2006-381: THE INTRODUCTION OF ENVIRONMENTAL AND INDUSTRIAL HEALTH AND SAFETY ISSUES AND EMERGING TECHNOLOGIES IN A BEGINNING MANUFACTURING PROCESSES COURSE

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Abstract

Introductory courses pertaining to manufacturing processes have traditionally been included in the curriculums of associate and baccalaureate programs in mechanical engineering technology. The majority of these courses emphasize such topics as forging, rolling, casting, welding, and machining, among others. While these courses typically provide an outstanding foundation in the particular subject area and process mechanics, many have not included any significant coverage in the areas of environmental management or industrial health and safety. In addition, non-traditional areas such as clean room manufacturing, green manufacturing, or nanomanufacturing have not been typically covered appropriately, if at all, in the majority of undergraduate technology programs.

Undoubtedly, it can be argued that any of these before mentioned manufacturing processes, both traditional and emerging, could present adverse conditions to worker health and safety as well as potential detriments to the environment. Conventional wisdom would lead one to believe that an engineering technology professional, well-versed in the environmental and occupational regulations in these types of manufacturing environments, would have a competitive advantage over those with little to no background. Thus, it could easily be argued that subject matter content in these courses should be modified to include an appropriate coverage of these topics.

Recently, a successful attempt was made to introduce environmental, health, and safety issues and non-traditional manufacturing processes to mechanical engineering technology undergraduate students in a beginning manufacturing processes course. The relative environmental, health and safety aspects of each particular process was discussed during the traditional lecture(s) as well as during an individual lecture prepared specifically on environmental, health, and safety issues pertaining to manufacturing. In addition, an effort was made to emphasize these important issues during the scheduled laboratory time of the course. Future efforts include the addition of formalized lab modules to complement course lectures.

Introduction

The manufacturing processes associated with heavy industry have traditionally contributed detrimentally to the overall health and well-being of factory workers exposed to various contaminants during a normal work shift [1-5]. These processes produce airborne toxins that many times exceed the worker permissible exposure limits allowed by current occupational standards. Since the societal pressures for the products created by heavy industries is expected to increase well into the future, it only makes good sense to adopt a

successful strategy for protecting potentially overexposed individuals employed in these occupations.

The majority of undergraduate curricula in mechanical engineering technology (MET) have at least one lower-division course in manufacturing processes, with the main impetus being the Accreditation Board for Engineering and Technology's (ABET's) accreditation criteria for technology programs [6]. While many of these courses do an outstanding job of covering the processes used in heavy manufacturing, traditionally there has been little emphasis put on the associated health and safety issues resulting from their usage. In essence, the typical course subject matter might thoroughly elucidate many of the advantages and disadvantages, engineering aspects, economics, etc. of a particular process without mentioning its potential for long-term, adverse influences on the environment and human health.

The need to integrate environmental/human impact subject matter into undergraduate curriculums in either engineering or engineering technology has become increasingly important over the last decade or two [7-10]. It is of popular opinion that it only makes good sense to promote ethical and professional responsibility with respect to human health issues and environmental stewardship early on in higher education and several years before an individual enters the work force on a full-time basis. A lower-division manufacturing processes course could provide a viable venue to introduce this important topic.

The purpose of this paper is to describe the integration of environmental and industrial health and safety (EIHS) issues into the curriculum of an undergraduate manufacturing processes course. The approach involves addressing EIHS, not as a distinct course item, but instead as a constant theme running the course of a complete semester. The assessment of the outcomes was conducted on the basis of comparisons made between student performances on EIHS test questions with those of other process-specific questions. The paper concludes with suggestions for future efforts for the inclusion of additional lab modules on clean and green manufacturing concepts in manufacturing processes coursework as well as in other undergraduate mechanical engineering technology offerings.

Methods

EIHS issues were introduced during the Fall Semester of 2004 in Purdue University's MET 142 "Manufacturing Processes I" and have been included for two subsequent semesters. The student make-up of this course is approximately fifty percent freshman, with the other three classes sharing the remainder of the open slots during a typical semester. The course has a required lab component of one hour and fifty minutes per week, which primarily stresses the concepts of casting, welding, and polymeric processes. The lecture meets twice per week for a total of one hour and forty minutes and emphasizes the same material as does the lab but, in addition, includes hot forming and powder metallurgy concepts. The Fall Semester typically has an enrollment of thirty-two students while the Spring Semester normally has one hundred twenty-eight students.

An effort was made to include environmental and human impact subject matter while discussing the different types of processing. While it could be argued that spending too much time on this aspect of the manufacturing process could take away from the gist of the introductory manufacturing processes course, the manner in which it is presented (i.e., concurrently) does not significantly change or eliminate any of the essential subject matter. As an example, during the discussion on casting, energy use concerns were first addressed by comparing and contrasting the various types of casting and the merits of choosing one over another when it comes to potential impact of human health and the environment. Further, the chosen casting procedure was then compared and contrasted with other manufacturing processing techniques and a justification was made. It is estimated that the new topics only make up about 3-5% of the total course subject matter.

One course activity involved a homework assignment that required the students to determine the impact of choosing one type of polymeric material, with associated processing technique, over another. The students were required to make the choice to minimize the potential adverse impact on human health and the environment. The assignment was given during the time period that the discussion in lecture involved polymeric processing techniques. Table 1 provides the lecture modules and any associated assignment that have been introduced into this course thus far. The modules on green manufacturing, clean room manufacturing, and the materials/processes decision support software were only introduced during the Fall 2005 term while all others have been included since Fall 2004.

Thus far, the most significant measurable outcome from this effort comes from a comparison of test scores on EIHS-related test questions with those of the total testing questions. Three exams were given during each of three consecutive semesters (i.e., Fall 2004, Spring 2005, and Fall 2005) and a total of one hundred and twenty-five questions were answered by the students all together. Of the one hundred and twenty-five questions answered, twenty (16%) had a theme related to EIHS. The "theme" questions were distinguished from the others based on whether or not there was an obvious relationship between question content (and potential answers) and environmental and/or human health impact. The mean, median, and range were calculated for both the student scores on all of the test questions and student test scores on just EIHS-related questions.

Results and Discussion

The results from the comparative study of student performance on total test questions over the three semester duration to those of EIHS-related questions are given in Table 2. A total of one hundred ninety-two students took at least one of the exams administered during their respective semester enrolled. As can be discerned by the elementary statistics, there is no apparent difference between student performance on the total test questions and those just with an EIHS issues theme. The students averaged answering just over two-thirds of the question correctly for both the total tests inclusive as well as for the EIHS-related questions. The median and range differences between the two were also not statistically significant. The one noteworthy difference between the two sets of

data shows up in the standard deviation calculations. The standard deviation about the mean for the student test performance on the EIHS-related questions was 13.7 while, in contrast, the scores overall on the questions had a standard deviation of 11.6. This infers that the students performed with a greater variation about the mean on the EIHS-related test questions than they did on the test as a whole.

Table 1
EIHS-Related Modules and Subject Matter/Assignments

Lecture Module	Subject Matter/Assignments Examples
Health and Safety Issues in Casting	Recycling sand, energy requirements, silicosis and lung cancer from free silica exposures, carbon monoxide poisoning, and health hazards from molding, patternmaking and core making, and noise
Health and Safety Issues in Plastics	Low impact material/process choices, green material, unreacted monomers, PVCinduced angiosarcoma, health effects from additives and reinforcements, thermal degradation products, and noise
Welding Hazards	Welders flash, chronic ailments from heavy metals, exposure to ozone and fluorides, welding next to degreasers and open pits, confined space issues, general safety hazards, noise, and ergonomics
Introduction to Green Manufacturing	Production optimizing, toxin sinks, recycle, reduce, reuse strategies, toxicity of materials, energy usage strategies, interpretation of environmental regulations, and advanced manufacturing practices
Introduction to Clean Room Manufacturing	Particle and biological monitoring, good manufacturing practice (GMP), ventilation design, filtration of particles and bioaerosols, personal protective equipment, and ISO versus US standards
Use of Materials/Processes Decision Support Software	The use of software as a support tool to make environmentally-friendly choices, decision trees, limit stages, bubble charts, constraints on processing and material choice, and alternative justification

Thus far, the subject matter covered by these test questions, homework assignments, and quizzes has been primarily focused on environmental and human impact issues associated with using a particular manufacturing process. In subsequent semesters, the following specific topics and questions related to environmental and industrial health and safety issues are expected to be addressed in the MET 142 course and in advanced courses in manufacturing processes:

1. The increased role of nanotechnology in society. Are we currently effectively protecting those employees exposed to nanoparticles in manufacturing? What types of manufacturing processes produce nanoparticles?

2. The use of clean room technology in advanced manufacturing. What techniques are currently available to ensure a stellar first run yield and an overall optimal product quality in areas such as industrial pharmaceuticals, biomedical device manufacturing, and electronics?

3. Increased efforts in advanced manufacturing processes and associated economics. Is it possible to recover costs from an environmentally sound operation by the selling of extra pollution credits?

4. The effects of globalization pressures on the state of manufacturing in the future. Will the challenges of the future in the areas of environmental health and safety be considerably different than they are today?

5. The use of alternative energy sources and future impact on the environment and the economical structure. How about recovering waste heat or burning potentially toxic manufacturing byproducts to generate power?

6. Life cycle costs of products can be significantly reduced by designing "recyclability" into each of them. Would reduced disposal and human impact costs translate into increased product residual value?

7. Casting metal closer to finished dimensions in order to reduce energy costs of melting metal that will be machined away, and subsequently, reducing potential employee exposures to associated contaminants produced during machining. Are the additional efforts at realizing better control actually a benefit?

TABLE 2
STUDENT TEST QUESTION PERFORMANCE

Question Type	*Number (N)*	*Mean* (X-Bar)	*Median*	*Range*	*Standard Deviation*
Total Number of Questions	125	67.3%	67%	48 (46 – 94)	11.6
EIHS-Related Questions	20	66.7%	66.5%	49 (42-91)	13.7

Summary

In summary, a process of integrating environmental and industrial health and safety (EIHS) into an undergraduate manufacturing processes course was described. The technique included addressing environmental and human impact not as a separate course item, but rather during each specific discussion on a particular manufacturing process. Six lecture modules that have been developed over the past three college semesters were described, and outcomes were measured comparing elementary statistics from total test

questions with those of just EIHS-related questions. Due to the realities associated with the resultant negative impact on society and the environment, EIHS issues need to be dealt with effectively by managers of heavy manufacturing in the U.S. A strategy like the one presented in this paper, which involves environmental and human health education early on in an engineering or engineering technology curriculum, would be beneficial to this cause.

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