Incorporating Case Studies into a Material Science Course at the United States Coast Guard Academy

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Abstract

Engineering educators are recognizing the value of case studies in preparing students to take on the complex challenges faced by engineers in the field across disciplines. Students in Mechanical Engineering and Naval Architecture and Marine Engineering at the United States Coast Guard Academy (USCGA) are required to complete a common engineering material science course. To better prepare graduates for their future role as engineers and Coast Guard Officers, the course has been evolving to incorporate material science case studies from the Coast Guard and other outside sources. This paper focuses on strategies for incorporating various case studies into the course to help cadets appreciate the importance of material science issues in the Coast Guard and in other venues. The course is normally taken in the sophomore year at USCGA, providing an excellent opportunity to get students interested in real world engineering issues early on in their education. By engaging Coast Guard engineers with current and recent field experience, numerous case studies are being developed that cover a wide range of material science applications. The goal is to have cases that highlight Coast Guard issues from the fields of marine safety, naval engineering, and aviation which are the most common career paths for graduates in the Mechanical and Naval Architecture and Marine Engineering majors. In addition, material science case studies from outside the Coast Guard will be examined to ensure that graduates have an appreciation for national and global material science challenges. By examining failures as well as successes, students will have an opportunity to consider the consequences of poor decision-making and will be able to explore ethical considerations. As case studies are incorporated, tools are being developed to assess the impact of this educational approach on student learning and motivation.

Introduction

As engineering educators continue to look for ways to make fundamental coursework more interesting and meaningful for their students, case studies have been gaining prominence. Davis and Wilcock of the University of Birmingham note that case studies help link course concepts to actual engineering, help reach students with a variety of learning styles, allow students to engage in their own learning, may enhance student interest, and can foster development of various skills such as problem solving and teamwork [1]. Researchers have also noted that the use of case studies can improve student cognitive skills [2]. Case studies have been successfully applied across disciplines and at various stages in student development. Norbert J. Delatte, Jr. has done extensive work on using case studies in engineering courses. He discusses the benefits of using case studies in introductory engineering mechanics courses as a way of showing students the practical application of material that can seem far removed from the real world as usually presented in fundamental courses. In particular, he notes the advantages of raising issues integral
to engineering practice such as decision-making, professional responsibility, and ethical considerations before students enter their upper division courses as a way of making the fundamental subjects more interesting and relevant to students. Delatte also provides helpful suggestions for integrating failure cases into courses. He suggests that the cases be clearly tied into course content, that the case history and causes of failure be described, that the problem be simplified if needed to allow students to perform calculations, and that ethical issues arising from the case be addressed. Delatte further suggests that teachers bring practicing engineers into the classroom to discuss their experiences with projects and engineering failures [3]. As educators have developed innovative methods for incorporating case studies, they also have been working on assessing the educational benefits of this teaching method. For example, researchers have discussed various methods that can be used to assess changes in cognitive learning to help gauge the effectiveness of case study use [2]. Educators in the Department of Metallurgy and Materials at the University of Birmingham have been using case studies for years. They stress the importance of assessing the impact of case studies on the overall learning experience beyond simply assessing the technical competency of their students’ deliverables. They suggest that both formal and informal assessment tools be used and they discuss several methods they have used to assess the impact of case studies on learning [1].

At the United States Coast Guard Academy (USCGA), students in the Mechanical Engineering and Naval Architecture and Marine Engineering majors are required to take an introductory material science course in the spring of their sophomore year. The course uses Material Science and Engineering: An Introduction-Seventh ed. by William D. Callister, Jr. [4] as the textbook. Until recently, the course was a survey course developed and coordinated through the Civil Engineering program. Over the past few years, the development and teaching of the course has shifted to the Naval Architecture and Marine Engineering Program. Since then, the depth of coverage has greatly increased, especially in topics of importance to the Coast Guard. The redeveloped course has also begun to incorporate case studies. As discussed above, case studies have enormous potential to reach students of various learning styles, to get students excited about becoming engineers, and to address issues beyond the technical such as ethical aspects of engineering projects. Educators are recognizing that material science and engineering courses can be a particularly good venue for case studies considering the many applications across engineering disciplines. Kathleen L. Kitto of Western Washington University points out that, because of the interdisciplinary nature of material science and engineering, introductory material science can be a challenge to teach. She has used case studies and other active learning techniques to enhance student learning and interest [5]. At the USCGA, most graduates of the Engineering Material Science course will serve either in the Naval Engineering, Marine Safety, or Aviation Programs as Coast Guard Officers. As such, the use of Coast Guard case studies from the field will help students see the relevance of their coursework and may spark enthusiasm for their chosen career at an early point in their education. This is especially important because many of these students will be involved with material science issues as Coast Guard engineers, but will have limited exposure to material science issues at the Academy after sophomore year. To emphasize the importance of material science in Coast Guard engineering, Coast Guard Officers who have been in the field recently dealing with material science issues have talked to the class about their experiences in the field. Guest lectures by Coast Guard Officers also provide an excellent venue for developing mentorships between students and practicing engineers. This paper outlines techniques being developed at the USCGA to incorporate case studies into the material science course.
Selection of Case Studies

The selection of appropriate case studies for the Engineering Material Science course considers several criteria including:

- The case must be adaptable to a level appropriate for a first materials course taught to sophomore engineers.
- Many of the cases should be related to engineering challenges our graduates are likely to encounter in the field. There should be a mix of cases using marine and aerospace applications.
- Most of the cases should support course topics and should span the range of topics covered in the course. A few cases can be used to introduce new topics that stretch the students beyond the scope of the course.
- The cases should ideally have sufficient information associated to make them meaningful topics of discovery and learning. This includes high quality pictures that illustrate the issues involved.
- Non Coast Guard cases should involve applications similar to those that students might encounter in the field.
- Cases should incorporate ethical issues.

The main sources of case information have included reports available online and through Coast Guard contacts, the *Journal of Failure Analysis and Prevention* [6], the journal *Engineering Failure Analysis* [7], as well as other books and journals.

Incorporation of Case Studies

Two major techniques are being used to deploy the case studies. First, Coast Guard Engineers visit the classroom to present cases directly to the students. In spring 2010, four Coast Guard Officers presented cases and each had one half of a 50-minute class period to present and engage the cadets in discussion. The Officers included a Commander from the aviation program who has been involved in material science issues with aircraft, two Lieutenant Commanders who have served in the marine safety program inspecting commercial vessels, and a Lieutenant Commander who has been involved with investigating material science issues for Coast Guard cutters. Each guest speaker had a unique way of presenting their case and engaging the cadets.

The second method of incorporating case studies in spring 2010 has been to assign a case to groups of three students. Each group received background material on their case and was asked to research the case and prepare a presentation for the class including: case background, a description of the failure or issue, an explanation of the material science theory involved in the case (either expanding on class material or exploring a new topic area), presentation of data and results of the case, and conclusions and recommendations that they found in reports plus their own insights into the case. To the extent possible, cases were assigned to groups based on student interest. The cases used in spring 2010 are outlined in Table 1.
Table 1: Case studies assigned to student groups – Spring 2010.

<table>
<thead>
<tr>
<th>Type of Case Study</th>
<th>Brief Description of the Case</th>
<th>Related Materials Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space</td>
<td>Cracking of an Al alloy nozzle weld in a propellant storage tank.</td>
<td>Welding, Stress-Corrosion Cracking</td>
</tr>
<tr>
<td>Aviation</td>
<td>Creep-fatigue failure of jet engine turbine blades.</td>
<td>Creep, Fatigue</td>
</tr>
<tr>
<td>Aviation</td>
<td>Failure of an aircraft propeller assembly.</td>
<td>Stress-Corrosion Cracking, Fatigue, Corrosion</td>
</tr>
<tr>
<td>Aviation</td>
<td>Nose strut fracture - USCG Falcon</td>
<td>Fatigue, Processing Problems</td>
</tr>
<tr>
<td>Land-Based Turbine</td>
<td>Failure of a gas turbine last stage bucket.</td>
<td>Corrosion, Creep, Fatigue</td>
</tr>
<tr>
<td>Land-Based Turbine</td>
<td>Failure of a feeder-line on a land-based turbine.</td>
<td>Corrosion, Fatigue, Welding</td>
</tr>
<tr>
<td>Ships</td>
<td>Failure of wet liners in maritime diesel engines.</td>
<td>Fatigue, Corrosion</td>
</tr>
<tr>
<td>Ships</td>
<td>Boiler rupture on the SS Norway.</td>
<td>Corrosion, Fatigue, Welding</td>
</tr>
<tr>
<td>Ships</td>
<td>Hull fracture on bulk carrier.</td>
<td>Ductile to Brittle Transition</td>
</tr>
<tr>
<td>Ships</td>
<td>Structural failure of tank barge.</td>
<td>Ductile to Brittle Transition</td>
</tr>
<tr>
<td>Ships</td>
<td>Failure of a stainless steel sailboat propeller shaft.</td>
<td>Fatigue, Stress-Corrosion Cracking</td>
</tr>
</tbody>
</table>

Alignment with Educational Outcomes and Program Educational Objectives

The USCGA has developed Program Educational Objectives (PEOs) and Educational Outcomes at the departmental and program level. Each course contributes to student achievement in a variety of outcomes and helps us achieve PEOs that embody the skills and competencies we would like our graduates to demonstrate several years after graduation. Case studies have the potential to contribute in a number of areas. As the case studies are fully incorporated, assessment tools will be developed for applicable outcomes and related performance criteria. The PEOs for engineering programs at the USCGA are as follows.

The U.S. Coast Guard Academy Engineering programs produce graduates who:

1. Are prepared for professional practice in engineering positions as U.S. Coast Guard junior officers.
2. Are prepared for a variety of U.S. Coast Guard career paths, based on their abilities to apply fundamental engineering principles in a dynamic technological environment.
3. Have the ability and a desire to continue to grow intellectually and professionally.

In addition:

- The Mechanical Engineering program produces graduates who are prepared to contribute to the safe design, construction, repair, and operation of Coast Guard related mechanical engineering systems.
- The Naval Architecture and Marine Engineering program produces graduates who are prepared to assume responsibility for the safety, operation, maintenance, logistics, design, and repair of ships and boats.
Case studies are likely to help develop cadets in ways that contribute to achieving PEOs after graduation. Exposure of cadets to actual cases in the Coast Guard presented by officers in their future career paths has a potential to contribute to their achievement of PEO 1 and PEO 2 once they are in the field as Coast Guard Engineers. By choosing cases from programs the graduates of the Mechanical Engineering and Naval Architecture and Marine Engineering majors are most likely to serve in, there is also support for the program specific PEOs listed above.

In addition to the PEOs, the USCGA Engineering Department prepares students to achieve a set of outcomes that represent the skills and competencies we prepare our students to achieve by graduation. These are basically ABET a-k outcomes with minor modifications. Although, the Engineering Material Science course is completed in the sophomore year, the use of case studies has the potential to contribute to a number of these outcomes. Case studies could be especially useful with outcomes that are difficult to achieve and assess using more traditional pedagogical methods. Case studies, as they are being developed and used in the Engineering Material Science course, may be particularly well suited to contribute to the following outcomes:

- an understanding of professional and ethical responsibility
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues
- the knowledge, skills, abilities and characteristics that will permit (graduates) to continue to develop as successful leaders in the Coast Guard

**Assessment of Learning and Motivation**

A grading rubric was developed to assess the case study projects. Grading criteria include an outline submitted as a preliminary deliverable, technical content/accuracy, use of visual aids, organization, and presentation quality. In addition to assessing technical understanding and the ability to apply concepts from the course, assessment tools are being developed to gauge the impact of case study use on achieving various educational outcomes and on student motivation and interest in the subject matter. A review of the literature will help inform the course surveys and other assessment tools under development. To date, informal student feedback during this first year of full case study implementation has indicated that students are enjoying learning the cases and that case studies have sparked interest in material science applications in the Coast Guard. By the end of the spring 2010 semester more formal feedback will be available.

**Conclusions and Recommendations**

The transformation of a sophomore level material science class at the USCGA from a survey course to one that incorporates case studies related to student career paths is well underway and has the potential to increase student interest, better prepare cadets for eventual service as engineers in the U.S. Coast Guard, and contribute to a variety of educational outcomes both technical and non-technical. The classroom involvement of Coast Guard Officers with field experience provides a venue to foster mentoring and student enthusiasm for their chosen career.
path. The development and deployment of assessment tools will help establish the benefits of using case studies and will identify areas for improvement in future course offerings.

To date informal feedback from students is extremely positive and indicates that case studies have a potential to increase student interest and engagement. Spring 2010 marks the first time the case studies have been fully incorporated into the course. As such, the instructors have been noting potential areas for improvement and refinement of the new pedagogical approach. A more formal assessment will no doubt provide other useful ideas for future semesters. Some areas for improvement noted to date include:

- Use case studies to introduce learning units of the course as a way to draw student interest and demonstrate the reason for learning each topic.
- The course instructors should constantly work on finding case studies for the course and simplifying the material as needed.
- The instructors need to expand their tentacles further into the Coast Guard and the general engineering community to discover the most appropriate cases and to develop a bank of cases that cover a range of topics of interest to the students.
- The instructors should provide more time for guest lecturers to present and discuss cases. Splitting a 50-minute lesson between two speakers was inadequate in spring 2010.
- Develop cases and teaching modes that emphasize the non-technical aspects such as ethics issues.
- The case study method should be considered for incorporation into other basic courses including Mechanics of Materials. This would open the potential topic areas to an even broader scope to support all three mechanics based engineering majors at the USCGA.

With a sustained effort on behalf of faculty and Coast Guard Engineers to identify and incorporate case studies into courses such as Engineering Material Science, engineering graduates of the USCGA should be better prepared and more motivated to serve the nation as engineers in the U.S. Coast Guard.

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References:


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