AC 2011-140: ENGINEERING AND TECHNOLOGY FOR NON-ENGINERING AND NON-SCIENCE MAJORS

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Abstract

This paper focuses on developing best practices for providing non-science and non-engineering majors with a basic level of engineering and technological knowledge for successfully dealing with real world technological issues.

For the past 20 years the principal author has taught a course, "The Environment," to non-engineering and non-science majors as a science core requirement. In Fall 2007 a section of this course was taught using the traditional lecture method. In the other sections of the course, methods for improving the technological literacy of these students were developed. Four best practices were selected from these methods and taught to an experimental group in summer 2010. The best practices are: (1) learning from three hands on and minds on labs, (2) use of charts and equations, (3) making students familiar with the top 20 bench mark numbers used in the industry, and (4) acquiring knowledge about the commercial applications of engineering and science.

The average grade of the control group was 64% and that of the experimental group was 76%, a 19% improvement over the control group. The groups were significantly different with a calculated t value of 3.3. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05. Among the four indices, making students familiar with the top 20 bench mark numbers used in the industry was ranked the highest.

These practices can be used in other science and engineering courses. The authors plan to use these practices in 2 other courses over the next three years. The practices can be used in other courses or schools with appropriate modifications in order to help our students acquire the knowledge they need to make informed decisions about technology.

Introduction

Technological literacy can be defined as a broad range of knowledge about technology and how humans develop, use and are affected by technology. A certain level of technological knowledge is needed for non-engineering and non-science majors because their success usually demands effective use of and making informed decisions about technological issues.

The Objective

This paper focuses on developing best practices for providing non-science and non-engineering majors with a basic level of engineering and technological knowledge.

Motivation

As stated previously, a certain level of technological knowledge is necessary for persons in fields other than science and engineering. The authors believed it was important to help their students gain the knowledge and expertise necessary to make informed decisions about technological issues.

Literature Review

There are local, regional and national needs for improved technological literacy among the general population. Studies conducted by many prestigious organizations, including the National Academy of Engineering, accreditation boards, and professional societies, indicate that the future success of a nation is based on spreading technological literacy from technology centers to the masses. Therefore, expanding technological literacy should become one of the top priorities for engineering educators across the nation. Several universities and institutions have been working towards this objective [1-8].

An engineering major typically has a curriculum [9] with a heavy load of prerequisite courses making it relatively difficult (when compared with other majors) to combine with another major. On top of this the learning structure of a typical academic institution makes it hard for non-engineering majors to gain a meaningful understanding of engineering and technology [10-12]. Non-engineering majors are faced with numerous forces that pull them in different directions—toward socialization, career, and technological literacy. They are not well equipped to lead the nation, through its diversified and challenging problems by making informed decisions about issues such as industrial globalization, nanotechnology, information technology or alternative energy [13-19].

Demography of the Students

The university where the authors teach has the most diversified student demography in the nation. The specific demographic of students taught in this study is as follows: African American 45%, Asian 9%, Pacific Islander 1%, American Indian/Alaskan Native, 1%, White 27%, and others 17%.

Methodology

In order to make a judgment regarding the validity of the measures and the numbers collected, a careful and through description of the testing methods is giving below. A controlled experiment was designed to test the effects of an independent variable, teaching practices, on a dependent variable, grade. Any difference in the outcome (dependent variable) between the experiment and the control was documented in order to study whether the effect of the independent variable tested is significant. The t-test was used because it assesses whether the means of two groups are statistically different from each other. This analysis is appropriate whenever the means of two groups need to be compared, and especially appropriate as the analysis for a posttest-only two-group randomized experimental design such as this one.

In Fall 2007 a section was taught using the traditional lecture method, the control group. In Summer 2010 an experimental group was taught using four best practices that are well established in the pedagogical literature. The influence of the best practices (independent variable) was measured on the grade (dependent variable).The best practices consisted of 20% of the grade which was taken from the final (15%) and midterm (5%) examinations of the control group. This was the only difference between the control and experimental groups as demonstrated by the grading formulas shown in Table 1. Therefore, the numbers are a fair comparison between the two groups.

The four best practices were chosen in the following way: The author, a senior faculty with an excellent teaching record for the past 20 years (taught over 3000 students over a wide variety of courses) and winner of several outstanding teaching awards at the department and college levels has used over two dozen teaching practices. A representative sample of each of these practices was demonstrated before a class of 30 students (ENVT 845- The Environment). The instructor asked the students to rank these practices. The top four practices were chosen and taught to the experimental group. The best practices chosen were: (1) learning from three hands on and minds on labs, (2) use of charts and equations, (3) making students familiar with the top 20 bench mark numbers used in the industry, and (4) acquiring knowledge about the commercial applications of engineering and science. Details about each of the practices are given in the following paragraphs.

Learning from three hands on and minds on labs: The following laboratory experiments were used: (1) measuring sound pollution at various locations around the university campus and developing a route map that exposes pedestrians to the lowest level of noise pollution, (2) measuring pH levels of various acids and bases and applying the knowledge to the real life problem of acid rain, and (3) measuring energy levels of various materials and applying the knowledge to the real life problem of saving energy in the student's own home and transportation.

Use of charts and equations: This strategy consisted of mastering chart reading, distinguishing the difference between charts and equations, and developing intellectual sensitivity to the limitations of equations such as not using them with a black box approach.

Making students familiar with the top 20 bench mark numbers used in the industry: The course, ENVT-845, covered the effect various industries have on the environment. Linking the curriculum to industry was the reason for the success of using the top 20 bench mark data. For example, on the topic of human health and toxicology, students learned the top five toxins, the levels at which they affect human health and the three most effective strategies for keeping the level within an acceptable range. For the topic of in-door and out-door air pollution, they were taught the three most common in-door and three most common out-door air pollutants and their acceptable levels. They learned the five most common causes of global warming and ways to keep the levels of toxins within acceptable limits.

Acquiring knowledge on the commercial application of engineering and science: The law of savings on the scale of economies, concepts of profit maximization and minimizing the cost of mass production of units were taught for various industries.

Results and discussion

The improvements of the four performance indices in the experimental group compared to the control group are shown in Table 2. Table 3 gives the statistical results of the t tests [2--22]. The improvements of the indices were statistically significant at an alpha value of 0.05. Among the four indices, making students familiar with the top 20 bench mark numbers used in the industry was ranked the highest. The authors consider this index to be the most important among the four indices because it provided the most effective way of achieving the objective of this study. In this category, the control group scored 67% on the average whereas the experimental group scored 82%. The experimental group showed a 22.4% improvement over the control group. Acquiring knowledge on the commercial application of engineering and science was ranked the lowest. In this category, the control group scored 67% while the experimental group scored 76%. The experimental group showed a 13.4% improvement over the control group. This is understandable because there are several industries and this is only a 3 credit hour introductory level course. Because of time constraints we were unable to include more information in the course. The experimental strategy can be applied to other science and engineering courses.

Summer classes are condensed in many schools. But the university of the authors is an exception. Summer and semester classes have exactly the same duration and requirements. Therefore this factor did not contribute to the improvements.

What is New?

Even though several universities and institutions have been working on these issues, this study presents two new aspects: (1) exact quantification of the improvements of the four performance indices supported by statistical data, and (2) the four practices were selected as the best ones from 15 strategies used by the authors for the past 20 years. It is interesting to note that these best practices are selected from and appropriate for the most diversified student group in the nation.

Conclusions

The average grade of the control group was 64% and that of the experimental was 76%, a 19% improvement over the control group. With a calculated t value of 3.3, the groups are significantly different. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05.

Among the four indices, making students familiar with the top 20 bench mark numbers used in the industry was ranked the highest. Linking the curriculum to industry was the reason for the success of using the 20 bench mark data.

This experimental strategy can be applied to other science and engineering courses. The authors plan to extend this strategy to 2 other courses over the next three years. The method presented in this study may be used elsewhere in the nation with appropriate modifications in order to help our students acquire the knowledge they need to make informed decisions about technology.

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Table 1. Grading Formulas

	Control group (Percent)	Pretest group (Percent)
1. Assignments	20	20
2. Attendance and class participation	10	10
3. Mid-term examination	30	25
4.Final Examination	40	25
5. 4 Best practices		20
Total	100	100

Table 2. Improvement of the Creative Group over the Control Group

Performance Index	Control Group (%)	Innovative Group (%)	Improvement (%)
(1) learning from three hands on and minds on labs	67	77	14.9
(2) mastering chart reading, distinguishing the difference between charts and equation, and developing intellectual sensitivity to the limitations of equations such as not using them with a black box approach;	67	78	16.4
(3) making students ease with the top 20 bench mark numbers used in the industry;	67	82	22.4
(4) acquiring knowledge on the commercial application of engineering and science.	67	76	13.4

Table 3. Statistical analysis of Performance Indices

Performance Index	Standard Deviation		t value
	Control Group	Creativity Group	
(1) learning from three hands on and minds on labs	8	11	2.4
(2) mastering chart reading, distinguishing the difference between charts and equation, and developing intellectual sensitivity to the limitations of equations such as not using them with a black box approach	12	10	2.2
(3) making students ease with the top 20 bench mark numbers used in the industry	10	13	2.5
(4) acquiring knowledge on the commercial application of engineering and science	9	12	2.7