# DEVELOPMENT OF AN ERGONOMICS COURSE FOR ENGINEERING TECHNOLOGY

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## 1. INTRODUCTION

Application of ergonomics has become a vital part in general industry as the potential savings of having an ergonomics program in place are significant. Leading the list of workplace injuries is overexertion - injuries that can often be prevented or limited through ergonomics. Liberty Mutual calculates U.S. businesses are paying a staggering $15 billion to $20 billion on workers compensation losses annually. Leading the top 10 workplace injuries in 2003, according to the Liberty Mutual Workplace Safety Index, is overexertion costing $13.4 billion and repetitive motion at $3.0 billion (www.libertymutual.com).

The Occupational Safety and Health Administration (OSHA) aims to ensure worker safety and health in the United States by working with employers and employees to create better working environments. OSHA plays a vital role in preventing on-the-job injuries and illnesses. It offers extensive help to employers and employees for addressing hazards and preventing injuries by providing ergonomic information including guidelines for specific industries (www.osha.gov). As such, it is important for students in Engineering Technology programs to be well-versed in the basics of ergonomics.

To address this need, we created a course in Ergonomics in the Mechanical and Industrial Engineering Technology (MIET) program at Indiana University-Purdue University Fort Wayne. The course covers areas of ergonomics such as, human biomechanics, hand tool design, handling loads, postures at work, and types of musculoskeletal disorders. The course includes a written report and oral presentation of student projects showing application of the ergonomic principles and practices.

The course has nine laboratory experiments that students perform hands-on in groups. These experiments cover major areas of ergonomics such as, anthropometry, displays and controls design, bench layout, light and noise measurements, dexterity tests, reaction time, and measurement of heart rate for different levels of physical work. Due to limited time of a semester where the basic theory has to be covered, it was felt that these nine experiments are sufficient for students to understand the different topics in ergonomics.

The assignments, experiments, and project work together allow students to integrate and apply the course material, and obtain sufficient breadth and depth of knowledge. Equipped with this knowledge, graduates can help employers install and maintain effective ergonomics program.

This paper describes the course - its basic layout, assignments, experiments, and typical examples of assignments done by students. The paper also describes the assessment feedback obtained so far that helps meet a number of program outcomes.

## 2. BACKGROUND

There are two programs in MIET: Mechanical Engineering Technology (MET) and Industrial Engineering Technology (IET). Only IET majors are required to take the ergonomics class, although students in MET often times take the course as a technical elective and sometimes students from OLS (Organization Leadership and Supervision) take the course.

Our Industrial Advisory Committee recommended to add ergonomics in the IET and MET curriculum. The industrial interest was driven primarily because companies have realized the tremendous benefits these ergonomic programs have in their companies – as a way to increase ease and efficiency in work, and decrease potential ergonomic disorders and injuries. In addition, there is a possibility of having to meet and exceed anticipated state and national ergonomics standards.

There is Work Methods Design course that teaches methods engineering or method study and time study. This is a traditional course of methods simplification and motion economy. It was decided to develop the ergonomics course that would supplement the material covered in Work Methods Design but still be independent of it in structure, course content and prerequisites.

Initially, this course was meant for junior level students but with the feedback from coop employers and the need of industry for a 2-year associate degree student to have basic knowledge of ergonomics, it was decided in 2003 to introduce this course in the freshman or sophomore year when students are ready to do their coop assignments.

## 3. COURSE STRUCTURE

It is difficult for students to understand and for faculty to teach ergonomics without performing hands-on laboratory experiments. This course was therefore designed to teach ergonomics theory and principles in the first part of the semester and then let students work in teams to do the experiments. The course topics and the type of experiments performed by students is given in Table 1. Each student writes a separate laboratory report using and comparing the data obtained on all the members in the team.

Even though OSHA rules and safety topics are excluded from actual course, students can take up these topics in their written project work that they have to finish by the end of the semester. In addition, OSHA standards can now be accessed on the internet and relevant website addresses are given to the class from time to time to guide them on project selection and to supplement class material. Also, these topics are covered in semester-long courses in other programs such as OLS, and interested students can take such courses as part of their technical elective requirements.

Table 1: Ergonomics Course Content.

| Course Topics | Laboratory Experiments |
|---|---|
| Human Physiology and Anthropometry – percentile calculations | Lab 1: Perform Anthropometric Measurements |
| Biomechanics | Lab 2: Perform Dexterity Tests |
| Metabolism and Energy Requirements of Work | Lab 3: Use of Audiometer |
| Design for Standing and Seated Workstations | Lab 4: Use of Reaction Time Apparatus |
| Effects of Noise, Illumination, Vibration, Temperature | Lab 5: Use of Heart Rate Monitor–Treadmill |
| Design and Selection of Hand Tools | Lab 6: Use of Heart Rate Monitor–Bicycle Ergometer |
| Manual Handling and NIOSH Equation | Lab 7: Hand Dynamometer, Pinch gage |
| Displays and Controls | Lab 8: Displays and Controls |
| Assessment of Postures at Work | Lab 9: Design a Work Bench Layout |
| Cumulative Trauma Disorders | Lab 10: Use of Light, Sound, & Vibration Meters |

3.1 *Sample Assignments in Ergonomics*

Some sample examples of work done by students as assignments are shown below. It gives a broad picture of learning that students go through meeting some of ABET criteria requirements of use of current technical literature, math, application of technical skills learned in class. They represented under the different learning outcomes of the course (Kroemer, *et al.*, 2001):
On percentile calculations and use of anthropometric data in design: If a female is at 45$^{th}$ percentile in elbow height from floor, what is her elbow height measurement in mms? If a male has a wrist height measuring 830 mms, what is his percentile value of wrist height? Determine the seat height for accommodating 90% of the workforce. Determine the height of a standing work surface where units are packed in flat boxes as shown in Figure 1. The height of flat box is 150 mms. Your design should be able to accommodate 90% of the workforce. Calculate the mean and standard deviation of a male body dimension that is a difference of stature and standing wrist height.

On using illumination in design: Calculate the required illumination where workers of all ages can perform a critical (accuracy) visual task of low contrast and very small size on a workstation that has a reflectance of 20% (Niebel and Freivalds. 2003).

On using hearing and noise in design: The sound pressure level of a machine is measured in a noisy workshop and found to be 92 dBA. When the machine is switched off the background noise is 88 dBA. What would the sound pressure level of the machine be without the background noise? Calculate the noise dose and the TWA where a worker is exposed to the following noise levels: 95 dBA for 3.5 hours, 105 dBA for 0.5 hours, and 85 dBA for 4.0 hours (Niebel and Freivalds. 2003).

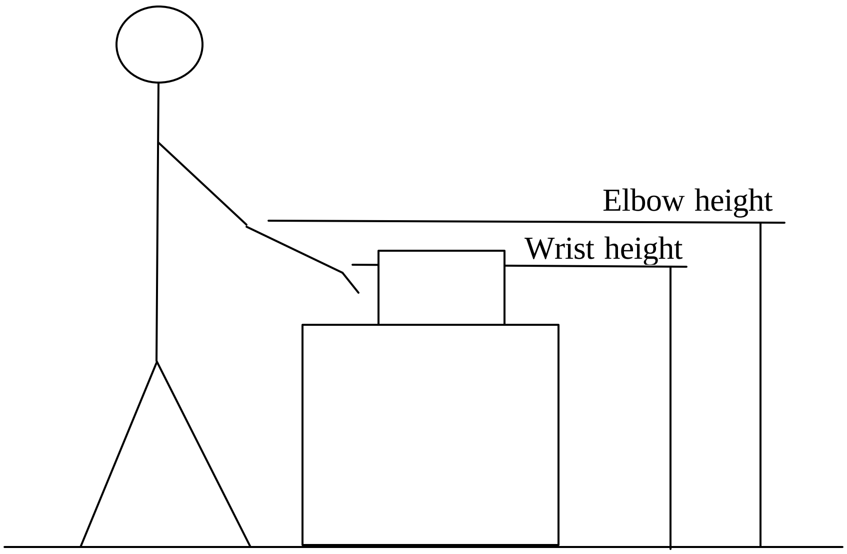


Figure 1: Determining Work Surface Height using Anthropometry.

On using posture assessment techniques: Apply the Nordic questionnaire and the RULA worksheet on an operation to analyze the job for potential ergonomic related injuries (Kroemer, *et al.*, 2001).

## 4. ASSESSMENT

As part of the course requirement, students complete a learning outcome survey immediately after their final exam when they are expected to have assimilated maximum of the course material.

Earlier, the learning outcome survey was given to the students in the last week of the classes. It was found that a number of students did not remember that certain topics were even done in class. Giving at the end of the final exam ensured that they had studied the course topics comprehensively and had them fresh in mind whether it prepared them to answer the questions on the final exam. This approach of giving the learning outcome survey after the final exam has worked successfully over the semesters in other courses as well.

For the survey students are asked to rate how well they learned a given learning outcome on a 0 to 10 scale, with 10 being ‘very satisfactory’ and 0 being ‘not satisfactory at all’. Table 1 contains the summary of their feedback for Spring 2004 class.

The learning outcomes also include their feedback on (a) functioning as a team in laboratory and (b) on use of effective verbal and written communication through project work that they present to the entire class and hand in a written report. Students are also given an opportunity to give general written comments on the survey sheet as well. Students commented in general that they liked doing the laboratory experiments, although opinions differed on the theory material. Some found it interesting and useful while few thought it was too abstract and detailed. Students did comment that the class assignments (given in section 3.1) helped them to appreciate the complexity of actual application of ergonomics. Overall student responses were positive and enthusiastic, and the only consistent suggestions for changing the course had to do with student dissatisfaction with the textbook.

## 5. CONCLUSIONS

Over the years, there has been greater interest in the knowledge of ergonomics to help reduce or avoid deterioration in worker health because of exposure to occupational work. Many industrial companies have taken a proactive step forward in implementing ergonomics program in their places of work.

Our introduction of the ergonomics course at an introductory level in freshman or sophomore years has been to meet the industrial need of graduates knowledgeable in ergonomics. The course gives sufficient skills in the breadth and depth in various topics of ergonomics.

At this time there are no major significant changes planned for this course. There may be need to make minor adjustments, but overall the course appears to be meeting its objectives according to both assessment data and student evaluation. The general feedback is that students are engaged in the course and are developing a grasp of the material to the desired level for an introductory course. The structure of first grounding in basic theory and then hands-on ergonomic measurements, and finally with an independent project work appears to be working well.

## 6. REFERENCES

www.libertymutual.com

www.osha.gov

Kroemer K. H. E., Kroemer H. B. and Kroemer-Elbert K. E. (2001) Ergonomics: How to Design for Ease and Efficiency, 2nd ed., Prentice-Hall, New Jersey.

Niebel B. and Freivalds A. (2003) Methods, Standards, and Work Design, 11th Ed., McGraw-Hill, New York.

Table 2: Course Assessment Summary of the Ergonomics course.

| No. | Learning Outcomes | Program Outcomes | 6* | 7 | 8 | HW | E1 | E2 | Lab | FE | S/NS** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Perform anthropometry calculations. | a2, f, k | | 1 | 2 | 92, 89 | 92 | | 94 | 86, 95 | S |
| 2 | Use human biomechanics in design. | a2, f, k | | 1 | 4 | 86 | | | 95, 96 | | S |
| 3 | Determine energy requirements of work. | a2, f, k | | 2 | 3 | 89 | 82, 91 | | | 94 | S |
| 4 | Use reaction time concept in work design. | a2, f, k | | 1 | 4 | 91 | 99 | | 95 | | S |
| 5 | Understand relationship between demand, capacity, and performance. | a2 | 1 | 1 | 3 | | 78, 89, 87 | | 84, 84 | | NS |
| 6 | Design work environ. for proper use of human senses. | a2, f, k | | 1 | 3 | 97 | 84 | | 93 | | S |
| 7 | Understand the effect of temperature and vibration on human body. | a2 | 1 | 1 | 5 | | | | | 94 | NS |
| 8 | Understand the effect of shift work on body. | a2 | | 2 | 3 | | | | | | S |
| 9 | Evaluate postures at work. | a2 | | | 6 | 80 | | | | | S |
| 10 | Design workstation for standing or sitting operator, and with appropriate foot controls. | a2 | 1 | | 5 | | 83 | | 88 | | NS |
| 11 | Apply design rules for hand tools. | f, k | | 1 | 2 | 83 | | 89 | | | S |
| 12 | Understand the different types of repetitive strain injuries or overuse disorders. | a2 | | 1 | 4 | | | 86 | | 95 | S |
| 13 | Design workstations to eliminate potential repetitive strain injuries. | a2, f, k | | 1 | 4 | | | | | | S |
| 14 | Design effective controls and displays in the workplace environment. | a2, f, k | | 1 | 1 | 82 | | 84 | 91 | 83 | S |
| 15 | Design effective handling of loads. | a2, f, k | | 1 | | | | 95 | | | S |
| 16 | Apply NIOSH formula for lifting or lowering loads. | a2, f, k | | 1 | 2 | 93 | | 83 | | 90 | S |
| 17 | Function effectively in teams. | | | 2 | 1 | | | | | | S |
| 18 | Communicate effectively through technical writing. | a2, d, i | | 2 | 1 | | | | | 89 | S |
| 19 | Communicate effectively through oral presentation. | g | | 4 | 1 | | | | | 87 | S |

* The number of students who gave scores of 6, 7, or 8, the least scores given on the 0-10 scale. Total Respondents = 14.

** Learning outcomes that should be improved are given as NS (not satisfactory).

Table 3a: Revisions for the Next Offering of Ergonomics course.

| **Program Outcomes** | **Recommendations to Improve Student Performance:** |
|---|---|
| a2 | Understand relationship between demand, capacity, and performance.<br>Understand the effect of temperature and vibration on human body.<br>Design of workstation for standing or sitting operator. |
| f | Homework on effect of temperature and vibration on human body. |
| k | Timeliness to be emphasized in homework due dates. |

Table 3b: Learning Outcomes for the Next Offering of Ergonomics course.

| **No.** | **Learning Outcomes** | **Assessment Method** |
|---|---|---|
| 1 | Perform anthropometry calculations. | HW, E1, Lab, FE |
| 2 | Use human biomechanics in design. | HW, Lab |
| 3 | Determine energy requirements of work. | HW, E1, FE |
| 4 | Use reaction time concept in work design. | HW, E1, Lab |
| 5 | Understand relationship between demand, capacity, and performance (HR graph, aerobic/anaerobic) | E1, Lab |
| 6 | Design work environment for proper use of human senses. | HW, E1, Lab |
| 7 | Understand the effect of temperature and vibration on human body. | HW, FE |
| 8 | Understand the effect of shift work on body. | |
| 9 | Evaluate postures at work. | HW |
| 10 | Design workstation for standing or sitting operator, and with appropriate foot controls. | E1, Lab |
| 11 | Apply design rules for hand tools. | HW, E2 |
| 12 | Understand the different types of repetitive strain injuries or overuse disorders. | E2, FE |
| 13 | Design workstations to eliminate potential repetitive strain injuries. | |
| 14 | Design effective controls and displays in the workplace environment. | HW, E2, Lab, FE |
| 15 | Design effective handling of loads. | E2 |
| 16 | Apply NIOSH formula for lifting or lowering loads. | HW, E2, FE |
| 17 | Hawthorne effect | |
| 18 | Function effectively in teams. | survey |
| 19 | Communicate effectively through technical writing. | Written report |
| 20 | Communicate effectively through oral presentation. | Project presentation |