# An Ergonomics Course for Manufacturing Engineering Technology Students

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## Introduction

Ergonomics has become an important part of manufacturing process design, for even without an OSHA standard in the area, the potential savings of having an ergonomics program in place are significant. As such, it is important for students in a Manufacturing Engineering Technology (MET) programs to be versed in the basics of ergonomic process design. To address this need, the Engineering Technology (ET) Department at Western Washington University (WWU) recently created a course in Manufacturing Ergonomics, Safety, and Health (MESH) for students in the MET program. The new course predominantly covers ergonomic process design, and it also includes a section on safety, health, and Occupational Safety and Health Administration (OSHA) regulations so that students are aware of responsibilities in that area as well. At the heart of the course are six active learning assignments, four on ergonomics and two on safety and health, that allow students to apply the course material to realistic and open-ended problems. The first two assignments are ergonomic assessments, one on body position during a work task and one on analyzing a lifting task. Students are required to find situations to observe for these two assignments, so they all analyze different situations. The next two assignments are design assignments, one for an assembly workstation and one for a process control panel. Students are all given the same specific problems for these two assignments. The final two assignments are on safety and health, one on researching an OSHA standard and one on an accident report. Students are given specific standards to research for the former assignment, but are required to find their own accident for the latter, so all students examine different situations. Together these assignments allow students to integrate and apply the course material. This paper describes the impetus for the course, its basic layout, the active learning assignments, including some examples, and the assessment findings so far.

## Background

MET is one of six programs in the ET Department at WWU. The department also has programs in Electronics Engineering Technology (EET), Plastics Engineering Technology (PET), Industrial Design (ID), Industrial Technology (IT), and Technology Education (TechEd). The Industrial Technology program supports options in Vehicle Design and CAD/CAM, as well as a Self-Designed option. Of these programs, only the three engineering technology programs fall under the rubric of ABET. The department has approximately 450 declared majors, 50-60 of them in the MET program, and currently has fifteen full-time and six part-time faculty with backgrounds ranging from Engineering to Art. Only the MET majors are required to take the MESH class, although students in PET, IT, and Manufacturing Management (from the College of Business and Economics) sometimes take the course as a technical elective.

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The MESH class is a complete rework of a Manufacturing Safety and Health course that had been part of the MET program since its inception. The old course was focused almost entirely on OSHA standards, although it did include one week on ergonomics. MET program faculty felt it was time for the course emphasis to change. No one was under the delusion that OSHA rules had become less important to manufacturing, but the change was an acknowledgement that getting students to memorize OSHA standards was less relevant given the ease with which the standards can now be accessed on the internet, coupled with the increased interest by our local industry in ergonomics, and our understanding that it takes a little more than a week to comprehend the fundamentals of a field as rich and diverse as ergonomics. Admittedly the industrial interest was in part driven by anticipated state and national ergonomics standards that have since been overturned, but that change has not stopped some manufacturers from seeking to introduce ergonomic programs as a way to increase efficiency and decrease the costs of injuries.

Courses on ergonomics are still relatively rare in manufacturing programs, and there does not seem to be agreement as to how and where such a course should be taught. Some programs teach ergonomics at the graduate level,[1] while other programs are willing to invest more resources into ergonomics so that they can include multiple courses, laboratories, and even minors in ergonomics and safety.[2-4] With the MESH course the ET Department at WWU has taken the approach that all students in MET should be introduced to ergonomics, but there is also a realization that resources are very limited, so a course sequence or laboratory is not possible. As a result, the MESH course relies on open-ended assignments to engage students and meet the course's overall learning objectives, which are listed in Table 1.

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| Understand how the human body limits the ability to do work |
| Assess a task's potential to cause injury |
| Recognize and alleviate ergonomic risk factors |
| Design an ergonomically safe workstation for a diverse population |
| Design a clear, effective, and ergonomically safe interface |
| Find and explain relevant OSHA standards |
| Find, interpret, and follow material safety data sheets |

Table 1: MESH Overall Learning Objectives

**Course structure**

The MESH course provides an overview of the field of ergonomics and an introduction to industrial safety and health. The course is intended to make students aware of the fundamental issues in ergonomic design and industrial safety and health, and make them aware of the resources that exist in those areas. An outline of the course topics is provided in Table 2. The course is not intended to be the first course in an ergonomics or human factors curriculum, so it does not go into great depth in any of the areas, especially topics on the human physiology. The course has a midterm and a final, but the at the heart of the class and student learning are six open-ended assignments that allow students to apply some of the ideas from ergonomics and explore issues surrounding OSHA in more depth. These assignments are: a task assessment, a lifting analysis, an assembly workstation design, an interface design, an OSHA standard summary, and an accident report.

| | |
|---|---|
| Introduction and Overview | Hearing |
| Anthropometry | Lighting Design |
| Biomechanics | Models of Decision Making |
| Human Physiology | Interface Design |
| Ergonomic Assessment Methods | Environmental Effects |
| Manual Materials Handling | Introduction to OSHA |
| Design for Standing Tasks | Machine Guarding |
| Design and Selection of Hand Tools | Hazardous Materials Safety |
| Design for Seated Tasks | Workers' Compensation |
| Sight | Safety Programs |

Table 2: Course Topics

*Task Assessment*

For the task assessment assignment, students are required to observe a work task for postural risk factors. Students are given a choice of task assessment tools. All of the assessment tools use a combination of joint angle thresholds (including back and neck angles) and time to assess the level of risk associated with the task; meaning that if a worker spends more than a certain amount of time with one or more of his or her joints held past a certain angle, then he or she is at risk for an injury due to posture. The assessment tools only truly vary in terms of level of detail, so students are encouraged to use more than one so that they can compare their findings with different tools. Students are responsible for finding a work task, they must observe the task for at least two hours, and they then must write a 1-3 page brief that describes the task, findings from the assessment, and suggestions for task improvement. Students generally select single person tasks such as clerking at a grocery store and changing the tire on a wheel.

This assignment serves to get students to look at work tasks with an eye toward ergonomics. Students are only required to observe the work task, but many try different methods of assessment such as video tape or still photography, and they, almost all, also interview their subject(s) to get a better understanding of the task and its difficulties from the worker's perspective. When work tasks are very rapid, such as the case of a grocery cashier, students find that they must study different aspects of the task at different times, so students might spend half of their time documenting wrist posture and half documenting back and neck posture. Students more often than not find some risk factor in the work task; this is probably in part a selection effect, for they choose tasks that are likely to have risk factors as it makes the assignment more interesting. What they discover, however, is that it is often easier to identify a problem than it is to come up with a reasonable solution, which in turn gives them more appreciation for the challenges of implementing an ergonomic program. Overall the assignment serves its purpose as an introduction to ergonomic assessment, and differences in grades are more of a reflection of students' ability to clearly and concisely express ideas than in the quality of their assessments.

*Lifting Assessment*

For the lifting assessment assignment, students are required to analyze a lifting task using both the National Institute of Occupational Safety and Health (NIOSH) and the Washington Industrial

Safety and Health Act (WISHA) lifting analysis tools. Both tools make use of the same basic information: weight of load, location of load relative to body centerline at pick up and drop off, frequency of lifting, and twisting of the torso. The NIOSH approach also includes distance traveled by the load and how easy the load is to hold (load coupling). The NIOSH tool is more conservative than the WISHA tool, so it is likely that students will get different answers as to whether the task is putting the worker at risk for injury. As with the previous assignment, students are responsible for selecting a task to analyze, doing both forms of analysis, and then writing a 1-3 page brief that describes the task, their findings, and suggestions for improvement if the task has been deemed to be unsafe. Students generally select tasks associated with retail such as unloading a truck or arranging a stock room.

This assignment is more challenging than the previous one in that students must collect a number of measurements on the task quite accurately, and then they have to perform the analysis properly in order to draw valid conclusions. Students rarely make an error with the WISHA approach (which speaks well to its use by non-experts), but more often than not students do make at least one error with the NIOSH approach. Sometimes the calculation error changes the results, and sometimes it does not. When calculations are done correctly, fewer students found lifting tasks that put the worker at risk than had found risky tasks in the previous assignment. Unlike the task assessment, however, students who did find risky lifting tasks were better able to suggest changes that would reduce the risk of the lifting task. This is due in large part to the fact that many of them found the worker was unnecessarily enhancing the risk by working too fast or stacking boxes too high in order to get the task done quickly. That training and proper procedure can reduce risk turns out to be one of the great lessons students get out of this assignment, and this seems to stick with them longer than the details of the NIOSH lifting analysis tool.

*Assembly Workstation Design*

For the assembly workstation design assignment, students are required to design a workstation for a standing or seated worker (their choice) who will be manually assembling a small product with at least ten parts. There are two major features to this assignment: students need to make use of anthropometric data, and students need to find an alternative to just laying the various parts containers out on a table, which will not keep everything within easy reach. Anthropometric data provides height, reach, and size information, and this in turn gives students limits for their designs. Students must determine what fraction of the population their workstation will serve, and what parts of it will be adjustable or reconfigurable. Students must design the basic layout, including the dimensional information, and they must also provide a 1-3 page description of their design and its features. In the Fall 2004 term, students were given a high voltage plug assembly for the workstation design problem. The plug had 14 parts, 10 of which were different, and students were told the size of the part containers and how many parts each one held.

This assignment requires students to think three dimensionally in order to achieve a solution that is both ergonomically sound and efficient. Students who do develop some kind of a design that includes tiers for parts generally develop a sound solution. Some students insist on keeping all of the parts on the same surface, and the result is a design that forces the worker to move around too much, which would be less efficient. Some students also find using the anthropometric data to be a bit of a challenge, but most become proficient with it quickly. A few students also turn in

solutions that are conceptually sound, but lack sufficient detail. It is difficult to discern if this is due to a lack of understanding of the use of anthropometric data, or is the result of procrastination, as the assignment takes most students longer than they expect it will due to the amount of detail necessary for a complete design. There are also a few students who fail to develop an ergonomically sound design. There are two causes for unsound designs: parts that are too far away, which is generally a problem with using the anthropometric data, and parts that require the worker to twist in order to reach them, which is more of a conceptual issue. Students who make the latter error also have a tendency to make the former error as well. Students do seem to get from this assignment as sense of what is required to develop an ergonomically sound workstation, and since most students will be entering the manufacturing field and will be expected to do some process design, this is also arguably the most important of the ergonomics assignments.

*Interface Design*

For the interface design assignment, students are required to develop an interface with displays and controls to allow a user to monitor and control a continuous chemical process. A typical process will have three input chemicals and one output chemical. Students' designs must be able to control flow rates and temperature, monitor pressure, and allow for the addition of a neutralizing chemical in the case of a potential run-away reaction. This assignment requires students to consider the selection of displays and controls, and also the layout of all of the components. Students need to provide details of the displays and controls used, and they also need to develop a detailed layout drawing of the interface. In addition students must provide a 1-3 page description of their design and its functions. In the Fall 2004 term students were given a chemical process interface with three inputs, one output, flow rate and temperature controls, flow rate, temperature and pressure sensors, and an emergency stop system to incorporate into their designs.

This assignment generally goes very well, and results in an impressive amount of variety in the designs. Information on types of controls and displays, what types are appropriate for what uses, and recommendations on sizes and relative locations are very well documented, and students are able to make use of this information very effectively. Most of the variety in the designs is the result of some students preferring analog displays, while others prefer digital displays, and the rest is generally the result of students developing standing or seated workstations. The only problem that arises with any consistency with student designs for this assignment is insufficient size and location detail, and as with the previous assignment, it is difficult to discern if this is due to lack of understanding or procrastination, as this assignment is also fairly time consuming to do thoroughly.

*OSHA Standard Summary*

For the OSHA standard summary assignment, students are required to research an OSHA standard and to prepare a written summary and an oral brief. Students are asked to take the perspective that their company is adding an operation that will result in having to meet an OSHA standard that has not previously been relevant such as the addition of a new chemical (e.g. acrylonitrile) or a new type of operation (e.g. oxygen-fuel gas welding) as part of the new process. The purpose of the assignment is twofold. The first is to get students to become comfortable finding relevant information at the OSHA website.[5] The second is to get students to become comfortable

translating the information from OSHA standards into a concise (1-2 page) yet thorough brief. A list of standards that students are likely to need to follow in industry is selected, and then every student is randomly assigned a standard on which to report, so that each student has a different standard to research, yet the class as a whole gets to hear about many different standards.

This assignment has variable challenges depending upon what standard students end up drawing and how well they write. Not all OSHA standards are equally easy to understand and summarize. Some standards are very long, and others are challenging to interpret and may require accessing additional references, while some standards are very straightforward. In addition, with the short page limit on this assignment, students have to be very direct and very organized in their writing. More than any other assignment, this one seems to favor students who have completed their technical writing requirement or have significant work experience and therefore understand expectations of brevity. Overall, the assignment seems to serve its purpose quite well, as students become familiar with how to find information on OSHA's vast web site, and become comfortable with the language and style of OSHA standards.

Unlike all of the other assignments, the OSHA standard summary also includes an oral presentation. Students are asked to give a 4-5 minute summary of the standard to their classmates without the use of props such as PowerPoint or overheads. The purposes of the presentation are to introduce students to the idea of giving informal briefings to their peers, and to make students aware of the vast number of OSHA standards. Students in the MET and PET programs end up giving at least ten formal presentations as individuals or part of teams, so they all become quite proficient at formal speaking, but they do not have many opportunities for informal speaking. Most students find the informal presentation to be no more challenging or intimidating than a formal presentation, but a small number of students are very uncomfortable giving a presentation without props, so it is a very good experience for these students. The presentations do make all students aware of the different types of OSHA standards, but they will need to look up details on any of them if they need to make sure of compliance at some time in the future.

*Accident Report*

For the accident report assignment, students are required to research an industrial accident, describe what went wrong and why, outline what relevant OSHA standards were violated, and explain how a similar accident can be avoided in the future. Students are once again asked to take the perspective of preparing a brief for their supervisor. In this case students are asked to pretend that they work for a company in the same industry as the one at which the accident occurred, and that their boss heard about the accident and wants to make sure that it is unlikely to occur at the students' company. In some sense this assignment builds off of the previous assignment in that students often have to look up several OSHA standards to complete their reports. Unlike the previous assignment, however, students are required to find information about the accident on their own. Students must either select an accident at a site that was under the purview of OSHA, or must select an accident that led to the development of safety standards in that area or industry. The accident does not have to include fatalities, but most students find accidents that do in part because the recording of fatal accidents is often more thorough. Since students must summarize the accident as well as outline the relevant OSHA expectations, students are asked to write a longer (3-5 page) brief than they are allowed for the other assignments. Students generally select

smaller accidents involving one or two people, but they find very diverse accidents. Accidents have included a hand injury while cleaning out a CNC, a gas explosion while welding in an enclosed space, loss of consciousness in a spray both, and many construction accidents. A few students look for more spectacular events, and they select events like explosions at chemical plants.

This assignment is either the most interesting or the most frustrating for the students depending upon how much difficulty they having finding information on an accident that interests them. Finding reports on industrial accidents is fairly easy, but finding enough detail to be able to reference specific OSHA violations is more challenging. Nevertheless, there are more than enough accidents out there with sufficient reporting to allow everyone in class to find a different one whether they are interested in a single person accident or a chemical plant explosion. Once students get past the hurdle of finding information they consistently do a good job with this assignment, and they seem almost universally impressed with how disregard of safety standards almost always is the significant factor in the accidents. In most cases there are multiple safety violations, and the lack of regard for safety is sometimes hard to believe. As a result, this assignment makes a good ending to the course because it leaves a strong impression on the students, and it seems to help cement in their minds the importance of maintaining thorough and consistent safety standards.

**Assessment**

As part of this course, students complete an exit survey on their learning in the course. In a great sense exit surveys measure student confidence as much or more than student learning, but they still provide valuable feedback on the course and where it is falling short of its goals. For the survey in the MESH course students are asked to rate how well they learned a topic on a 1 to 5 Likert scale, with 5 being 'very significantly' and 1 being 'not at all'. Table 3 contains the questions and average responses for the Fall 2004 class of 18 students.

| Learning Outcome | Avg. | S |
|---|---|---|
| Understand how the human body limits the ability to do work | 4.19 | 0.75 |
| Assess a standing work task's potential to cause injury | 4.56 | 0.63 |
| Assess a seated work task's potential to cause injury | 4.44 | 0.63 |
| Assess a manual materials handling task's potential to cause injury | 4.40 | 0.51 |
| Assess a task's potential to cause injury based on loads on the body | 4.19 | 0.91 |
| Assess a task's potential to cause injury based on body postures | 4.50 | 0.63 |
| Design an ergonomically safe workstation for a diverse population | 4.25 | 0.78 |
| Design a clear, effective, and ergonomically safe interface | 4.27 | 0.80 |
| Find and explain a relevant OSHA standard | 4.50 | 0.63 |
| Understand the uses and importance of material safety data sheets | 3.56 | 0.89 |
| Understand the uses and importance of maintaining a safety program | 4.06 | 0.77 |
| Apply creativity in the design of ergonomically safe workstations | 3.94 | 1.00 |
| Improve your ability to write precise and concise reports | 3.56 | 0.96 |
| Understand the ethical responsibility to maintain ergonomic and safety programs | 3.94 | 1.00 |
| Develop a commitment to quality, timeliness, and continuous improvement | 3.33 | 1.11 |

Table 3: Student Learning Outcome Exit Survey Results

The first eleven outcomes encompass the primary learning objectives of the course, so the goal is that the average student rating for each of these will be 4 or higher. While the overall results are quite good, and students seem satisfied with their learning, clearly the course needs to put more time into material safety data sheets and into maintaining safety programs. The last four outcomes are secondary learning objectives in the courses, so the goal is that the student rating on each of these will be 3 or higher. As such, the course is meeting its goals in these areas.

Students are also given an opportunity to give written comments on the feedback sheet as well. Students commented in general that they liked the various assignments, although opinions differed as to which was the most fun/interesting/useful. Students did comment in various ways that the assignments helped them to appreciate the complexity of actual application of ergonomics and safety programs, and they felt that this was especially important because the topics seem to be so straightforward until you actually try to apply them to industrial situations. Overall student responses were positive and enthusiastic, and the only consistent suggestions for changing the course had to do with student dissatisfaction with the time of lecture (before 10:00 a.m.) and the textbook.

## Conclusions/Future Work

At this time there are no significant changes planned for the MESH course. There will be some minor adjustments, but overall the course appears to be meeting its goals according to both assessment data and observation. As a result of the new structure with active learning assignments, students are engaged in the course and are developing a grasp of the material to the desired level for an introductory course. The six active learning assignments—task assessment, lifting assessment, work station design, interface design, OSHA standard report, and accident report—are the heart of the course, and they are the reason that the course is able to meet its goals.

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