research historical case studies and apply the relevant engineering lessons. Finally, this project will develop project-specific measurable outcomes.

This Phase 1 Exploratory project addresses all five components of the CCLI cyclic model, as follows:

- Research on STEM teaching and learning – this project will evaluate how implementation of case studies improves student learning in engineering courses. It will synthesize the results of previous case study workshops, and formally assess the impact on engineering education and student learning within the CSU undergraduate civil engineering curriculum.
- Creating learning materials and teaching strategies – new case study materials will be developed, and new teaching strategies to use case studies in engineering courses will be developed and evaluated. The previously developed case study materials will be extensively revised in light of the findings of the assessment process and feedback from the faculty workshops.
- Developing faculty expertise – this project will develop faculty expertise at CSU and at other colleges and universities in the pedagogy of case study implementation. The case study project web site will be modified to make it more interactive to support the community of engineering educators employing case studies, allowing users to post additional case study materials and assessment results.
- Implementing educational innovations – the educational innovation of integrating case studies in civil engineering courses will be implemented in depth at CSU, and broadly across a wide variety of programs through the community of scholars developed during the workshops. The workshops will provide intensive dissemination of case studies and case study based teaching and learning strategies. Other implementation will include publication of papers in ASCE and related peer-reviewed journals, and presentations at national and international conferences.
- Assessing learning and evaluating innovations – the major change to this project from the prior proof-of-concept work will be the development and implementation of formal assessment strategies and instruments, as discussed in detail below.

Goals of the program

In order to address the need described above, the research team has established the following goals:

1. Greater breadth of knowledge: Crowded engineering curricula may neglect some fundamental tools that should be a part of undergraduate learning. Students can learn simultaneously if the learning process is carefully planned. Though use of failure case studies, students will learn

Obj. a. the process of failure analysis,
Obj. b. engineering ethics,
Obj. c. engineers' role in and value to society

2. Greater depth of knowledge: Mastery of engineering tools requires depth. Deepening knowledge demands a "supercharged" learning process, driving students more quickly to use higher level learning skills while not leaving behind fundamental learning skills at lower levels. Students will
   Obj. a. begin to develop intuition about expected behavior of engineered systems,
   Obj. b. better understand load paths,
   Obj. c. refine their understanding of how engineering ethics is applied to real problems, and
   Obj. d. be able to better visualize the interaction of components of engineered systems.

3. Improved learning with a reasonable benefit/cost ratio for faculty: Facilitation of this learning style could significantly increase faculty time in administering a course. Minimizing the investment of faculty time in utilizing these tools while facilitating both student and faculty learning is fundamental to making the program fruitful as a learning tool. Faculty will
   Obj. a. be able to incorporate failure studies into courses with minimal advance preparation, and
   Obj. b. gain a greater appreciation for factors contributing to failures

To do this, this project will

1. teach faculty to guide students to develop higher level learning skills in multiple learning domains,
2. provide better access to particularly useful case studies that could not be used by faculty without extensive case development, and thus
3. foster more efficient, broader, and deeper student learning within traditional engineering curricula

To better understand how use of failure case studies can facilitate broader and deeper learning, a brief review of learning skills classification is appropriate. Learning skills may be classified into four domains, as shown in Table 1, with each domain being one side of a four-sided learning pyramid. At the base of each domain, and at the base of the pyramid, is the lowest level learning skill, *language development*. At the top of the learning pyramid is the highest level learning skill, *assessment*. Between these common bounds, each domain features unique levels of learning.

Learning that occurs in multiple learning skills domains and exercises higher level learning skills is crucial to successful engineering education. This must, however, occur efficiently because engineering curricula are already overcrowded. This is one reason why failure case studies should be an essential part of engineering classes.

Table 1: Classification of Learning Domains[12]

Cognitive	Social	Affective	Psychomotor
Assessment			
Research	*Management*	*Aesthetics*	*Tool Usage*
Problem Solving			
Critical Thinking	*Teamwork*	*Personal Development*	*Motor Development*
Information Processing	*Communication*	*Value Development*	*Wellness*
Language Development			

The single activity of using a case study as part of a traditional course lesson plan simultaneously fosters learning in three different learning domains, thus making learning more efficient:

1. Affective: The failure is interesting and sometimes dramatic, thus increasing initial acquisition and permanent retention of knowledge from the learning exercise because of the emotional state of the student during the learning process.
2. Cognitive: The failure validates the science, showing that our engineering tools work and thus motivating the students to learn and retain more knowledge.
3. Social: Students discover or rediscover how engineering decisions impact individuals, communities, and society

As a result of case study inclusion, students will demonstrate an ability to process failure analysis, apply ethics in engineering, and demonstrate an understanding of the engineer's role in and their value to society. Students will also demonstrate a greater depth of knowledge by developing intuition about expected behavior of engineered systems, understanding path loads, and better visualizing the interaction of components of engineered systems. Finally, students should experience a change in attitudes about quality engineering as a result of studying failures of engineered systems.

Results from Prior NSF Support

This project seeks to build on the results of a previous project. Case studies were prepared for educators as onscreen PowerPoint slide shows (on CD-ROM), which are also suitable for use in the Board Notes format for instructor blackboard, whiteboard, and overhead transparency presentations. The diverse course material formats support teaching methodologies used by the USMA Department of Civil and Mechanical Engineering (DC&ME), the NSF-funded Teaching Teachers to Teach Engineering (T^4E) workshops at USMA, and the ASCE-funded Excellence in Civil Engineering Education (ExCEED) workshops at USMA and the University of Arkansas.

To date, this project has produced a number of products. A total of 5 complete case studies have been developed during the proof-of-concept project. The project has subsequently received three additional grants – two awards of $ 3,500 from the American Society of Civil Engineers (ASCE) Technical Activities Committee for workshops in 2004 and 2005, and an award of $ 5,000 from the CSU University Center for Teaching and Learning (UCTL) for additional case study development. A textbook proposal has been accepted for a contract by ASCE press.

a. Publications

This ongoing project and previous related case studies work under NSF Project EEC-9820484, Research Experiences Site in Structural Engineering, have resulted in 6 refereed journal papers[11, 13, 14, 15, 16, 17] and 6 refereed proceedings papers[18, 19, 20, 21, 22, 23] published. Two of the papers received the ASCE Journal of Performance of Constructed Facilities annual Best Paper Award.

b. Project Web Site

The materials developed so far are available on the internet at http://www.csuohio.edu/civileng/faculty/delatte/new_case_studies_project/csuweb.htm. The web site contains an extensive detailed bibliography of case study materials. Under the proposed project, the web site would be significantly enhanced to include additional case studies as well as pedagogical and assessment materials.

c. Human resources development

The students who have developed case studies as part of this project have demonstrated the following research skills:

1. Literature review, including obtaining obscure materials through interlibrary loan and locating investigative reports
2. Synthesis of the details of a case study
3. Writing skills
4. Presentation skills, developing presentation and web materials
5. Ability to discuss technical, ethical, procedural, and other details of a case study

These case studies have been excellent for development of undergraduate student research skills. Therefore, this project has contributed substantially to the professional development of the undergraduate students preparing the case studies. The case study development also provides a template for other students at other institutions to follow this model.

Because of the important human resource impact of this work, the CSU University Center for Teaching and Learning (UCTL) provided a $ 5,000 grant for two students to undertake additional case studies of the Point Pleasant/Silver Bridge Collapse of 1967 and the Mianus River Bridge Collapse of 1983.

d. Case Studies Workshop results

Participants of the July 12, 2003 workshop were surveyed to determine the impact of workshop attendance on their teaching. They estimated that over two years, 75 courses and 2,150 undergraduate students would be affected.

Although primarily concentrated in civil engineering, the participants represented a wide range of engineering disciplines as well as different types of institutions. The participants indicated strong interest in the products of this research and looked forward to receiving future materials. Dr. Peter B. Keating of Texas A&M University provided excellent feedback on his use of the Burnaby collapse in his steel design course.

Due to the success of the 2003 workshop, ASCE TAC provided $ 3,500 for a faculty workshop at CSU on September 17, 2004. Approximately two dozen faculty attended this workshop also. An additional grant was subsequently provided by ASCE TAC for a third and fourth workshop, on July 15, 2005 and October 6, 2006.

The two offerings of the case study workshop started the development of a community of scholars working in this area of pedagogy. The approximately four dozen prior workshop attendees have employed the materials with considerable success. Two universities, the University of Louisville and the University of Dayton, invited the first author to present case study lectures at their institutions.

e. Relation of completed work to the new project

The work completed was a proof-of-concept project. The Case Studies Workshop was publicized through forum articles in the ASCE Journal of Performance of Constructed Facilities and ASCE Journal of Professional Issues in Engineering Education and Practice. Presentations have been made to national meetings of ACI, ASCE and a national meeting of the ASEE. The workshop was also publicized on three separate email lists, to CE department chairs, the ACI Faculty Network, and an engineering technology list.

Although the previous project was highly successful in developing case studies, the workshop participants (as well as reviewers of previous follow-up proposals to NSF) identified the need to assess the impact of case study implementation. Therefore, this new project focuses on implementation and assessment. The research team has been expanded to include faculty from the CSU College of Education and Human Resources.

f. Example case study – The Quebec Bridge Collapse, 1907

The use of case studies can best be illustrated through an example. The 1907 collapse of the Quebec Bridge during construction represents a landmark of both engineering practice and forensic engineering[17, 24]. The Quebec Bridge was the longest cantilever structure attempted until that time. In its final design, it was 1,800 ft long. The bridge project was financially troubled from the beginning. This caused many setbacks in the design and construction. Construction began in October 1900. In August 1907, the bridge collapsed suddenly. Seventyfive workers were killed in the accident, and there were only eleven survivors from the eighty-six workers on the span.

A distinguished panel was assembled to investigate the disaster. The panel's report found that the main cause of the bridge's failure was improper design of the latticing on the compression chords. The collapse was initiated by the buckling failure of Chord A9L, immediately followed by Chord A9R. Theodore Cooper had been the consulting engineer for the Quebec Bridge project, and most of the blame for the disaster fell on his shoulders. He mandated unusually high allowable stresses, and failed to require recalculation of the bridge dead load when the span was lengthened.

i. Statics – truss analysis

The bridge was a cantilever truss. As the two arms of the bridge were built out from the pier, the moments on the truss arms increased, and the compressive stresses in the bottom chords of each arm also increased. Both the method of joints and the method of sections, traditionally taught in statics courses, may be used to analyze the compressive strut forces at the different stages of bridge construction.

ii. Mechanics of Materials – allowable stresses

Mr. Cooper increased the allowable stresses for his bridge well beyond the limits of accepted engineering practice, without experimental justification. He allowed compressive stresses that were considerably higher than that provided by the modern AISC code, and were highly unconservative given the state of knowledge at the time. The compression struts of the truss were too large to be tested by available machinery, so their capacity could not be precisely known. Development of engineering codes and standards requires tradeoffs between structural safety and economy, and there must be mechanisms for resolving disputes between competing criteria.

iii. Mechanics of Materials – structural deformation

The bending of the critical A9L member reached 2 ¼ inches and was increasing at the time of the collapse. The bending was discussed at the site and by Mr. Cooper, attempting to supervise the project from New York, but no action was taken. In fact, the bending showed that the member was slowly buckling.

iv. Mechanics of Materials – buckling of columns and bars

The critical A9L compression member failed by buckling. It was a composite section, which meant that it required lacing to require the members to bend together. The moment of inertia, and buckling capacity, of the composite section may be compared to that of the individual truss members, showing the importance of the latticing system.

v. Structural Analysis – predicting, computing, and correcting dead loads

One critical error made in the design was that the dead load was greatly underestimated. When material invoices showed that 17 – 30 % more steel had gone into parts of the structure than had been planned for in the design, no attempt was made to analyze the bridge for the new loads.

vi. Design of Steel Structures – analysis and design of built-up members

This point follows from the discussion of buckling of columns and bars, above. Many existing steel bridges use built up members, and engineers involved in assessing and rehabilitating such structures need to know how to evaluate member capacity and likely failure modes.

vii. Engineering Management – the requirement for the engineer of record to inspect the work on site

Mr. Cooper attempted to supervise the construction of a bridge in Quebec from his office in New York City. When problems arose, the problems were referred to him for a decision. The absence of an onsite engineer with authority to stop the work meant that there was no way to head off the impending collapse. A meeting was held to decide what to do, and the bridge collapsed just as the meeting was breaking up.

viii. Engineering Ethics – professional responsibility

Mr. Cooper planned for the Quebec Bridge to be the crowning achievement of an illustrious career as a bridge engineer. However, by this time his health was poor and he was unable to travel to the site. He was also poorly compensated for his work. Following the collapse, organizations such as ASCE began to define better the responsibility of the engineer of record. Unfortunately, the collapse of the Hyatt Regency Walkways three quarters of a century later showed that much remains to be done[24].

ix. Classroom Implementation

As an example, the following problem statement may be used in a structural analysis or capstone design/professionalism course, in conjunction with the Quebec Bridge collapse case study. The problem should be assigned before the discussion of the case study, probably as an overnight homework. Following discussion of the case study, students should be better able to identify potential problems with an unusual construction technique.

You are the engineer for a cantilever truss bridge across a major river in North America. The bridge owner has asked you to prepare specifications, including allowable stresses, and has emphasized that they have a very shaky financial situation. The bridge was initially intended to be 1,600 feet long – to reduce the cost of the piers, they have been moved into shallower water and it will now be 1,800 feet long. When completed, it will be the longest bridge of this type in the world.

Problem: list all of the things you can think of that can go wrong during this bridge construction project.

Once the collapse case has been discussed, the problem may be reassigned with the additional assignment to propose communication and quality control measures to ensure against collapse. Students should refer to the case study in formulating their answers.

Relation to the State of Knowledge

In a survey conducted by the ASCE Technical Council on Forensic Engineering (TCFE) Education Committee in December 1989, reported by Rendon, about a third of the 87 civil engineering schools responding indicated a need for detailed well-documented case studies. The University of Arizona said "ASCE should provide such materials for educational purposes" and Swarthmore College suggested "ASCE should provide funds for creating monographs on failures that have occurred in the past"[2].

The ASCE TCFE conducted a second survey in 1998, which was sent to all Accreditation Board for Engineering and Technology (ABET) accredited engineering schools throughout the United States[10]. Similar to the 1989 survey, the lack of instructional materials was cited as a reason that failure analysis topics were not being taught. One of the unprompted written comments in that survey was "A selected bibliography is needed on the topic, which could be accessed via the Internet." Such a bibliography has been provided on the project web site. One product of this research will be further development of this much-needed bibliography.

The use of case studies is also supported by the latest pedagogical research. *From Analysis to Action*[25] refers on page 2 to textbooks lacking in practical examples as an emerging weakness. Much of this document refers specifically to breadth of understanding, which may be achieved through case studies. Another issue addressed (p. 19, ref. 25) is the need to "incorporate historical, social, and ethical issues into courses for engineering majors." The Committee on Undergraduate Science Education in *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*[26] proposes that as many undergraduate students as possible should undertake original, supervised research. *How People Learn*[27] on page 30 refers to the need to organize knowledge meaningfully, in order to aid synthesis and develop expertise.

The case study materials developed so far have been very well received by faculty across a wide range of civil engineering programs, as well as some other related programs. To date, however, the benefits identified have been anecdotal (although nevertheless impressive). There remains a need to identify, quantify, and assess the impact of case studies on teaching and learning.

Detailed Project Plan

This new project will be carried out in the following steps:

a. Develop Case Studies

Further develop the linkage between civil engineering and engineering mechanics courses, course topics, and case studies. A master plan linking cases, courses, and topics was developed under the proof-of-concept project. In addition, opportunities to expand the use of case studies into other engineering disciplines and also natural science and mathematics courses will be explored. Where appropriate, case studies of successful projects will also be included.

Although a wide variety of materials exists, the format is generally not suitable for easy use by educators, and the materials do not reflect recent advances in pedagogy. Assembling and distilling these materials into onscreen (PowerPoint) presentations and board notes, with the necessary supporting documentation, will be of immense help to the engineering professorate.

The format of new cases developed will follow that of papers previously published and cited above. These cases used the following outline:

- Design and Construction
- Collapse/Failure
- Cause(s) of Failure
- Legal Repercussions
- Technical Aspects
- Professional and Procedural Aspects
- Ethical Aspects
- Educational Aspects

The fully developed new cases, as well as the accompanying PowerPoint presentations and board notes, will follow the same outline.

Although all case studies will include a section on ethical aspects, some cases will be developed specifically to explore ethical issues. An example is a presentation on William LeMessurier's actions following his discovery of the structural problems at the Citicorp Tower, as discussed by Morganstern[28].

b. Develop a Community of Scholars

Disseminate these materials through a program of three one-day workshops to 20 faculty members per workshop, and follow up with them to determine how they use the materials in the classroom, and how the materials may be improved. The workshops will review the materials and educator's experiences in incorporating them in the undergraduate curriculum.

- A binder with photocopies of papers, board notes, presentation slides, and other printed materials.
- A CD-ROM with presentations and other electronic materials (board notes, etc.).
- Other references have been provided in past workshops, as available[29, 30, 31].

c. Develop Assessment Materials and Methods

Assessment materials and methods will be developed. Researchers from the CSU College of Education and Human Resources will lead the assessment effort.

d. Test Assessment Materials in CSU College of Engineering

As a test, case studies will be integrated into various courses of the civil engineering and engineering mechanics curriculum at CSU. The assessment materials and methods will be included in the test, and refined through successive iterations.

e. Further Development of Web Site

Continue to develop the web site for courses, topics, and case studies, and a version in print and CD-ROM (with PowerPoint presentations) for field-testing and dissemination. Interactive features will be added to the web site to help develop the community of scholars working on case study development, case study implementation, and assessment.

f. Development and Publication of Textbook Supplements

Selected cases will be submitted to the ASCE Journal of Performance of Constructed Facilities or other journals as appropriate. As stated below, under Results from Prior NSF Support, this journal has already published four papers written under earlier projects.

A web site will make the draft case materials available for download. The materials will be prepared on CD-ROM for the workshops. Publication of a CD-ROM and printed version will be discussed with the ASCE press. ASCE published a previous set of short case study summaries prepared by the ASCE TCFE Education Committee[31].

The project will develop course supplement books under the auspices of the ASCE TCFE Education Committee to be sold through ASCE publications. Given the high price of engineering textbooks and codes that students must already purchase for most courses, it will be important to keep the supplements focused and inexpensive. Due to the sponsorship of the ASCE TCFE Education Committee it will be a relatively straightforward matter to have these published by ASCE.

Project Evaluation and Assessment

This project is strongly student focused – its importance and impact is on preparing engineering students to become better engineers. However, the assessment will focus first on faculty expertise, and second on student learning. Faculty expertise is an important first step because until faculty are able to extract full benefits from the case studies, it will be difficult to substantially enhance student learning. Desired student learning outcomes are:

1. Improved understanding of technical issues in civil engineering and engineering mechanics

2. Improved understanding of ethical, professional, and procedural issues in civil engineering and engineering mechanics

These measurable outcomes may be used to monitor progress, guide the project, and evaluate its ultimate success.

Assessment of a large and complex project of this nature represents a significant challenge. Therefore, the project team includes assessment expertise from the CSU College of Education and Human Resources. The primary assessment question is: "In what ways does the use of failure case studies improve students' ability to demonstrate competencies that prepare them to be better professional civil engineers?"

Assessment efforts will focus on student performance, attitudes towards the use of the case studies, faculty experience and cost/benefit factors (e.g., time to learn how to use the case study, value-added). The assessment will use *both direct and indirect measures* and every effort will be made to triangulate the methods chosen (both breadth and depth). Surveys, focus groups, interviews and classroom observations will be conducted for program assessment. Faculty will analyze the effect on student learning on those activities designed to capitalize on the demonstrated levels of learning that occur as a result of using case studies.

When possible, student performance will be compared to those students who are expected to have the same learning but are not using the case studies. This could be students in a different section of the same course, or students who are having the same pedagogical experience in different courses. Results will also be analyzed to see if there are differences in the study variables among students according to such factors as learning styles, academic standing, gender, ethnicity, and personality type preferences.

Evaluation will focus both on process and on product. The assessment of process will determine whether implementation followed the plan, and the assessment of product will evaluate whether the expected student learning outcomes were achieved.

The assessment questions are as follows:

- Does the use of failure case studies improve students' ability to demonstrate competencies that better prepare them as professional engineers for the 21st century?
- How does the implementation of failure case studies encourage deep learning in civil engineering students?
- What has been the time commitment and value-added experience for faculty who integrate failure case studies in the course curriculum that improves student learning of civil engineering concepts?

Specifically, assessment will consist of the following:

Preparation of Assessment Materials. Preparation of assessment materials will comprise a significant effort in the first year of the program. In order to permit implementation of pilot studies in year 1, early emphasis will be on the development of the materials to be used in each course and to be administered during faculty workshops. Development of assessment tools should be 75% complete by the end of year 1. Focus group scripts and faculty interviews will be developed during year 2 based on the information received from the first set of course surveys and class observations administered during year 1.

Pilot Studies. Program assessment should measure whether the desired learning occurs in pilot implementations in a diversity of classroom settings. The program will thus include pilot studies at CSU where the materials will be implemented in at least new one course each of the three years of the study.

1. Pre- and post-course surveys of students. Standard surveys will be developed by CSU College of Education and Human Resources researchers, administered by the course instructors, and interpreted by CSU College of Education and Human Resources personnel. Pre- and post-course surveys will be administered for each course offering, so a total of 20 pre/post surveys will be conducted. When possible, the surveys will also be administered to another group of students taking the same course but without benefit of the use of failure case studies.
2. Student focus groups. Focus groups are a highly useful means of assessment program success and for identifying areas for improvement. Scripts will be created for administration of focus group studies. Administration of focus group activities will be by personnel independent of the faculty instructor to assure students will provide both positive and negative insights. CSU College of Education and Human Resources researchers will interpret the focus group feedback provided by the focus groups.
3. Faculty interviews and surveys. CSU College of Education and Human Resources researchers will interview each of the faculty administering the pilot study courses to assess progress towards the program goals and objectives. Interviews will be conducted with each faculty twice in the year program. In addition, CSU College of Education and Human Resources researchers will prepare and administer surveys of faculty participants to be used in conjunction with the program of workshops.

Perceived Impact of Workshops. The three proposed program workshops provide an opportunity to assess faculty participants' impressions of whether the workshop and materials will have or have had an impact on the learning in their courses. Surveys will be developed for faculty participants to complete prior to and immediately after each workshop. Each workshop will also feature a 30 minute roundtable to foster brainstorming and evolution of the program for continuous improvement. Follow-up surveys will be administered by email 12 months after the workshop for all workshops conducted. For the three workshops featuring 20 participants each, this constitutes 60 pre-workshop surveys, 60 end-of-workshop surveys, 3 roundtable discussions, and up to as many as 60 surveys administered 12 months after workshop completion.

Conclusions: Intellectual Merit

The case studies prepared under this project will be of considerable value to engineering education. Current Accreditation Board for Engineering and Technology (ABET) requirements[32] under Criterion 3 mandate that graduates of accredited engineering programs must have:

- "an understanding of professional and ethical responsibility" (3f)

- "the broad education necessary to understand the impact of engineering solutions in a global and societal context" (3h)
- "a recognition of the need for, and an ability to engage in life-long learning" (3i)
- "a knowledge of contemporary issues" (3j)

These abilities must be demonstrated with examples of student work. Of the 11 Criterion 3 program outcomes, these four are notoriously difficult to document. In large part, this is because these require synthesis and higher order thinking.

However, these program outcomes lend themselves very well to a case studies approach. Case studies require students to synthesize the facts and engineering principles they have learned, and combine them with their broader education in the arts, humanities, and sciences. These intellectual merits, on a small scale, have been demonstrated so far with the students who have developed case studies under the proof-of-concept phase of this work. Case studies tie together technical aspects, ethical issues, and procedural issues and require students to undertake higher order thinking in order to synthesize the relevant issues.

The case study products of this research will help civil engineering educators improve their teaching of specific technical topics within the discipline. In addition, the cases integrate ethics and procedural/professional issues into the courses. The web site provides links between courses, lesson topics, and cases. The case study materials provide references and background for faculty to integrate into existing courses.

The cases may also be used by faculty teaching engineering mechanics, mechanical engineering, and other engineering disciplines. Introduction to Engineering and Capstone Design courses which cover ethical topics will also find the materials useful. Also, case development integrates writing with technical topics for the students developing the cases. Faculty members from other disciplines have been invited to the Case Studies workshop.

Conclusions: Broader Impact

The broader impacts of the proposed activity will be the implementation of a set of fully developed case studies for civil engineering education. These will be of considerable value for engineering programs throughout the U.S. This has been found to be an excellent way to prepare undergraduate students for graduate school, and to evaluate their research and writing abilities.

Based on survey returns from the participants selected for the pilot workshop, each of the 60 faculty can expect to directly influence an average 3.2 courses and 215 students in the two years following workshop attendance. Thus, the broader impact will be approximately 190 courses and 13,000 students across the U.S. Furthermore, students will participate in this program developing case studies under the supervision of the faculty investigators. This work will contribute to their educational and professional development. The cases will be broadly disseminated, with particular emphasis on applications to other engineering disciplines, in order to enhance the impact of the work.

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There is much that engineering students and engineers can learn from failures, and failures play an important role in engineering design. Therefore, there is a recognized need for failure awareness in the undergraduate engineering curriculum. This need has been documented in a number of papers and at a number of conferences over the past 15 years. This project is a specific response to that need, and will provide much needed access to thoroughly developed examples, and a heightened appreciation of the role failure analysis knowledge can play in higher education and public safety. AC 2007-761: Assessing the Impact of Case Studies on the Civil Engineering and Engineering Mechanics Curriculum. Article. Full-text available. Jan 2007. Norbert Delatte.Â There is much that engineering students and engineers can learn from failures, and failures play an important role in engineering design. Therefore, there is a recognized need for failure awareness in the undergraduate engineering curriculum. This need has been documented in a number of papers and at a number of conferences over the past 15 years. This project is a specific response to that need, and will provide much needed access to thoroughly developed examples, and a heightened appreciation of the role failure analysis knowledge can play in higher education and public safety. â€¢ Ac 2007-761: Assessing the Impact of Case Studies on the Civil Engineering and Engineering Mechanics Curriculum more. by N. Delatte. and Joshua Bagaka's. Publisher: icee.usm.edu. Publication Date: 2007. Research InterestsÂ For the last five years a summer undergraduate research site in structural engineering, funded by the National Science Foundation (NSF), has operated at the University of Alabama at Birmingham (UAB). During this time 25 students from 18 more. For the last five years a summer undergraduate research site in structural engineering, funded by the National Science Foundation (NSF), has operated at the University of Alabama at Birmingham (UAB). During this time 25 students from 18 colleges and universities have participated. A degree in Engineering (Civil and Structural) (BEng) is taught via a selection of compulsory and optional courses to enhance your learning and prepare you for a future career or further study. Depending on the number of compulsory and optional courses offered by your degree, you can also choose other courses which fit your timetable. First Year Compulsory Courses. â€¢ Principles of Electronics â€¢ Fundamentals of Engineering Materials â€¢ CAD and Communications in Engineering Practice â€¢ Fundamental Engineering Mechanics â€¢ Engineering Mathematics 1 Optional Courses â€¢ Select a further course, e.g. GR

Civil Engineering Materials and Design. Properties and manufacturing of concrete, steel and timber structural products. Design principles and examples for concrete, steel and timber members.Â Topic areas include the impact of climate on infrastructure, vulnerability studies and adaptation design and management techniques. Studies in knowledge areas of design, management and resilience of transport (roads, ports and wharves), water provision, stormwater and wastewater systems. Prerequisite: CIVIL 203.Â A range of selected topics in traffic engineering and transportation planning which will provide a basis for extension into further studies. Restriction: CIVIL 361, 460. CIVIL 661. 15 Points. Highway and Pavement Engineering. Profession civil engineer. Civil engineers conduct research, advise on, design, and direct construction; manage the operation and maintenance of civil engineering structures; or study and advise on technological aspects of particular materials. Would you like to know what kind of career and professions suit you best? Take our free Holland code career test and find out. Personality Type. Realistic / Investigative.Â The engineering discipline that studies the design, construction and maintenance of naturally built works such as roads, buildings, and canals. Skills. Ensure compliance with safety legislation.Â troubleshoot assess project resource needs manage air quality address public health... Â© American Society for Engineering Education, 2007. Assessing the Impact of Case Studies on the Civil Engineering and Engineering Mechanics Curriculum Abstract. Engineers design.Â Case studies require students to synthesize the facts and engineering principles they have learned, and combine them with their broader education in the arts, humanities, and sciences. These intellectual merits have been demonstrated so far with the students who have developed case studies under the proof-of-concept phase of this work.Â The case study products of this research will help civil engineering educators improve their teaching of specific technical topics within the discipline. In addition, the cases integrate ethics and procedural/professional issues into the courses. In some cases, this impact has been cases where the engineers involved in the creation of. clearly positive, such as in the case of house appliÂ a particular solution, constrained with a limited view. ances and water purification. In others, the impact of the situation they were trying to address, were not. has been negative, as in the case of bombs with ever- aware or could not possibly imagine the impact that. increasing destructive power.Â Perspectives in their curricula? tal impact of aerospace/mechanical engineering. products, including those they have designed in.Â Fluid mechanics is a junior level course required for aerospace, mechanical and civil engineers. In the most. 80 N. DeJong Okamoto, J. Rhee & N.J. Mourtos.