

Learning by Doing: A Studio-Based Approach to Teaching Ergonomics and Human Factors

Laura Moody¹

Abstract – This paper describes the development of a studio-based approach for teaching ergonomics and human factors to undergraduate engineering students. Studio-based methods in engineering education draw on the concept of a “design studio” as the basis for learning and applying fundamental skills and knowledge through a series of directed exploration and design projects under the guidance of the course instructor. The use of these methods for teaching foundational courses in ergonomics and human factors is especially promising, as laboratory experiences and design projects are often an integral part of the course. The first course to implement these methods was Ergonomics and Work Measurement in the spring semester of 2010. The author’s experiences and lessons learned will be described, as will the evaluation methods and preliminary results.

Keywords: studio-based learning, ergonomics course.

INTRODUCTION

Problem-based and Studio-based Learning

Problem-based learning (PBL) approaches to education in engineering and science utilize extensive, open-ended problems to guide students through a process of discovery that is meant to lead to a greater understanding of concepts. Hoffman and Ritchie [Hoffman, 1] define PBL as “a student-centered pedagogical strategy that poses significant, contextualized, real-world, ill-structured situations while providing resources, guidance, instruction, and opportunities for reflection to learners as they develop content knowledge and problem-solving skills”. Starting with problems that are based on those students are likely to encounter in their professional lives, PBL expects the students to work in directed teams and take responsibility for learning. In this way, learning is organized around finding solutions to real world problems rather than acquisition of isolated discipline-specific knowledge. Hung [2] provides a brief summary of the history of PBL and the challenges associated with developing effective PBL methods, and proposes a method for problem development intended to increase the overall effectiveness of the result. PBL approaches have been used in a number of science and engineering courses, including a “green engineering” elective at the University of Sydney [Harris, 3] that used a number of case studies to introduce the principles of “green engineering” to upper level engineering students.

Studio-based learning (SBL) is related to PBL, but includes significant interaction with the instructor, frequent critiques of work-in-progress, and the implementation of a studio “space” designed to be conducive to team learning efforts. The goal of SBL is to create a creative environment within which students engage in active exploration of a problem space. While the approach in US schools has its roots in schools of architecture, SBL methods have been used in education [Brocato, 4] and computer science [Kuhn, 5; Hundhausen, 6], in addition to engineering. Little and Cardenas [Little, 7] explored the application of these methods in an introductory engineering design course at Harvey Mudd College. They found it to be an effective method, but cautioned that instructors should be prepared to help students understand course expectations. Similarly, Foulds et al [Foulds, 8] describe the implementation of studio-based methods in an introductory biomedical engineering course. The success of their approach has led to an

¹ Associate Professor, Industrial Engineering, Mercer University, moody_le@mercer.edu

expansion of studio-based methods in the curriculum and the construction of additional studio spaces. Thompson [9] also describes an “aircraft studio” at Rensselaer Polytechnic Institute that provides an opportunity for students to work with faculty and professional experts to design and build working aircraft.

The Course

ISE 311, Ergonomics and Work Measurement, is a junior level course in which the fundamental concepts of physical ergonomics, work and workplace design, and the measurement of work (learning curves, time study, and predetermined time systems) are taught. The course is required for students specializing in industrial engineering, and is also a popular elective for students in industrial management, biomedical engineering, and mechanical engineering. The textbook used is *Work Design: Occupational Ergonomics* [Konz, 10], selected because it has the most comprehensive coverage of the course topics. The stated learning objectives for the course are: 1) analyze an operation using a variety of techniques; 2) evaluate work places and work methods from physiological, biomechanical, and anthropometric perspectives; 3) design work places and work methods for increased effectiveness, efficiency, and safety; 4) develop and conduct studies to determine the time it takes to perform a task and to develop appropriate labor standards; and, 5) understand the basics of predetermined time systems.

The SBL approach to Ergonomics and Work Measurement is especially fitting, as laboratory and design exercises are an integral part the course. Traditionally, it has been taught as a lecture course, with a number of integrated laboratory assignments to introduce students to the tools and techniques of workplace evaluation, work design, time study, etc. In addition, two term projects were assigned in which teams of students performed a workplace evaluation and redesign (in project 1) and performed a process analysis, time study, and MTM or MOST analysis of a task (in project 2). The instructor also developed a number of in-class group exercises designed to supplement the lecture material. These exercises, laboratory assignments, and projects formed the basis for the studio-based course.

SBL APPROACH TO TEACHING ERGONOMICS

The first attempt to use a studio-based approach to teaching ergonomics occurred in the Spring 2010 offering of ISE 311 Ergonomics and Work Measurement. In the spring semester there were 30 students enrolled, including 7 students specializing in industrial engineering, 3 in biomedical engineering, 17 in mechanical engineering, and 3 majoring in industrial management. The large class size was unusual and a cause of concern for the instructor because of the anticipated difficulty in providing real-time feedback and guidance to student teams during the class period. Also, because of scheduling constraints the timing of the course (three 50-minute sessions) could not be changed before the semester began, so the time available in class to address team questions was limited. To compensate, a scheme was implemented which allowed student teams to indicate a need for attention via color-coded cards (green for “all’s well”, yellow for “we have a question”, and red for “we need help now!”). In addition, a decision was made early on to allow one period to be “attendance optional” for students so that teams could meet on their own schedule to complete work in a less constrained time period.

As a studio-based learning course, ISE 311 was designed to promote team-based, self-directed learning in a “studio” atmosphere. Learning activities centered on group laboratory experiences, in-class exercises, and two major projects. Short lectures were offered as needed to introduce technical concepts and guide team efforts. When a majority of red or yellow cards were displayed in the room, the instructor called the class’s attention to the front of the room and engaged in a short question and answer session. This usually helped clarify and focus the groups’ efforts and they were able to resume their activities. Individual accountability for contribution to the team effort was reinforced through peer assessments and individual learning was assessed through a midterm and final exam.

“Studio” Space

An ideal space for an SBL course would be a dedicated “studio”, analogous to the studio space found in schools of architecture, in which each student team is assigned a space to work during and outside of the designated class period. This space is typically equipped with all of the materials and equipment required for completion of the assigned activities. In the case of the course in ergonomics and work measurement, for instance, this would include computers with all necessary software, a reference library, a variety of tools and supplies (sound and light measurement devices, anthropometric measuring equipment, etc.) It might also allow for spaces in which demonstrations might be set up and left for a period of time. Such a space does exist within the School of Engineering, but it is a relatively small lab space (the Human Factors/Statistical Quality Control Lab) that can accommodate a maximum of six to eight students (or two or three groups).

While the school of engineering does not have the facilities to provide a dedicated space for the studio, there are two multimedia classrooms with moveable tables, projection capability, and available laptop computers that student teams can use to complete in-class assignments. Tools, equipment, and demonstration materials were brought in by the instructor as needed. Figures 1 and 2 below show the generic layout of the room and how the student teams used the space, respectively. In addition, the course website, hosted on Blackboard™, provided the ability for students to participate in online discussions, and to submit and receive feedback on interim and final assignment submissions.



Figure 1. Multimedia classroom



Figure 2. In-class design exercise

Team Exercises and Projects

A variety of exercises and projects were developed. The goal was to help students develop their capacity for self-directed learning, as well as their ability to work in teams to solve open-ended problems. Students worked in teams on a number of laboratory assignments, in-class group exercises, and larger projects. Group work was generally preceded or accompanied by individual homework assignments designed to prepare individual students to participate fully in the group effort. A typical series of exercises was designed to introduce and integrate the concept of anthropometry to students, as follows:

Individual Homework Assignment. Students were required to read relevant sections of the textbook and respond individually to several review questions. Homework assignments were not collected and graded by the instructor, but the teams discussed each member's response and compiled a "group response" which they posted to the discussion board of the Blackboard™ site. In addition, subsequent group work required the students to reference material from the assigned reading.

Laboratory Assignment. Teams were first given a laboratory assignment in which they were required to measure a body segment (forearm length) for five people not in the class, compile and evaluate the resulting data from all student teams, and use the concepts they encountered in the assigned reading to evaluate a common item (grocery store shelf, kitchen sink, etc.) based on common anthropometric data. In addition, an in-class laboratory exercise required the students to make observations regarding grip strength as a function of arm and wrist configuration.

In-Class Team Exercise. Team exercises for this portion of the course covered two weeks and involved integrating the material on anthropometry with the next topic of the course. In the first week, student groups worked together in class to evaluate the forearm length data and take data on grip strength (due to resource limitations – i.e., only one hand dynamometer – the data had to be taken in class). The deliverable for the first week's exercise, in addition to the posting of the group response to the review questions, was a Powerpoint presentation summarizing the results of the grip strength demonstration and the team's description of the implications of the results. All of the Powerpoint presentations were published on the Blackboard™ site, and reviewed and graded by the instructor. In addition, two teams were selected at random to present their results to the class.

The material from the exercises on anthropometry appeared again for the students in the next week, when it is incorporated into the in-class team exercise on process analysis. In this exercise, the teams are asked to define a process with which they are familiar (a self-selected “typical” college student activity) and develop a process map for that activity. As part of the exercise, student teams were asked to note specific requirements for reach, fit, or strength and address those based on the material on anthropometry covered in the previous week. (This method of linking previously seen material to current exercises was a pattern throughout the course as a means of reinforcing the material and integrating the concepts.)

Term Projects. The first of two term projects required students to evaluate and redesign a workplace or piece of equipment in the school of engineering under the assumption that the workplace or equipment is being used continuously in an industrial setting. For example, one group chose the drill press in the school’s machine shop, and evaluated it as if it were to be used as part of an industrial process. The teams used the concepts of anthropometry, work physiology, workplace and tool design, and other fundamental concepts as appropriate to evaluate the current design and layout, and propose a redesign as needed.

In the second term project, the student teams developed a hypothetical task (assembly, production, etc.) involving the workplace or equipment from the first project, developed the associated process analysis, and determined the time required to perform the task using both a stopwatch time study and a predetermined time system (MTM or MOST).

EVALUATION AND LESSONS LEARNED

Formative evaluations and minor modifications to the course occurred throughout the semester. This occurred both informally (in response to student feedback and observations by the instructor) and formally through a written course evaluation and class discussion of the results at the midterm. The previously noted practice of stopping the class for a question and answer session when a number of yellow or red cards were displayed is an example of an “informal” modification that resulted from instructor observations. In addition, modifications to the schedule or nature of team exercises (e.g., taking a little more time on a given concept or adjusting the next assignment to reinforce a concept) resulted from observations and student feedback. As a result of the midterm evaluation and discussion, class sessions in the second half of the term included regular short lectures at the beginning of class on Monday to introduce critical concepts and guide student efforts; while these lectures were kept short (generally 20 minutes or less) to maintain a focus on self-directed learning, they provided a stronger foundation for the student teams as they embarked on their own explorations. In addition, more formal review and critique of the student contributions to the discussion boards on Blackboard™ were instituted in an attempt to make that aspect of the course more relevant to the students.

A more thorough course evaluation conducted at the end of the term was designed to elicit student opinions on the relative value of a number of the features of the course (teamwork, group exercises and projects, labs, and discussion boards and a other Blackboard™ tools used in the course), and to obtain more feedback on what aspects enhanced learning, what detracted from learning, and what they would change about the course. This evaluation, which was in addition to the online university course evaluation that students were encouraged to complete, was submitted anonymously and students were informed that it would not be read until after grades were assigned (to encourage students to be as forthright as possible). Key findings resulting from both evaluations were:

- The overwhelming majority of students found the group activities (both in-class and laboratory exercises) and project-based learning to be either “Helpful” or “Valuable” (the two highest possible ratings) on a 5-point Likert scale. These two aspects were also listed most often in response to the open-ended question, “What one aspect of the course did you find most useful and enjoyable? (What most ENHANCED the learning experience for you?)” and were noted several times as positive aspects in the online university course evaluation.
- A clear majority found the requirement to contribute to discussion boards on Blackboard™ to be “Neutral” at best (with 14 students rating the discussion board requirement as “Detracted from the Course” or “Not Helpful”). The discussion boards were also most often listed in response to the question, “What one aspect of the course did you find least useful and enjoyable? (What most DETRACTED from the learning experience for you?)”.
- Other comments that were seen several times on both course evaluations indicated:

- the pace of the course might be a little fast for a self-directed approach;
- mini-lectures were needed to help students understand the material they were learning (the material in the textbook was not always clear);
- the size of the class impeded the instructor's ability to adequately address team questions and concerns in the classroom; and,
- although students enjoyed this approach and believed they learned a great deal from the projects and other assignments, they were not always sure that they were learning everything they needed to know for the exams. While the results of the final exam compare well to those of previous classes, this lack of confidence in their level of knowledge negatively impacted students' perception of the class.

Based on the experiences and lessons learned from the Spring 2010 offering of the course, the following changes will be implemented in the Spring 2011 offering:

1. The class size is limited to 15 students.
2. Mini-lectures have been planned and will be given at the beginning of each week.
3. Exercises and projects have been redesigned to allow for more time to be spent on each (e.g., a larger exercise covering two or three topics simultaneously will replace three shorter exercises that loop back to include previous topics).
4. The discussion board is still considered to be a valuable tool for the class, but it will be used more effectively. Rather than requiring students to respond "generically" to other groups' discussion posting for every assignment, less frequent and more directed critiques will be required and a separate, optional discussion thread will be available to address questions and concerns as they arise.
5. The instructor is developing a series of concept inventory quizzes that will allow students to periodically test their knowledge of the concepts and applications they are learning through the team exercises. These quizzes will also allow the instructor to assess the effectiveness of the course in conveying key concepts.

CONCLUSIONS AND MOVING FORWARD

The SBL approach to teaching Ergonomics and Work Measurement holds great promise in terms of providing an effective means of introducing students to the fundamental concepts and engaging them in the learning process. Integrating the lessons learned from the first offering of the course is expected to enhance the offering and provide a mechanism for assessing the effectiveness of the approach. Based on this experience, the instructor hopes to expand the approach to other courses in the curriculum beginning with the senior-level human factors course in the fall of 2011. This course has also been taught in the traditional lecture format supplemented with laboratory exercises, in-class exercises, and a design project. This fall, the human factors course was taught in a problem-based learning format and the transition to a studio-based course will be informed by this experience.

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Laura E. Moody

Dr. Laura Moody is an associate professor and chair of Industrial Engineering at Mercer University. Dr. Moody taught for 12 years in Mercer's School of Engineering before leaving Mercer to spend 2 years as the manager of the North American Usability Group for Whirlpool Corporation. She returned to Mercer in 2003 and has served on the faculty of the Industrial Engineering and Industrial Management department ever since. At Mercer, she's taught a variety of courses at the graduate and undergraduate levels. At Whirlpool, in addition to managing the usability group and conducting user research, she participated in a variety of global innovation efforts and worked with colleagues in a variety of fields in the US, Europe, Latin America, and Asia to promote customer-centered design. Her primary research and teaching interests are in ergonomics and human-machine systems design. She has conducted independent research investigating the link between usability and desirability in product design, worked with ARINC Engineering Services, LLC to provide human-systems integration support on a variety of projects for the US Navy, and has more recently been directing student teams on a number of projects with Piedmont Hospital in Atlanta and Disability Connections in Macon.