Outcomes-Based Ergonomics Education

Proposed Course Content

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This article examines minimum content that academic institutions should cover with respect to ergonomics. Such education will strengthen the portfolios of graduating safety and health professionals and make them more marketable to prospective employers.

OSHA'S ill-fated ergonomics program management standard was intended to prevent work-related musculoskeletal disorders (MSDs)—a leading problem in American workplaces. According to agency estimates, if implemented, the standard would have prevented 460,000 injuries each year; OSHA stated that these efforts would cost employers $4.5 billion annually, but would yied an estimated yearly savings of $9.1 billion. Despite the regulatory defeat, ergonomics will likely remain a compliance issue and citations will likely continue under the General Duty Clause.

The term MSDs encompasses overexertion and repetitive motion injuries such as back injuries, carpal tunnel syndrome and tendinitis. About 1.8 million of these disorders are reported each year, and OSHA estimates that an additional 1.8 million go unreported. Of the reported cases, approximately 600,000 are serious enough to cause people to miss work.

This article examines minimum content (structured around ABET criteria) that academic institutions should cover with respect to ergonomics. Such education will strengthen the portfolios of graduating safety and health professionals and make them more marketable to prospective employers. In addition, while this information is presented in terms of undergraduate study, the topics covered also apply to current practitioners seeking to expand their knowledge of the ergonomics field.

COURSE CONTENT CRITERIA

In accordance with the criteria for accrediting engineering-related programs, the Accreditation Board for Engineering and Technology (ABET) requires safety graduates to demonstrate competency in ergonomics (among other disciplines) in order to obtain a B.S. in Safety. While no competency guidelines or outcomes criteria for ergonomics (or any other specific course) are listed, outcomes criteria for the safety program as a whole have been outlined. Under these, graduates must demonstrate:

1) knowledge of contemporary issues within a global and societal context;

2) understanding of ethical and professional responsibility;

3) an ability to function on multidisciplinary teams;

4) an ability to analyze/interpret data;

5) an ability to apply knowledge of mathematics and science;

6) an ability to anticipate, identify and evaluate hazardous conditions/practices;

7) an ability to develop hazard control designs, methods, procedures and practices ("Criteria for Accrediting" 16).

ABET also publishes a list of course content assessment guidelines that its examiners use to evaluate these outcomes. None of these references provide guidance on actual course content.

In addition to accreditation requirements, academic curriculum is influenced by factors such as the demands of the job market. Graduating students must have competencies that employers find valuable. Therefore, a course (and overall academic program) must not only satisfy accreditation requirements, it must also meet needs of the customers—the students and industries that hire them. The following recommendations outline course content for undergraduate ergonomics education that the author believes will satisfy these needs. Identified topics need not be covered separately under one or two courses, but may be incorporated into other courses (such as systems safety, industrial hygiene and safety engineering) where appropriate.

KNOWLEDGE OF CONTEMPORARY ISSUES WITHIN A GLOBAL & SOCIETAL CONTEXT

In this age of globalization, such knowledge is crucial. To fully comprehend current affairs in the U.S. and internationally, students (and current practitioners) must understand how the field has evolved over the years; such knowledge also sheds light on skills that will be required as this evolution continues.

In addition, regulatory issues are continuously changing; these activities have far-reaching effects on industry and consequently on society. Staying current on these issues requires an understanding of the rulemaking process and the regulatory climate that exists in Washington, DC. With such understanding, safety professionals can successfully participate in any lobbying efforts regarding regulations—a duty that a future employer may require. It is also important to understand how future standards may affect the nation's ability to compete globally.

Working for a multinational corporation typically requires an understanding of the regulatory climate in foreign countries as well. For example, significance of global and cultural anthropometry should be covered. Entry-level professionals may be expected to design systems for use in other countries and must understand the anthropometric differences among world populations.

One study found that Japanese males had shorter arms and legs than Caucasian males, but that their torsos and mean sitting height were not much different (Huchingson 77). In the U.S., most anthropometric data in use are based on studies conducted on U.S. military populations during the 1960s and 1970s; these data have been extrapolated to civilian populations because to date, anthropometric surveys of civilians have been rare (Kroemer, et al 28; Robinette 18).

Finally, the assumptions that anthropometric dimensions are normally distributed and that an individual has the same percentile body dimensions as his/her stature is invalid and may lead to serious design compromises (Vasu and Mital 19).

Staying current on issues such as vendor equipment, software and technological advances will serve to address requirements under this section as well.

UNDERSTANDING ETHICAL & PROFESSIONAL RESPONSIBILITY

Practitioners in the field of ergonomics have a professional and ethical responsibility to influence human-machine systems to minimize misuse and harm to users. Therefore, the overriding philosophy presented in academic courses should be that when it is equally easy to perform tasks the right way as it is to perform them incorrectly, humans will invariably do things the right way.

The challenge is to design systems that are easier to use the right way than the wrong way. From a practice perspective, safety professionals must acknowledge the following:

1) Systems are built to serve humans—not the other way around—and must be designed with the end user in mind.

2) Differences in human capabilities and limitations have design implications.

3) Individuals, work methods, equipment and environments do not exist in isolation.

4) Design of the work environment, methods and equipment influence human behavior and well-being (Sanders and McCormick 5).

Students must also understand that ergonomics encompasses much more than merely completing checklists, applying guidelines or using common sense. It requires a systematic, dedicated approach to understanding the user and designing systems accordingly. The science of ergonomics in the workplace attempts to optimize the interaction between humans and machines interfacing within an environment to achieve a set of systems goals.

Systems goals are invariably geared toward bottom-line results. In addition, optimum systems are not ideal systems and will always have residual risks that must be shared by the worker and the company. Thus, safety professionals must continuously strive to convince management that when circumstances dictate (when a recommendation is based on cost-avoidance rather than cost-justification), management should be willing to accept more of the initial risk.

Anyone hoping to practice ergonomics in industry will be asked to justify ergonomic changes—often in economic terms. In most cases, savings arise from reducing workers' compensation (WC) and medical costs, eliminating citations and fines, cutting litigation costs and the resulting increases in productivity due to reduced absenteeism, turnover, downtime and non-value materials handling.

Beyond these visible economic issues, one can also point to more-subtle issues that, if ignored, can negatively affect the bottom line. For example, consider employee well being. Apart from morale and other ethical issues, it makes good business sense to care about employee well-being especially involving a relatively "difficult-to-prove" class of trauma such as repetitive motion. If employees believe their well-being is being ignored, they may "convert" minor injuries (no missed days) to major injuries involving several days off.

ABILITY TO FUNCTION ON MULTIDISCIPLINARY TEAMS

By its very nature, definition and approach, ergonomics is multidisciplinary; it encompasses fields such as psychology, cognitive science, physiology, biomechanics, anthropometry and industrial engineering. In industry, the ergonomics function rarely exists in isolation and is invariably part of another department such as human resources, safety and health, or compliance engineering. In addition, success in ergonomics requires a true team effort.

Team members will likely have varied backgrounds, experience and personalities; the ergonomics practitioner must be able to work with this diverse group to achieve established goals. Therefore, students must be given the opportunity to work in teams in the academic environment. Class group projects that provide an opportunity to present to and convince others will enhance skills in this area.

ABILITY TO INTERPRET & ANALYZE DATA

In addition to methods for interpreting and analyzing existing injury data, students must also know how to develop injury predictive statistics. In addition, they must learn how to express data in ways that will convince management of the need to address identified issues. Understanding how to gather, analyze and present injury data is a key component of that process.

In many cases, ergonomic principles are used to address non-traumatic (occur over time) strains, sprains and back injuries. To conduct meaningful analysis of data on MSDs, hours worked (or head count) by job and/or department must be documented. This will permit calculation of incidence and severity rates, which will permit equitable comparison of injury statistics across a company's departments and jobs. Such statistics also enable a company to compare itself to similar operations (based on SIC code). (*Author's note:*

Although OSHA's rule on Occupational Injury and Illness Reporting is final, the requirement to record MSD information on the new OSHA 300 log will be delayed while the agency clarifies key definitions concerning MSDs.)

WC costs are another important measure. If the goal is to compare jobs and departments, then WC cost per (production) hour is more relevant than total WC costs. These statistics can also be used to establish corrective action priorities.

Beyond understanding how to track and understand after-the-fact statistics, students (and practitioners) must be able to generate and analyze other measures and data on proactive approaches to injury prevention. Monitoring unsafe acts and/or conditions either continuously, or through statistical sampling, is one such method. For example, poor lifting practices and hand and wrist motions (e.g., wrist flexion beyond a recommended range) are unsafe acts. Policies, procedures, training and engineering changes could target such behaviors and conditions to ensure that injuries do not occur in the first place.

With respect to expressing data in terms that will convince management to act, consider the following situation. A company has gross sales of $7 billion with a 15-percent average margin per unit on its product, which sells for about $1. One particular year, the company has $30 million in WC costs.

While this is a large amount, it has an even greater impact on management when expressed in terms of sales, production and operating margins. For example, based on these figures, the company would have to generate about $200 million ($30 million/0.15) in sales just to offset its WC costs. If the amount of time required to produce $200 million worth of product is considered, it would idle a strategic production facility for about 2.5 months. Such a comparison is particularly powerful in this case because on one occasion, a strategic facility had a double power failure (backup failed too), which caused the plant to shut down for one day. This event prompted the CEO to call the plant manager and led to large insurance claims.

ABILITY TO APPLY KNOWLEDGE OF MATH & SCIENCE

Topics that will help students strengthen and apply their knowledge of mathematics and science include:

- Information theory and applications will require students to work with logarithms, statistical probabilities, regression parameters and graphical interpretations (Kantowitz and Sorkin 137-191).
- Biomechanical analysis and applications will test one's ability to apply physics, statics and dynamics to the design of safe manual materials handling limits (Chaffin and Anderson 1+).
- Work physiology and anatomy of the musculoskeletal system, and health issues of work at computer workstations will make students apply their knowledge of biology and related sciences to evaluating jobs (Astrand and Rodahl 1+; Scalet 1+).
- Another opportunity to apply statistics will be provided in applied anthropometry where calculating the range and variability of various body links dimensions for workstation design requires the manipulation of at least the normal distribution (Tayyari and Smith 41-63).
- Students will demonstrate their ability to use and manipulate equations and data through the application of the NIOSH lifting equation, push/pull/carry tables and other manual materials handling analysis techniques (*Applications Manual* 1+; Snook and Ciriello 1197+; Ayoub and Mital 1+).

ABILITY TO ANTICIPATE, IDENTIFY & EVALUATE HAZARDS

The first step in the hazard control process is to identify hazards/conditions that need to be controlled. Hazards can then be ranked by level of risk in order to establish corrective action priorities. This process requires the application of various analytical tools. The following topics are suggested minimum requirements in this area.

Human Factors

- review of human capabilities and limitations;
- human information processing and application that includes:
  - reaction/response times;
  - single and multidimensional information coding and presentation;
- concepts of compatibility, redundancy, channel capacity, stimulus dimensions, stimulus recognition and discrimination;
- influence of learning on motor skill development;
- human performance and human error—evaluation and control.

Applied Work Physiology

- physiological measures and their applications to work evaluation and design;
- measurement (especially in-situ) and interpretation of physiological measures;
- workings of the respiratory, circulatory and metabolic systems;
- concepts and applications of energy expenditures, fatigue, shiftwork and rest breaks.

Occupational Biomechanics

- musculoskeletal anatomy and body planes relevant to ergonomics;
- occupational and non-occupational causes of MSDs;
- musculoskeletal mechanics (static and some dynamic analysis) of the back, neck, shoulder and wrist, including center of mass calculations for various anthropometric link configurations.

Applied Anthropometry

- sources of anthropometric variability and their design implications;
- statistical calculations related to anthropometry;
- concepts and significance of static Vs dynamic anthropometry;
- generation of class anthropometric data on selected link dimensions (group project) and comparing this data to available U.S. population data.

Manual Materials Handling

- factors affecting manual materials handling;
- use of the NIOSH lifting equation to analyze and rank lifting/lowering tasks by levels of severity (*Applications Manual* 1+);
- application of psychophysical data to analyze and rank push/pull/carry tasks by levels of intensity (Snook and Ciriello 1197+);
- use of techniques such as rapid upper limb assessment (RULA) and methods developed by the American National Standards Institute Z365 committee to determine the relative severity of tasks involving repetitive motion (McAtammey and Corlett 91+);
- use of static strength and energy expenditure prediction software to evaluate manual materials handling tasks.

Seated Work & Work at Computer Workstations

- theories of sitting and work posture;
- evaluation criteria for office and data entry work;
- ergonomic issues of working at computer workstations;
- safety and health issues related to use of video display terminals.

Safety professionals must be able to express data in ways that will convince management of the need to address identified issues. Understanding how to gather, analyze and present injury data is a key component of that process.

The Controlled Environment

Principles and design applications of these topics as they afect human work:
- noise and vibration;
- temperature and humidity;
- lighting and glare.

ABILITY TO DEVELOP CONTROL DESIGNS, METHODS, PROCEDURES & PRACTICES

Once hazards have been identified and ranked according to risk, controls can be developed and implemented. Identifying appropriate controls is the first step; however, one must also consider the issues of paying for and implementing these controls. The three key factors in this area are technical, economic and implementation feasibility.

Technical feasibility refers to whether the technology needed to control the hazard is available or can be developed. The two major categories of controls are engineering and administrative. Engineering strategies include automation, workstation design (sit/stand, reach, clearance and posture), job design (job enlargement, rotation, rest breaks, shiftwork) and mechanical aids (tool balancers, scissors lifts, vacuum hoists). Administrative strategies include personnel selection and placement; training and education; medical management; uniformity of work; exercise programs; housekeeping practices; and maintenance procedures.

Economic feasibility refers to whether suggested controls can be paid for; it can take the form of cost savings or cost avoidance. Typically, hazard controls will be sanctioned if the return on investment (ROI) generated by their implemention meets or exceeds the company's minimum ROI requirement. However, controls based on cost avoidance are more difficult to sell. Here, strong analysis skills (such as those discussed earlier) will be valuable, as will a basic understanding of economic analysis and project justification techniques.

Implementation feasibility refers to whether a control can be successfully implemented. Not all controls that are technically sound and economically feasible are implemented successfully. Implementation efforts may raise policital issues; thus, the practitioner must work with all affected parties as early in the process as possible. This includes employees, who will interface with the controls. In the academic setting, students should be given the opportunity to address these issues via individual and/or group projects.

CONTENT EVALUATION

Internally, documentation must be maintained and tracked to determine whether course content is being administered in accordance with proposed goals and objectives and to support an ABET evaluation (if sought). This could take the form of representative grading materials sampled from, but not limited to, tests, quizzes, projects and assignments.

Externally, the institution must determine whether the material being taught is relevant. Feedback in the form of surveys of alumni, employers and practicing experts are a good start. In addition, faculty should stay current on regulatory and technical advancements in the field through consulting, plant visits, internships, seminars, conferences or other relevant professional development activities.

CONCLUSION

This article has provided guidelines on minimum course content for ergonomics education at the undergraduate level. ABET program outcomes criteria and OSHA's since-defeated ergonomics program management standard were used as a basis for these guidelines.

The reasons for such guidelines are many. First, despite the revocation of the federal standard, ergonomics will remain a compliance issue; in addition, the agency is likely to pursue new rulemaking in the future. Second, while ABET has established program outcomes criteria and course content assessment guidelines, no guidance is published on actual course content. Finally, in addition to attempting to address requirements of academic accrediting bodies, such programs must satisfy the needs of industry, where MSDs continue to be a cause for concern. ■

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