

AC 2008-400: MODERN TOOLS AND TECHNIQUES FOR TEACHING MANUFACTURING ENGINEERING IN THE DIGITAL AGE

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Modern Tools and Techniques for Teaching Manufacturing Engineering in the Digital Age

1. Background

The hypothesis presented in this paper is that within the contemporary teaching – learning environment, the students are to be perceived as *customers*, and in a consumer-driven market, customers are gods. The educator is expected to identify and satisfy students' needs, treat them well, provide service, and above all, communicate with them! Their language is not English, Spanish, French, Arabic, Chinese, or Hindi. They have a common, global language in this flattened world—it is called the *Digital* language. It's the language that they and their machines understand and thrive on. And, therefore, if you don't understand the digital language or don't employ it, you have lost them. You are frustrated and the customers are dissatisfied. So, what do these customers need? They want things to happen rapidly—at the click of the mouse! They want to be in the driver's seat as they explore the unknown. They want to control the time, place, and speed of their learning. They want to be significant partners in their learning process. They mainly learnt through the interaction with machines and men. They know the world is a complex network of different objects and issues. They want the teaching to reflect this complex connectivity. They are not happy with a linear lecturing process. They want the things they interact with to be friendly, colorful, multitasking, and efficient. They simply cannot stand a monologue of a lot of words! That is just not their thing! The only way to satisfy their needs is to master their digital language and incorporate it in your thinking, talking, teaching, and testing^{1, 2)}.

By realizing these changing student expectations, the teaching methods at the author's institution are being overhauled over the past three years in almost all engineering courses. This paper describes the efforts made by the author in the four core courses within the Manufacturing Engineering major: Engineering Materials, Production Engineering, Fundamentals of Manufacturing Engineering and Product and Tool Design. Various digital tools (available free or for charge) are surveyed and some of them, as given in the paper, were incorporated in teaching. The effectiveness of the changes made in the teaching methods is demonstrated *via* ABET outcomes assessment and student instructional surveys.

2. Course Descriptions

The courses covered in this paper are briefly described as follows. Applicable ABET outcomes and track-specific outcome for these course are also given as follows.

Engineering Materials (Sophomore Year Fall Term): The course content includes an examination of engineering materials such as metals, plastics, ceramics, and composites with an emphasis on material selection. Processing for the optimization of material properties is covered extensively, as is material cost estimation for manufacturing. Applicable ABET Outcomes are: 1, 2, 4, 5, 7, and 11. Applicable Track-Specific ABET Outcomes are: M1 and M5. The definitions of the applicable ABET outcomes are given for quick reference at the end of this section.

Production Engineering (Junior Year Fall Term): This course presents the techniques of production engineering and fundamental manufacturing process concepts, at an introductory

level. Methods of production are introduced, and productivity improvement methods are explored with an emphasis on quality, efficiency, and product cost. Basic metrology principles are also introduced. Applicable ABET Outcomes are: 1, 3, 5, 7 and 8. Applicable Track-Specific ABET Outcomes are: M2 and M4.

Fundamentals of Manufacturing Engineering (Junior Year Spring Term): This course is an introduction to the discipline of Manufacturing Engineering. The role and function of the manufacturing engineer are introduced in the context of the production, inspection, quality control, and enterprise environments. Manufacturing engineering methods, techniques and algorithms are introduced, and engineering ethics issues are also discussed. Applicable ABET Outcomes are: 1, 2, 3, 4, 5, 7, 8, 9, and 11. Applicable Track-Specific ABET Outcomes are: M1, M2, M3, and M4.

Product and Tool Design (Junior Year Spring Term): This course provides an introduction to product design issues including design for manufacturing and assembly, the producibility index, process planning and tolerance selection. The course also covers the design and engineering of jigs, fixtures, and tooling used in various manufacturing and inspection processes. Applicable ABET Outcomes are: 1, 3, 4, 5, 7 and 11. Applicable Track-Specific ABET Outcomes are: M1, M2 and M3.

ABET Outcomes are: Engineering graduates have (1) an ability to apply knowledge of mathematics, science and engineering, (2) an ability to design and conduct experiments, as well as to analyze and interpret results, (3) an ability to design a system, component or process to meet desired needs, (4) an ability to function on multi-disciplinary teams, (5) an ability to identify, formulate and solve engineering problems, (6) an understanding of the professional and ethical responsibilities, (7) an ability to communicate effectively, (8) the broad education necessary to understand the impact of engineering solutions in a global societal context, (9) recognition of the need for, and an ability to engage in life-long learning, (10) a knowledge of contemporary issues, (11) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice

Manufacturing Engineering Track-Specific ABET Outcomes are: Engineering graduates have (M1) proficiency in materials and manufacturing processes, understand the influence of manufacturing processes on the behavior and properties of materials, (M2) proficiency in process, assembly and product engineering and understand the design of products and the equipment, tooling, and environment necessary for their manufacture, (M3) appreciate the necessity for manufacturing competitiveness and understand how to create competitive advantage through manufacturing planning, strategy and control, (M4) ability to design manufacturing systems through the analysis, synthesis and control of manufacturing operations using statistical or calculus based methods, simulation and information technology, (M5) had laboratory experience, which enable them to measure manufacturing process variables and make technical inference about the process

3. A Survey of Digital Resources

The following section summarizes some of the important digital resources that were incorporated in teaching the manufacturing courses listed in Section 2.

3.1 Materials Engineering

The following is a list of innovative ideas that are in-tune with the contemporary teaching – learning environment and that add value to materials education³⁾. These ideas include the following:

- Using multi-media resources such as educational videos and recorded interviews to give an overview of the materials world. For example, a compact disk made by Struers (Struers is a major manufacturer of metallurgical laboratory products, see www.struers.com for more information) presents the history of materials evolution right from the pre-historic times to the present age. In addition, computer simulations on various topics such as solid solubility of carbon in steel, diffusion, and dislocation motion provided on the instructor's resources compact disk (IRCD) for Callister's textbook were shown and discussed.
- Accessing the Internet to obtain freely-available materials information and simulation programs; e.g., MATTER project in UK (www.matter.org.uk). The web site contains information, property data, application notes, on-line experiments, and case studies on a number of industrially-significant aluminum and ferrous alloys. The students were asked to explore this website and subsequently take a quiz (also available on the same website) during one of the laboratory sessions.
- Alliance for Innovative Manufacturing at Stanford University: How Everyday Things Are Made? (<http://manufacturing.stanford.edu/hetm.html>)
- CES Materials Database⁴⁾
- The History Channel (<http://www.history.com/>)
- Manufacturing Engineering Resource Center Online (<http://www.merconline.net/>)
- The Minerals, Metals and Materials Society – TMS, Digital Resources Center, (<http://materialstechnology.tms.org/TECpage.asp>)

3.2 Production Engineering

The Society for Manufacturing Engineering SME (<http://www.sme.org/cgi-bin/getsmepg.pl?/new-sme.html&&SME&>), the History Channel and the Instructor's Resource CD from the textbook all have made available a series of videos to demonstrate important manufacturing processes in action. These videos include the following:

- Concept Modeling – covers new techniques in rapid prototyping (SME)
- Fundamentals of Plant Layout – a set of three VHS tapes – covers important topic of designing a factory layout based on manufacturing process type (SME)
- History Channel: Modern Marvels: Machine Tools – an excellent DVD record of the evolution of basic machines (lathe, milling, shaping, planning, sawing, grinding, punch press, drill press)

- M. P. Groover's book includes a CD that has short and succinct video clips covering dozens of manufacturing processes

3.3 Fundamentals of Manufacturing Engineering

The Society for manufacturing Engineers and the Manufacturing Engineering Resource Center on-line have made available an incredible amount of digital resources to enrich education in this overview course. Some of these resources employed in teaching and that have worked out well with the student are listed as follows:

- Layout improvements for Just-In-Time (JIT)
- Success Factors for Manufacturing (Airborne, Nucor, Toyota)
- Factory Makeover
- Lean Supply Chain
- Understanding Manufacturing Costs
- Lean Manufacturing
- Failure Mode, Effects and Criticality Analysis (FMECA)
- Supplier Development
- Lean Six Sigma
- Work Measurement
- Flexible Materials Handling
- Case studies presented in a CD accompanying Stevenson's textbook

3.4 Product and Tool Design

The digital resources for this course were obtained from internet as well as from SME as given below.

Some of the internet resources are:

- Textbook companion website: www.ulrich-eppinger.net
- <http://www.consumerreports.com>
- National Bureau of Standards
- Patents
- Census Data
- www.baddesigns.com (demonstrates common design errors)

The video resources employed in teaching are:

- Failure Mode, Effects and Criticality Analysis (FMECA)
- Design for Manufacturing
- Design for Assembly
- What is an Idea?
- Ergonomic Safety

4. Implementation and ABET Outcomes Assessment

These digital resources were incorporated into teaching over the past two years during Spring and Fall semester as appropriate. The student response was found to be enthusiastic. This section summarizes the ABET outcomes assessment for all of the courses being considered here.

ABET outcome assessment for ENGR 2180 is shown in Figure 1.

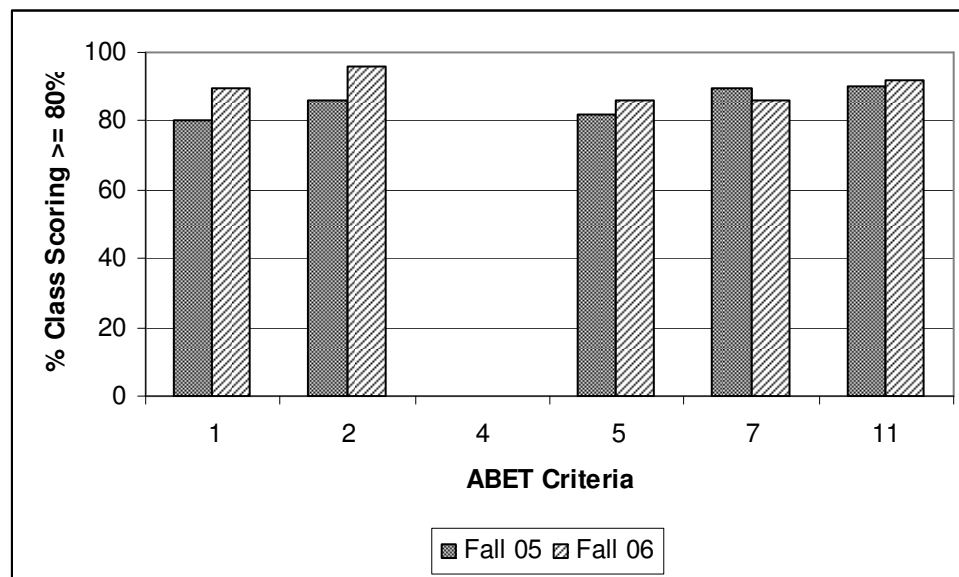


Figure 1: Class performance in ENGR 2180 with respect to ABET outcomes. (The current benchmark for class performance is 80%).

It is noted that outcome #4 was not assessed in both the terms and therefore no data is available for this outcome.

The ABET outcome assessment for ENGR 3600 is shown in Figure 2.

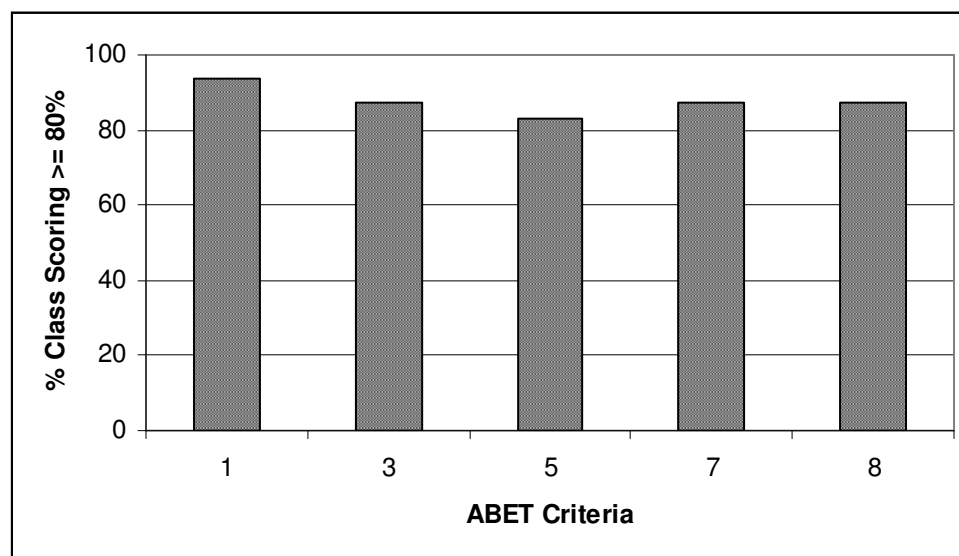


Figure 2: Class performance in ENGR 3600 with respect to ABET outcomes. (The current benchmark for class performance is 80%).

The ABET outcome assessment for ENGR 3610 is shown in Figure 3.

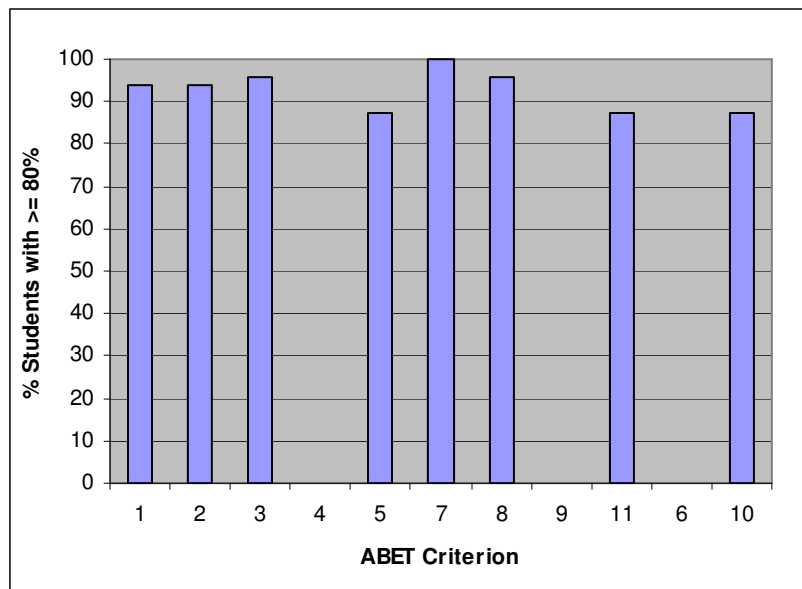


Figure 3: Class performance in ENGR 3610 with respect to ABET outcomes. (The current benchmark for class performance is 80%).

Outcome #10 was not listed as an expected outcome, but was actually covered and assessed during the course. Based on this, the list of outcomes for ENGR 3610 will be modified in future. The ABET outcome assessment for ENGR 3650 is shown in Figure 4.

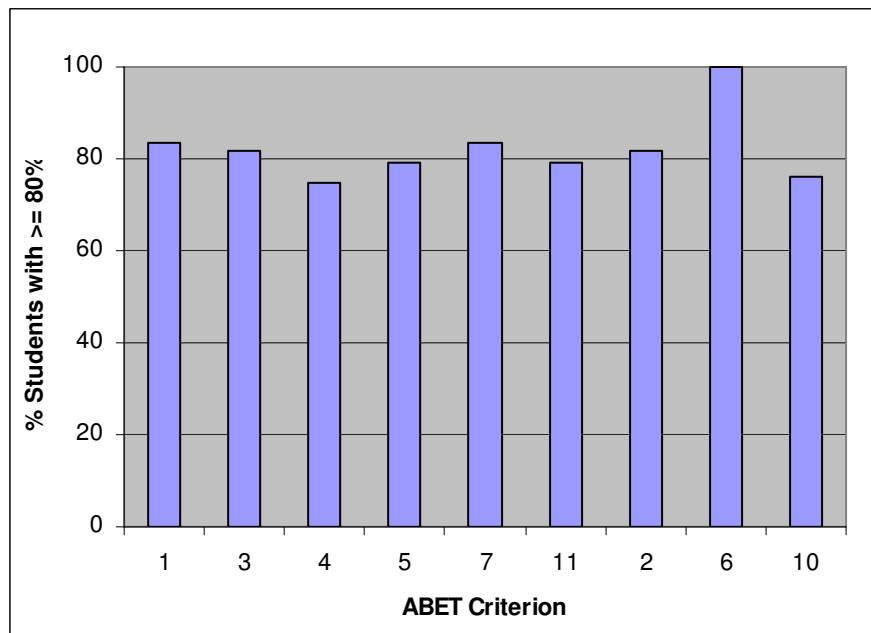


Figure 4: Class performance in ENGR 3650 with respect to ABET outcomes. (The current benchmark for class performance is 80%).

Outcomes #2, #6, and #10 were not listed as expected outcomes, but as it turned out these outcomes were actually covered and assessed during the course. Based on this, the list of outcomes for ENGR 3650 will be modified in future.

The ABET outcomes assessments met the benchmark for ENGR 2180, 3600 and 3610. The outcomes assessment for ENGR 3650 demonstrated that Outcomes 4, 5, 10 and 11 require additional specific actions such as assigning multi-disciplinary projects, develop more familiarity with the available manufacturing equipment through lab sessions within this or other courses, and so on to close the loop.

5. Student Feedback

The end-of-term student satisfaction survey was conducted using *Student Instructional Report II* (SIR II). The survey is analyzed and a third party issues reports based on the survey data. These data given in Table 1 clearly shows that the students felt that they learned more and their interest level and knowledge increased significantly during the term.

Table 1: Selected survey items from SIR II report from the most recent Spring and Fall terms.

Item	ENGR 2180	ENGR 3600	ENGR 3610	ENGR 3650
Course Organization and Planning	3.97	4.63	4.50	4.62
Faculty / Student Interaction	3.75	4.34	4.64	4.38
Effectiveness of Student Assessment Tasks	3.63	4.40	4.65	4.58
Course Outcomes (interest, learning, knowledge)	3.53	4.03	4.10	3.94
Use of Supplementary Teaching Tools	Effective	Effective / V/effective	Very Effective	Very Effective
Overall Evaluation	3.75	4.57	4.50	4.30

6. Summary

The emerging communication technology has influenced the students' learning patterns to such an extent that the instructors need to take notice and modify their teaching tools. It is proposed that the teaching – learning environment could be enhanced, enriched and made more effective by incorporating digital technology as an integral part of the teaching methods. The various digital resources incorporated into teaching a set of courses in Manufacturing Engineering major are listed. The effectiveness of these resources and the new teaching method is demonstrated *via* ABET outcomes assessment and student feedback survey.

References

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