Semester-Long Project of a Part Failure for Freshman Students in Mechanical Engineering Technology

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Introduction

Freshman Mechanical Engineering Technology (MET) students typically have very little engineering knowledge or experience to complete a part failure project, so it is difficult to develop an assignment for them to complete that will be interesting, academic level appropriate, and achievable. Another challenge is to use varying topics of the course to coincide with the completion of the project.

This paper presents how a semester-long project of a part failure for freshman MET students was implemented into a Manufacturing and Materials course. At the beginning of the semester, students were assigned the task of acquiring an everyday part that had failed under normal operating conditions and to use it as the subject of a paper that is collected at the end of the semester. The paper was to include the name and application of the part, material of the part, description of the reason and type of failure of the part, how the part was manufactured, and recommendations for how the failure could be prevented in the future. Students were provided the guidelines for the assignment, the paper format, and the grade sheet that would be used for the paper.

The project has proven to be rewarding and challenging to both the student and the instructor. Also, the project provides other benefits that greatly help to measure achievement of ABET outcomes [1]. The student outcomes used were based on the ABET Criterion 3 “a through k” in use at the time of the project: ability to apply knowledge to engineering technology activities, ability to conduct standard tests, ability to function as a team member, ability to apply written communication and use appropriate technical literature, and a commitment to quality and timeliness. The mechanics of the project are discussed in this paper in addition to student feedback about the assignment.

Background

A Manufacturing Materials and Processes course is taught to freshman MET students. It is comprised of two hours of lecture and two hours of lab per week. During lecture, topics like manufacturing processes, part failure and product improvement to prevent failures are discussed. The labs reinforced these topics with hands-on activities. Most students were happy with the how the course was conducted and felt that it was a good learning experience. The instructor concurred with the students in thinking that it was a valuable learning experience; however, the disassociation of the topics nevertheless left the instructor with the impression that more needed to be done to bring those topics together to make for a much more valuable learning experience. A new semester-long assignment was developed to integrate those topics.

Assignment

The goals of this assignment included the following:

- Students will acquire a better understanding of manufacturing processes.
- Students will acquire a better understanding of part failure methods.
- Students will acquire a better understanding of failure prevention.

As mentioned in the introduction, students needed to acquire a part that had failed and identify the general conditions that led to the failure of the part. Students could obtain the part by different methods: the student may have had first-hand experience with the failure of the part or the student's friends or family members may have had a part that failed. The part was expected to be a discrete part and not an assembly because failure analysis of an assembly complicates the project. Also, the part should be as common as possible. Some example parts that have been used include: plastic coat hangers, plastic cookware, impact sockets, chisels, plastic closet supports, and motorcycle sprockets. The failure was required to be a service failure and not a manufacturing, inspection, or test failure. Students were required to write the project paper in teams of two to three students. Students could obtain the failed part from any source; however, all work performed must be performed by the student team. The students were required to obtain approval from their instructor before starting their project by presenting their part to their instructor during his/her office hours. Once the student's project topic was approved, the instructor provided the student with a grade sheet.

Only one project paper was required per team. The students needed to divide the tasks of completing the paper among each other. The paper was expected to contain the following information:

- Name of the part and application of the part.
- Material of the part. The student may or may not know the type of material. They are to determine as best as they can from the testing they perform. This means that a lab session must be reserved for students to perform part testing.
- Once the students determine the type of material, they need to defend their decision with sound engineering logic and with the results of their testing. Their testing results are to be compared and matched to material data from matweb.com. Students were also graded on their ability to organize their data.
- Students were to describe the type of failure the part underwent: impact, tensile, fatigue, compression, shear, creep, or vibration. Also, students were to determine whether the part suffered a brittle fracture or ductile fracture.
- Students were to describe the manufacturing process or processes employed to create the part.
- Students were to discuss how to prevent the failure from occurring again (e.g. suggest a new material, a different type of alloying agent, increase the cross-sectional area, heat treatment).
- Students were to create a solid model or working drawing of the part.
- Students were to include a teamwork assessment.

Grading

The paper was worth 100 points. The criteria for grading are summarized in table 1:

Table 1: Grading criteria for Project

Grading Criteria	Points
Cover Page	5
Table of Contents	5
Summary	5
Page Numbers	5
Bibliography	5
Name and Application of the part	10
Material of the part	10
Describe the type of failure the part underwent	15
Manufacturing process or processes employed to create the part	10
Tests performed to verify the current material of the part	10
Defend current material or suggest a new material	10
Working Drawing and Solid Model	10
Total	100

Student Feedback

Students were surveyed to gain insight on their thoughts about the project. All twenty-four students from the previous semester completed the survey. While the assignment has been run for years, the data was from the last year that the assignment was performed. The following shows the survey questions and the students' responses:

1. Q: The project was interesting?

   Student Response: Likert Scale 6.3/7.0
2. Q: The level of complexity of the assignment was adequate for this course?

   Student Response: Likert Scale 6.1/7.0
3. Q: You feel that this assignment should be included in this course for future students?

   Student Response: Likert Scale 6.3/7.0
4. Q: What changes would you make to the assignment?

   Summary of student responses: Most often stated was that there should not be any changes. Other suggestions included working as individuals and not in teams.
5. Q: You enjoyed the challenge of the assignment?

   Student Response: Likert Scale 6.0/7.0

6. Q: Comment on the assignment (i.e. level of adequacy, interesting, informative, etc...).
   Summary of student responses: Interesting and feel that the information and knowledge gained will be used in the future.
7. Q: Did you get the grade you thought you were going to receive?
   Student Response: Likert Scale 7.0/7.0
8. Q: If you did not get the grade you thought you were going to get on the assignment, why do you think you didn't?
   Summary of student responses: Students overwhelmingly stated that the assignment was appropriately graded. Not one student felt the grading was not adequate or inappropriate.

Another benefit of this assignment is its usefulness in assessing the ABET student outcomes.

The only negative to the assignment is that the grading is quite time consuming depending on the number of students. Allowing more students per team has been considered as a way to reduce the grading load.

Outcome Assessment and Rubrics

The value of formative assessment is described in works such as [2] and [3], Formative assessment of the following ABET student outcomes could be achieved with this project:

(f.) An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;

(i.) a commitment to quality, timeliness, and continuous improvement.

To facilitate this formative assessment, the program adopted the use of developmental rubrics as described in works such as [4] in its Mechanical Engineering Technology (MET) programs. Since the program's institution offers both two-year (Associate's) and four-year (Bachelor's) degree programs, the developmental rubrics were created in a "cascading" format to reflect the continuum of outcome development that students could expect by matriculating from the two-year program into the four-year.

The program's outcome assessment rubrics for these two outcomes are shown here as tables 2 and 3. Note how the "Developing" achievement level for the four-year (BS) degree coincides with the "meets expectations" achievement level for the two-year (AS) degree, and "exceeds" for the (AS) degree coincides with the "meets" level for the (BS) degree. Also, note that the program has internally re-lettered these outcomes as "G" and "K," respectively, to allow the use of the developmental rubric in a seamless fashion for both the AS and BS degree offerings.

Table 2: Assessment Rubric for Outcome G

	Performance level			
	Developing (AS)	Meets Expectations (AS)	Exceeds Expectations (AS)	
Performance Indicator		Developing (BS)	Meets Expectations (BS)	Exceeds Expectations (BS)
1. Ability to apply written, oral, and graphical communication in technical environments	Technical communications have little content that distinguishes them from that for a general audience.	Technical communications include properly labelled graphics & CAD drafting & design, geometric dimensioning & tolerancing	Technical communications properly employ drawings, graphs, charts, & equations suitable for audience.	Technical communications exceptionally clear & concise: advance knowledge beyond classroom content
2. Ability to apply written, oral, and graphical communication in non-technical environments	Non-technical communications are poorly organized and presented, difficult to comprehend.	Non-technical communications are well-organized, grammatical, and avoid jargon. Graphics easily understood by non-technical reader.	Non-technical communications are well-organized, grammatical, and avoid jargon. Graphics easily understood by non-technical reader. Both communicate content from BS level.	Non-technical communications exceptionally clear, explain engineering topics from across the curriculum to non-technical or non-college audience.
3. Ability to identify and use appropriate technical literature	Technical communications limited to popular or introductory sources.	Technical communications use textbook content, basic familiarity with industry codes, specifications & standards	Technical communications identifies and uses thorough application of industry codes, specifications, and standards.	Technical communications identifies & incorporates journal article results, patent research, or novel techniques.

Table 3: Assessment Rubric for Outcome "K"

	Performance level			
	Developing (AS)	Meets Expectations (AS)	Exceeds Expectations (AS)	
Performance Indicator		Developing (BS)	Meets Expectations (BS)	Exceeds Expectations (BS)
1. Commitment to quality	Implementation of quality in processes, products, or services motivated by personal understanding.	Implementation of quality incorporates customer's criteria for cost, strength, finish, or weight considerations.	Implementation of quality incorporates customer's criteria and includes system integration, failure criteria such as FMEA, service life, or life-cycle cost	Able to develop definitions of quality in novel or unique situations; can apply criteria to multiple customers with differing definitions
2. Commitment to timeliness	With guidance, able to follow Plan of Action & Milestones (POA&M) for multi-step projects	Able to follow own POA&M for multi-step processes, and hold oneself to it.	Able to follow POA&M in a team environment for multi-step processes, and help keep team on track.	Able to maintain POA&M in dynamic team environment with changing deadlines, iterative processes, and evolving requirements.
3. Commitment to continuous improvement	With guidance, can apply test results to make design changes to improve quality	Able to interpret test results to improve quality in areas of cost, weight, strength, or finish.	Able to interpret test results to improve quality in areas of system integration, failure mode, service life, and life-cycle cost	Able to design and implement novel test procedures to measure quality or use results to return design changes that exceed customer's definition of quality

Results:

Three samples of scored student work were assessed using the outcome assessment rubrics shown in tables 2 and 3. These works were selected to be representative of "excellent," "average" and "marginal/poor" student performance, and represent the work of a total of twelve students, with numbers in each group ranging from three (marginal/poor) to five (excellent). Results of this assessment are shown in table 4. For each outcome, performance indicators are numbered to correspond to those shown in tables 1 and 2. Each box indicates the level of achievement using the scale "D" (Developing), "M" (Meets expectations) and "E" (Exceeds expectations) as assessed on the Bachelor of Science scale. The notation "D-AS" indicates work that is at or below the "Developing" level for Associate's Degree students. Insufficient data to assess is indicated by "N/A."

Table 4: Assessment results

		Outcome G			Outcome K		
	Perf. Indicator	1.	2.	3.	1.	2.	3.
Student group	Excellent	D	D	D	N/A	D	D
	Average	D	D	D	N/A	D	D
	Marginal/Poor	D-AS	D	D	N/A	D	D-AS

Conclusion:

Based on the work performed by the students and the student feedback, the assignment was found to be very appropriate and rewarding for the students. From the instructors perspective, the papers are sometimes laborious to grade because of the freshman-level technical writing skills. It is very rewarding to see students engaged with an assignment and with other students.

The limited assessment data returned results that were largely as expected. While the scores on the assignment ranged from excellent ("A" level work) to Marginal/Poor (borderline failing), the assessment results largely indicated results at or near the "Developing" level for bachelor's degree students. Indeed, for a freshman-level course, it would be unusual to discover students that had a ready-for-graduation level understanding of engineering content at this early stage in their education. The only difference was evident with the marginal group, which suffered from an inability to present its written work in a manner substantially different from that suitable for a general audience. It is also perhaps unsurprising that this same group assessed the lowest in terms of time management skills. While the program has not yet been able to use this assignment as a source of data to assist with the formative assessment of outcomes G and K as described in [5], the rudimentary results obtained to date hint a possible issue with the level of preparation that engineering technology students have in the areas of communications and time management—skills not necessarily explicitly addressed in the programs course of study. More detailed assessment would most likely require the creation of a new rubric with finer increments of outcome achievement between the various performance levels (Developing, Meets Expectations, Exceeds, etc.), to resolve differences of student outcome achievement in a course of this nature.

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