

Using Experiential Learning to Teach Office Ergonomics in the Undergraduate Classroom

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Abstract

Knowledge of contemporary issues is an important component of every industrial engineering undergraduate student's curriculum. As professors in Industrial Engineering, it is our duty to continually update our courses to meet the changing needs of our students. The traditional topics of an industrial engineer have historically focused on the manufacturing and product industry. Specifically in the area of workplace design, the legacy workplace was impacted by the industrial revolution and corresponding tools for improvement in productivity. However, the knowledge economy and the explosion of information technology have changed the typical workplace.

This paper demonstrates an office ergonomics productivity evaluation that was incorporated into an undergraduate ergonomics class as a lab experiment. The experiment integrated a collection of topics and allowed students to learn in an experiential fashion. The lab experiment covered workplace design by comparing three potential computer workstation configurations: the traditional seated design, a standing design, and a treadmill walk station. The experiment quantified productivity with an input task based on Fitts's Tapping Task, another basic topic of ergonomics curriculum. The data for the experiment followed a factorial experimental design and were analyzed using multiple regression and analysis of variance, thus combining additional topics.

The experiment also allowed students to relate the results of the experiment to the design problem. The results of the research show that walking adversely affects productivity yet comparing seated and standing postures yields mixed results. For more simple tasks, the ideal posture is sitting while for more complex tasks the worker should be standing for improved productivity. The ergonomics class was enhanced by the discussions about the tradeoffs of various factors in workplace designs that are relevant in the application of this topic to real-world experiences.

1. Background

Faculty members teach the importance of contemporary topics for undergraduate engineering students by sharing research in various ways. Active participation as a research assistant with a funded faculty member represents one direct method of immersing students into research. A lack of substantial and programmatic undergraduate research opportunities limits the impact of this hands on research experience to a handful of students who are funded by individual faculty research programs.

Including research methods and results as part of the lecture in a traditional classroom comprises an indirect method of sharing faculty research. The impact of this method extends to an entire class of students and it provides a large number of undergraduates the opportunity to hear about a carefully designed research experience. Achieving active student engagement in a the classroom can enhance the quantity and quality of learning that will result from the experience.

This paper describes a direct method of teaching ergonomics topics by incorporating a research study into a classroom laboratory experience. This results in a hands-on, active learning experience that will impact all students in the class. In addition to learning research methods by participation, this approach incorporates additional topics and broader contemporary topics.

2. Purpose

The traditional ergonomics syllabus has focused on the physical requirements of manual labor workers. While manufacturing and other jobs requiring physical labor remain vital components in the workforce, many developed countries have transitioned to a knowledge economy. By 2003, more than half of all workers in the United States used a computer¹ and the number of computers in use worldwide exceeded the 1 billion mark in 2008². Rather than bending, lifting and assembling in a factory setting, workers now look at a computer monitor, move and click a mouse and type on a keyboard while sitting at a desk. Computer based work has led to new sources and types of worker health problems including an increased rate of cumulative trauma disorders.³⁻¹⁴ This necessitates changes in the ergonomics curriculum to include the impact of the new work environment on productivity as well as health & safety. Determining the human

factors that affect productivity and safety in the workplace has become a primary goal in the ergonomics classroom.

To address health and safety issues resulting from computer based work, product designers have developed new styles of workstations. The treadmill workstation is a relatively new and novel approach to get office workers to stand up and move while on the job. However, the impact of the treadmill workstation on worker productivity and safety has not been fully explored. Studies have shown there are many confounding variables¹⁵⁻²¹ which makes the impact of the treadmill workstation on worker productivity an ideal topic for discussion and debate.

3. Method

This paper contains the results of a research study conducted in an ergonomics class that has both a lecture and a laboratory component. During the one semester class, students will participate in eight different lab experiments with a written lab report requirement. Lab topics include anthropometry, strength, and hand tool design among others. Lab experiments are rotated and refreshed to keep the class up to date. The lab topic included in this paper tests the hypothesis that computer workstation has an impact on productivity. In the lab, students compare three computer workstation designs where worker productivity is measured using a computer input task based on Fitts's Tapping Task. As background, the Hick-Hyman equation and Fitts's Tapping Task²² are discussed during the lecture prior to this lab. In this lab, as is the case with the other labs in the course, the students serve as both subjects and data analysts for the experiment.

The lab experiment utilizes three computer workstations. One computer workstation is a traditional desk with the worker in a sitting posture. A second computer workstation integrates a treadmill into the worker's environment allowing the worker to assume a walking posture at a speed less than 2 mph. When discussing the lab setup, it was noted that comparing the traditional sitting workstation to the treadmill workstation introduced two design differences between the workstations: sitting versus standing and stationary versus movement and that these two differences are confounded. This suggested the need for a third workstation design to separate the two effects; therefore, the standup workstation was added to the study that allowed the

subject to work in a standing posture without walking. Figure 1 shows a study participant at each of the three workstations.



Figure 1: Study Subject Performing Input Task at Sitting, Walking and Standing Workstations

The participants in the study consisted of the eleven students in the class. After conducting the experiment, each student analyzed the resultant data and produced a written lab report. During the lab, the students had to identify variables that might affect the results and control those variables as much as possible. For example, to keep the mouse in the same relative position, the height of the standing and walking workstations needed adjustment to compensate for the varying height of the students. Fortunately, the students identified many constants in the study. For example, the participants all had experience using computers with a mouse, they all owned their own personal computer, were all right handed with no physical disabilities. A discussion also noted that the study only contained younger people as subjects who may perform differently than older subjects which could potentially introduce a bias into the results.

Students performed a computer input task using a mouse as the input device in each of the three workstations. The computer task consisted of a series of point and click exercises to illustrate the Fitt's Tapping Task. The goal of the task was to perform the clicks as quickly as possible. Students performed two trials at each of the three workstations (subjects used workstations in different orders to randomize learning during the study) yielding 24 time values for each subject. This results in two replicates of a 2x2x3 full factorial design in the Distance (Close and Far),

Size (Small and Large) and Workstation (Sit, Stand and Walk) factors. This allowed students to gain a better grasp of experimental design concepts by participating in the various configurations of the design factors. Figure 2 shows the Lab Handout that also served as a data sheet.

Computer Input Efficiency or Fitts's Tapping Task Lab

The purpose of this lab is to examine the effects of target size, spacing, posture and movement on the amount of time it takes to accurately tap alternately between two targets. Theory suggests that the process obeys Fitts's Law.

Method: There are several computer test stations in the lab. Each computer may be set up with a workspace that requires the subject to modify their posture (e.g. sit, stand, walk, other) or utilize a unique input device (e.g. mouse, trackball, joystick, tablet, other) while performing a standard task.

Variables

Dependent: Movement Time in seconds

Independent:

Distance between target centers in inches (Close Spacing = 2, Far Spacing = 4)

Target Width in inches (Small button = 0.5, Large button = 1)

Posture (Sit, Stand, Walk)

Analysis: Perform appropriate statistical analysis to determine what independent variable has the most effect on movement time. Use Hicks-Hyman regression equation to predict movement time for various levels of difficulty. What assumptions must be made to use regression analysis rather than ANOVA?

	<u>Sit</u>				<u>Stand</u>				<u>Walk</u>				
	Close		Far		Close		Far		Close		Far		
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	
<u>Trial</u>													
1													
2													
Avg													

Conclusions: Discuss your findings in terms of Fitt's Law and the implications your findings have for the design of work.

Figure 2. Lab Handout

4. Results and Conclusions

After the lab session, the students analyzed the class data and interpreted the results. This allowed incorporating statistical analysis techniques into the lab experiment as well as class discussions of the results. The data yielded significant and interesting results for the students. Most students began by evaluating the linear relationship suggested by the Hick-Hyman Law as discussed in class and in the textbook. They fit regression models using index of difficulty as the independent variable. The resulting regression models proved to be significant ($p\text{-value} < 0.001$) but demonstrated a significant ($p\text{-value} < 0.0001$) lack of fit. Thus, they reasoned that the relationship between time to perform the task and index of difficulty is not linear. Students also fit the data using a three-factor ANOVA model (Workstation, Size, and Distance) model.

Students used graphical techniques to demonstrate the relationship found in the data. Figure 3 shows box plots of time for each combination of Workstation and index of difficulty (ID) grouped by posture. This graph shows that the relationship between Time and ID for Sit (the middle Workstation) appears linear. This suggests that in the sitting posture worker performance will consistently decrease as task complexity increases. Taking the other perspective, when working in the seated position, any task simplification will result in an increase in productivity. For the Walk and Stand Workstations, there is an increasing relationship between time and ID but there appears to be very little difference in time for ID's of 3 and 4. This graphically demonstrates the significant lack of fit for the linear models. In the context of workstation design, when workers are standing or walking there appears to be a middle range of ID values that require the same Time to perform the task or that productivity is somewhat robust to ID in this range. This suggests that under certain conditions, in the Move and Stand posture, worker complexity can be increased without any degradation in productivity.

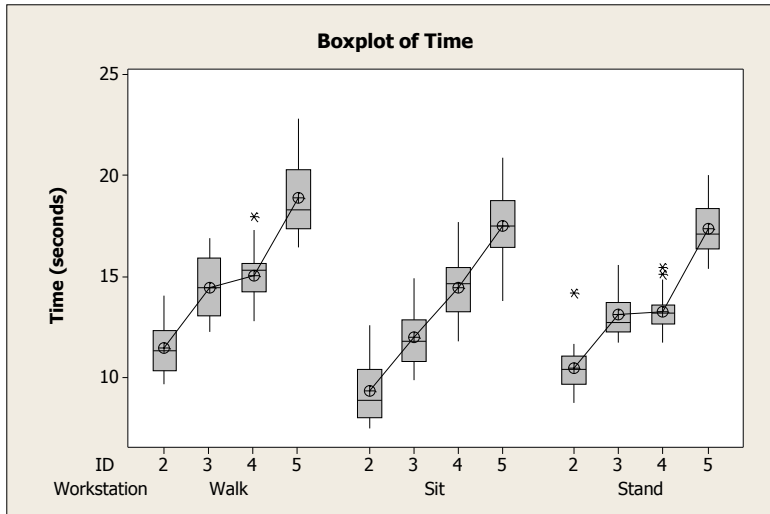


Figure 3: Boxplots of Time by Index of Difficulty for Each Posture

Other students organized their graphs in a different fashion. Figure 4 shows box plots of Time for each combination of Workstation and index of difficulty (ID) grouped by ID. Notice that the Walk Workstation has the highest Time value for all four ID values. This suggests that walking will result in lower worker productivity than the sitting or standing across the range of task complexity. The presence of a significant Workstation-Distance interaction combined with the absence of a Workstation-Size interaction shows that the two aspects of task difficulty (Size and Distance) may not combine in the same fashion for each Workstation. Figure 5 shows the same box plots as Figure 4 with index of difficulty relabeled as Distance and Size. Looking at the data this way explains the apparent anomaly when using index of difficulty. Small targets Close together have an ID of 3 while Large targets Far apart have an ID of 4. At the Walk or Stand Workstations these two combinations result in similar Time values; however, when using the Sit Workstation, Small targets Close together have lower times than Large targets Far apart. This suggests that in the seated posture, target proximity has more impact on response time than target size.

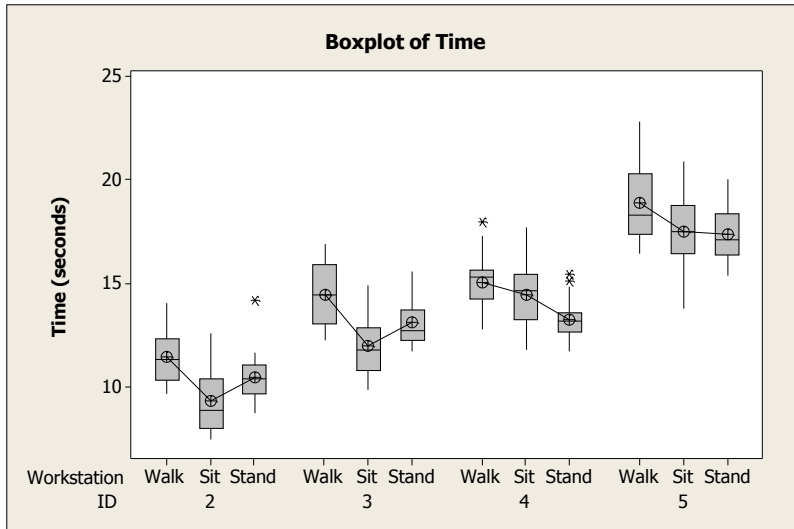


Figure 4: Boxplots of Time by Posture for Each Index of Difficulty

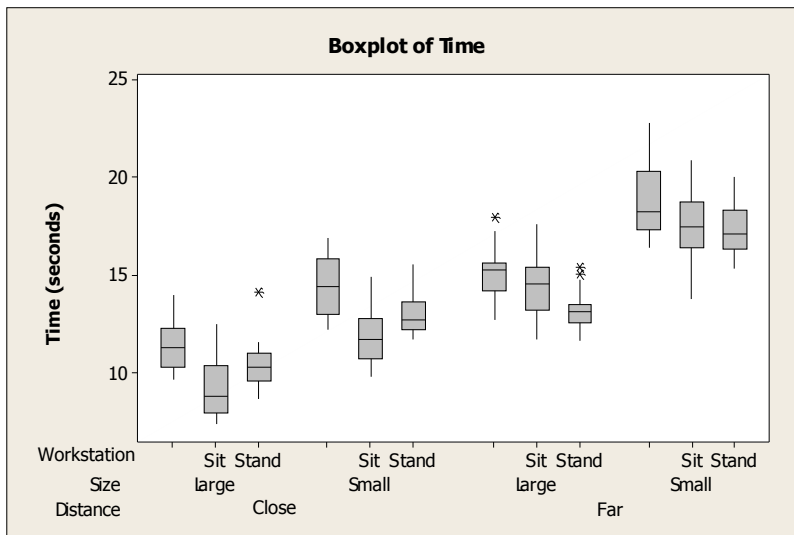


Figure 5: Boxplots of Time by Posture for Each Combination of Size and Distance

5. Evaluation of Learning

The attempt to evaluate whether students have learned anything can be tricky. In the most recent offering of the ergonomics course, students were asked to rate their self-knowledge on a five-point Likert scale prior to the start of the course and again at the end of the course just before the final learning experience. Average scores for 17 students (pre-test) at the beginning of the course and 11 students taking an identical survey (post-test) at the end of the class are compared in the graphs below. The self-assessment covered broad learning objectives as well as the individual course topics and the results are shown in Figures 6 and 7. It should be no surprise that students learned something across all course objectives and within all syllabus topics.

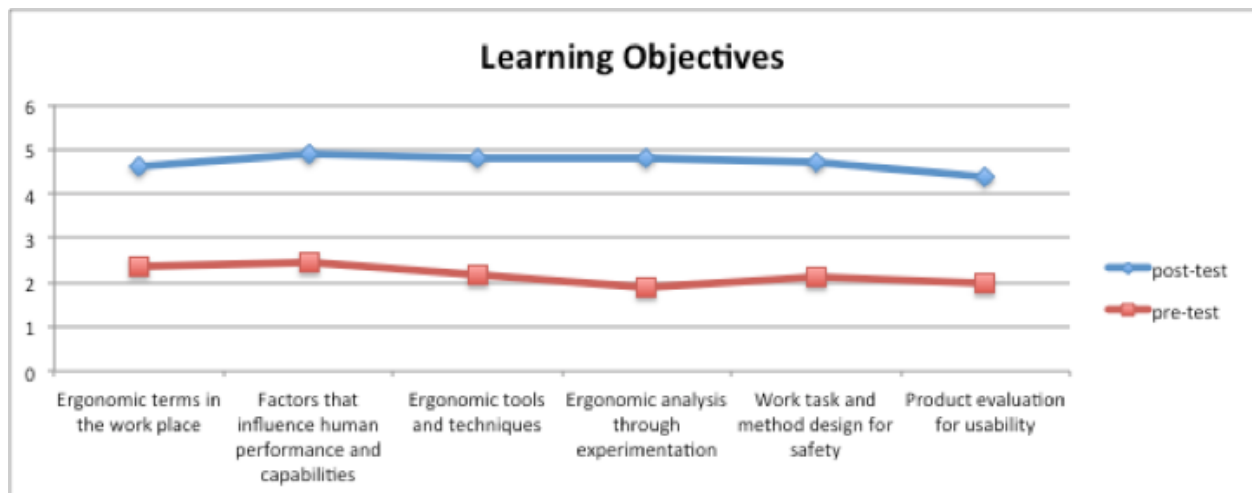


Figure 6: Pre and post test results for course learning objectives

The complete list of course learning objectives includes:

At the end of this course, students will be able to:

1. Define fundamental ergonomics terms in the work place (Knowledge)
2. Explain factors that influence human performance and capabilities (Comprehension)
3. Demonstrate the use of ergonomic tools and techniques (Application)
4. Analyze ergonomic principles through experimentation (Analysis)
5. Design safe work tasks and methods (Synthesis)

Stretch objective: Evaluate products for usability (Evaluation)

While there are many confounding variables, this particular lab experiment may have influenced the students learning in at least two of the objectives:

2. Explain factors that influence human performance and capabilities
4. Analyze ergonomics principles through experimentation.

The specific syllabus topics that were covered in this lab experiment include computer input efficiency and Fitts's Law and both show an increase in self-assessed knowledge from the beginning of the course to the end of the course.

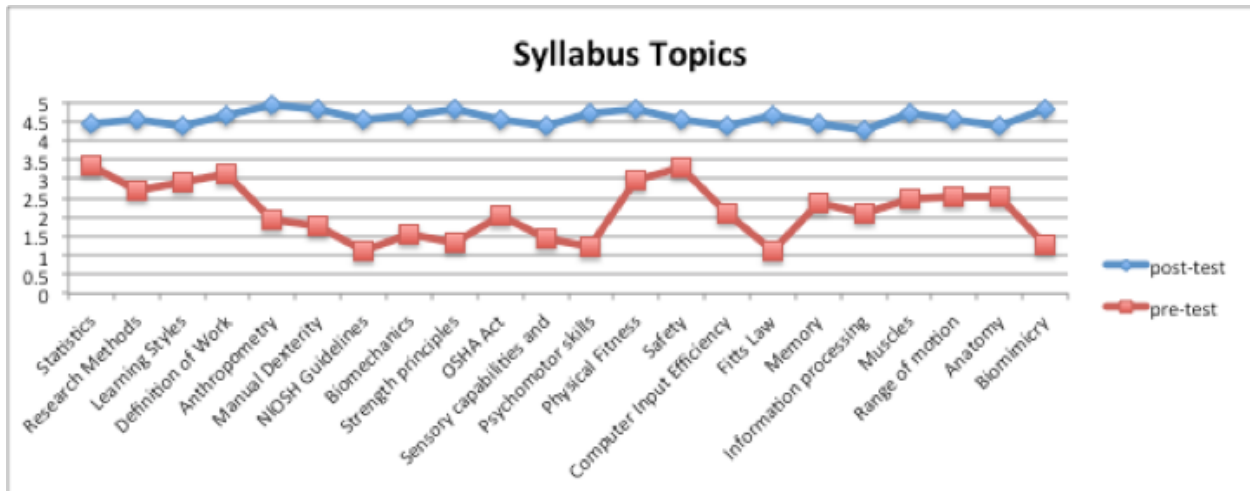


Figure 7: Pre and post test results for individual course topics

6. Discussion

This ergonomics lab experience attempted to integrate a variety of topics (research of a contemporary workplace design issue, Fitts's Tapping Task, experimental design and statistical analysis) in an experiential fashion into the classroom. The lab compared the effect of three postures - sitting, standing and walking – on computer worker productivity as measured by an input task based on Fitts's Tapping Task. As more jobs become computer based, workers will spend greater amounts of time on a computer. It is important that the Industrial Engineering curriculum stays current on such demographic changes and update individual courses accordingly. This paper demonstrates how relatively simple and low cost studies can be introduced into a traditional ergonomics class and benefit the students.

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