

Engaging students via failure case studies and problem-based learning

M. Zoghi^{1,*}, N. Delatte^{2,*}

¹California State University, Fresno

²Cleveland State University

*Emails: mzoghi@csufresno.edu,
n.delatte@csuohio.edu

ABSTRACT

It is widely known that nearly 50% of engineering students either switch majors or drop out within the first couple of semesters upon enrollment. Research has revealed that a combination of poor teaching and mentoring, difficulty of the curriculum, and lack of belonging are among the reasons for high attrition.

Over the years, educators have developed a wide range of techniques to address the attrition issues mentioned above. There have been many teaching and learning centers established across campuses to improve pedagogies to help enhance student learning. In addition, freshman and sophomore curricula have been revamped to incorporate more design projects, problem-based learning (PBL), etc. Better mentoring and engaging students in engineering activities and research have also helped students feel they belong in engineering.

All along, one of the challenges has been to introduce new courses and additional units in an already jam-packed curriculum. The authors have been incorporating failure case studies as an integral component of existing engineering and construction management courses to provide students a better insight regarding their chosen field and future profession. Student groups form forensic engineering or consulting companies; investigate technical and ethical aspects of a prominent engineering or construction failure; prepare technical reports, and deliver PowerPoint slide presentations in class. Myriad assessments have revealed that students become more conscientious about the subject at hand; working in teams gives them the feeling of belonging; a closer interaction is established between the instructor and students, and students gain a better perspective of real life projects. In addition, the venue provides an opportunity to teach ethics via case studies. The details of case studies, on failure to enhance student learning and retention and inculcating professional ethics as part of these case studies, will constitute the crux of our paper.

Keywords: failure case studies, ethics, student success, retention, assessment, ABET, ACCE

<http://dx.doi.org/10.5339/qproc.2015.elc2014.50>

© 2015 Zoghi, Delatte, licensee Bloomsbury Qatar Foundation Journals. This is an open access article distributed under the terms of the Creative Commons Attribution license CC BY 4.0, which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. INTRODUCTION

It is well publicized that more than 50% of engineering students either switch their majors or drop out early in their college education. Furthermore, nationally, only 50% of students who enter engineering majors actually graduate within six years. Recent studies^{1–3} have identified three key reasons for the high attrition rate: (1) poor teaching and advising/mentoring; (2) difficulty and inflexibility of engineering curricula; and (3) lack of a sense of belonging during the pre-engineering years. The first two years are especially critical in students' retention and success. This is because most traditional engineering curricula are front-loaded with non-engineering courses and heavy in math, science, and general education courses, which are taught by non-engineering faculty.

In recent years, there has been much effort expended to overcome the preceding challenges. There are now an abundance of teaching and learning centers/institutes established on university campuses to provide one on one and group workshops for the faculty to enhance their teaching skills and to develop better insights for advising/mentoring students. Moreover, the latest modern technologies are also introduced to equip the faculty with advanced delivery techniques in the classroom to create a collaborative environment and flipped classroom, so that students gain familiarity with the subject prior to class participation. Despite all these efforts, however, attrition is still high and there is room for improvement—to enhance the undergraduate engineering and construction management students' experience in ways that attract and keep more students. Among other approaches, failure case studies in engineering and construction have been successfully incorporated in existing courses to address the aforementioned challenges and to provide problem-based learning opportunities for students at all levels. Petroski⁴ puts this into perspective: *“To reengineer anything—be it a straight pin, a procurement system, or a Las Vegas resort—we first must understand failure.”* Following an overview of the use of failure case studies in engineering and construction education, we will present a summary of the results of a collaborative study conducted by a consortium of universities in relation to the impact of case studies on students' understanding of the subject and related ethical issues. The primary focus of this paper is student engagement and success. The manuscript will elaborate on the use of failure case studies in an introductory course as a venue to get students engaged and to gain a sense of belonging. Furthermore, the course learning outcomes relating to failure case studies can be readily mapped onto several student outcomes of ABET⁵ a through k and newly proposed ACCE⁶ student outcomes.

2. RESEARCH AND PROBLEM STATEMENT

Meador⁷ states: *“Disasters are inherently intriguing to students, and can motivate them to engage in high levels of analysis.”* Indeed, forensics and failure case studies have been successfully incorporated in engineering education for the past two decades. Delatte⁸ developed a master plan for the use of failure case studies in an undergraduate civil engineering curriculum. Accordingly, he identified a number of failure case studies relating to various principles discussed in a select few courses. The reference case studies were utilized to elaborate on the details of drawing correct and complete free body diagrams in a statics course, buckling of compression members in mechanics of materials and structures courses, shear strength of concrete beams for the reinforced concrete design course, and connection detailing and behavior in relation to the structural steel design course.

Adekoya and Patel,⁹ who had employed structural failure case studies in structural analysis and design courses at Rochester Institute of Technology and conducted surveys of students enrolled in these courses, have reported that the use of failure case studies enhances students' understanding of structural behavior and ethics. In the book *Success Through Failure: Paradox of Design*,¹⁰ Petroski draws the reader's attention to: *“Things that succeed teach us little beyond the fact that they have been successful; things that fail provide incontrovertible evidence that the limits of design have been exceeded.”* Petroski further points out that *“emulating success risks failure; studying failure increases our chance of success.”*

Not only do the failure case studies provide innovative course materials to convey the key concepts in analysis and design, they also afford the opportunity to inculcate soft skills. Recent studies^{11,12} reveal that today's engineering graduates need to have a broader perspective of issues that concern their profession, including global, social, environmental, economic, communication, and teamwork skills. Furthermore, it is essential that new graduates not only are grounded in technical knowledge of fundamental engineering science and computer literacy, but that they know how to apply them in practice.¹³ Failure case studies have proven to provide both, the technical grounding and soft skills, as evidenced in the applications described below.

3. RESEARCH STUDY

A well-publicized report published by the National Academy of Engineering (NAE), entitled the Engineer of 2020¹⁴ and its sequel, Educating the Engineer of 2020,¹⁵ note that, *“the engineering graduates should possess strong analytical skills, exhibit practical ingenuity, be creative, have good communication skills, be mastered in the principles of business and management, understand the principles of leadership, have a strong sense of professionalism and ethical standards, and be lifelong learners.”*

The National Academy of Engineering (NAE) has also identified 14 engineering grand challenges for the 21st century.³ In addition to the aforementioned grand challenges, the global economy and ever changing technology landscape and information will definitely require new professional skill sets for the future engineering graduates. While there will be considerably more competencies required of next generations of US graduates in engineering, many engineering programs are truncating the total number of units for graduation. For example, the California State University System has recently mandated the total number of units to graduate in engineering programs to be reduced to as low as 120 semester units (180 quarter units). The problem is compounded when one considers the lack of high school students' readiness for college, especially in calculus and science areas. Many students enrolled in engineering programs need remedial math courses to get ready to take the calculus series.

In view of the preceding paradox, educators need to become more creative regarding the curricula development and devise innovative approaches to address the above mentioned challenges. With this backdrop, a number of universities, led by Cleveland State University, received a grant from National Science Foundation (NSF) to extend the use of failure case studies and assess their impacts on student outcomes in various courses among partner institutions. It is not in the scope of this manuscript to discuss the details of this multi-university research study. The results have been disseminated in Delatte et al.¹⁶ In a nutshell, the study has identified that failure case studies can be employed to provide indirect, quantitative assessment of multiple student learning objectives. Furthermore, case studies provide the strongest results in relation to the ABET⁵ student outcomes f, h, i, and j.

The focus of the present paper is to demonstrate that the case studies project can serve as a way for students to become engaged in group activities and develop a sense of belonging early in their college education, which is an important factor in their long-term success and retention. The following scenario, implemented in an introductory course at a partner university, elaborates on implementation of the case studies and the related assessments.

The aforementioned course—Construction Management Orientation—is a one-unit semester required course for all freshmen at California State University, Fresno. Construction failure case studies constitute a core component of the course. They are used to explain various technical concepts, while myriad ethical scenarios are discussed to present professional ethics issues. At the onset of the semester, student groups (3 to 5 students in each group) are required to form forensic investigation companies and identify their group leaders (CEOs). The instructor will then correspond with various teams via memos to CEOs. Each group will select a prominent construction failure, upon approval of the instructor, as the term project. Throughout the semester, they will investigate both technical and nontechnical causes that had led to failure and any ethical issues associated with the failure. Members of the team are encouraged to conduct online and offline searches, and consult with experts and the instructor as they sift through various sources of information. They will then draft a technical report describing their findings. Toward the end of semester, student groups are required to prepare either posters or PowerPoint slide presentations to present their findings to the rest of the class and the instructor.

At the end of the term, students are surveyed to determine the impact of the reference case study projects on their learning and perspectives. The questionnaire for the survey is included herein. The compilation of survey results reveal that students strongly believe failure case studies project has a significant impact on their understanding of the behavior of structures and construction details, the importance of clear communication at all levels and how the lack thereof that could lead to disastrous consequences, professional ethics, and teamwork.

REFERENCES

- [1] Matthews M. “Keeping Students in Engineering: A Research-to-Practice Brief,” American Society of Engineering Education, ASEE, Editorial: www.asee.org, February 25, 2012.

- [2] Felder Richard. et al. A Longitudinal Study of Engineering Student Performance and Retention: IV. Instructional Methods and Students Responses to Them. *Journal of Engineering Education*. 1995;82(1):15–21.
- [3] National Science Board (NSB). "Moving Forward to Improve Engineering Education," National Science Foundation Document Number NSBo7122, November 19, 2007.
- [4] Petroski H. "Look First to Failure," *Harvard Business Review*, October 2004.
- [5] ABET (Accreditation Board for Engineering and Technology), Inc., Engineering Accreditation Commission, Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 204-2015 Accreditation Cycle, Baltimore, Maryland, 2013.
- [6] ACCE (American Council for Construction Education), Standards and Criteria for Accreditation of Postsecondary Construction Education Degree Programs, San Antonio, Texas, 2013.
- [7] Meador G. "Failure by Design." Source: http://www.bps-ok.org/physics/faildes/failure_by_design.pdf, Accessed on 10 September 2014.
- [8] Delatte N. Using Failure Case Studies in Civil Engineering Education. 2000;430–440, in *Forensic Engineering*.
- [9] Adekoya A, Patel J. "The Use of Failure Case Studies to Enhance Students' Understanding of Structural Behavior and Ethics," *Proceedings of the 9th International Conference on Engineering Education*, San Juan, PR, 23–28 July 2006.
- [10] Petroski H. *Success Through Failure: The Paradox of Design*. Princeton University Press 2008:p.256.
- [11] Henshaw R. "Desirable Attributes for Professional Engineers," In: Agnew JB & Creswell C. eds. *Broadening Horizons of Engineering Education, 3rd Annual Conference of Australian Association for Engineering Education*, 15-18 December 1991, University of Adelaide, pp. 199–204.
- [12] Lang JD, Cruise S, McVey FD, McMasters J. Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers. *Journal of Engineering Education*. 1999;43–51.
- [13] Mills JE, Treagust DF. Engineering Education – Is Problem-Based or Project-Based Learning the Answer? *Australian Journal of Engineering Education*. 2003.
- [14] NAE (National Academy of Engineering). *Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press; 2004:p.119.
- [15] NAE (National Academy of Engineering). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington DC: The National Academies Press; 2005:p.209.
- [16] Delatte N, Gisemba-Bagaka's J, Roberts MW, Atadero RA, Zoghi M, Johnson P, Cavalline TL, Thompson MK. "Results from Implementation and Assessment of Case Studies in the Engineering Curriculum," *Proceedings of the 120th ASEE Annual Conference & Exposition*, Atlanta, GA, June 23–26, 2013.

One of the key assignments in this course was the case study in construction failure. The intent of this survey is to determine the impact of this project on the student's learning and perspectives:

CM 1

CONSTRUCTION MANAGEMENT ORIENTATION

CASE STUDIES IN CONSTRUCTION FAILURE QUESTIONNAIRE

Please comment on how the study has impacted (based on the rating shown in the footer):

1. Your understanding ("intuition") of the behavior of construction systems and structures.

(5) (4) (3) (2) (1)

2. Your perspectives in relation to the realization of paying attention to details both in your education and (future) professional responsibilities.

(5) (4) (3) (2) (1)

3. Your appreciation of professional and ethical responsibilities.

(5) (4) (3) (2) (1)

4. Your ability to communicate problem solutions effectively.

(5) (4) (3) (2) (1)

5. Your ability to function in multidisciplinary teams.

(5) (4) (3) (2) (1)

6. Your oral presentation and technical writing skills (based on your power point presentation and technical report).

(5) (4) (3) (2) (1)

7. Additional remarks:

Use the rating: Strongly Agree (5); Agree (4); Neutral (3); Disagree (2); Strongly Disagree (1)