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Abstract

In this article, we are presenting a senior level course module on ergonomics that was developed at Purdue University. Instead of lecturing on the basic principles, this course module consisted of two core exercises. The exercises were based on a computer simulation package available on campus. With a two-hour brief of the domain knowledge, students learned how to manipulate the manikin in a virtual environment to accomplish a given task. After the students became familiar with the major functions of the software, various assembly process plans from industry partners were distributed, where the individual students were to model and verify human operations specified in the worksheets. Through the "hands-on" experience and group discussion in a problem-based learning setup, students were exposed to various topics of ergonomics in the workplace. The topics included postures, movements, viewing angles, and mental loads along with possible injures and health concerns. It appeared that the students' awareness and attitude toward ergonomics had significantly changed after taking this course module. A follow-up study to evaluate this course and investigate its potential contribution to undergraduate engineering and technology education is discussed at the end of the article.

Introduction

With the advance of information technology, today's market place has become more competitive than ever. Through the fully-developed supply chains, manufacturers are able to polish their edge by outsourcing part of their original operations. The outsourcing can be to other companies or to other countries with the benefit of lowering their production cost. However, as more and more key components become standardized and interchangeable, the difference between similar products due to technology gradually diminishes. To survive in this micro-profit age, it is not advantageous for a company to solely focus on product quality or functionality. Consumers are paying more attention to product design aspects such as aesthetics or ergonomics, which are more subjective and user-centered. One important example is the Apple Computer's iPod that was the top thirty percent of the 2004 mp3 music player world market[1]. While it may take time to foster an industrial designer, whose simple strokes could dramatically change aesthetic features, we believe that ergonomic properties can be achieved by an average engineer with proper training. Although some engineering disciplines such as Industrial Engineering have incorporated ergonomics into their curriculum, as a standalone subject, it is not easy to address related principles in this subject in regular product design courses without a specific effort.

In today's market place, the strategies that manufactures use to differentiate their products and changes made in new product design also has to address the ergonomic concerns. First, as the increasing complexity of new products brings better functionality, it also introduces more chances of human mistakes. An ergonomics-sensitive product design, not only is able to reduce the frequency of error,[2] but also would reduce the time for technology adoption. Secondly, as more products become customized or customizable, more human labor would be involved in every stage of product lifecycle activities. Principles and guidelines in ergonomics will help increase both the safety and efficiency[3] of these operations. Lastly, with a longer service life and a growing public environmental awareness, product sustaining and recycling activities become more important than ever. Engineers and technicians for product delivery[4] really need to pay attention to ergonomics issues right from the beginning.

In this paper an ergonomics module taught in an elective senior course is discussed in detail, including its design rationality, general information of the students, selections of themes, exercise design, different forms of assessments and their outcomes. This article is concluded with possible future improvements.

Course background

Product Lifecycle Management (PLM) is the latest IT innovation floating around in today's manufacturing industry. Purdue University has been engaging in PLM-related activities since 1999. Through the strategic partnerships and collaborative projects with industry and software vendors, Purdue University has built a strong reputation in the PLM area during the past six years. While many industries are interested in PLM, Purdue University has learned from our industry contacts that there is currently a great shortage of PLM-literate workforces. Recent college graduates do not have the necessary training to view the problem from a systematic aspect, although they might be proficient in using certain CAD/CAM software.

Realizing a lack of pertinent training might resulting from a poorly integrated curriculum, the faculty members at Purdue University have been working to reform the existing PLM-related courses. One of the efforts is the offering of the Computer Graphics Technology (CGT) Minor curriculum[5]. The minor allows engineering- and technology-majored students to be exposed to various aspects of PLM. In addition to the Freshman Engineering Drawing course, the minor requires the students to take another four courses, including Solid Modeling, Surface Modeling, Manufacturing Graphics Standards, and one of the following two courses, Industrial Applications for Simulation or Manufacturing Documentation Production and Management.

The first three courses offered in the students' sophomore and junior years, are intended to build up the students' basic PLM knowledge and skill sets. The final two senior-level electives provide a problem-based learning environment to help the students integrate what they have learned into a bigger picture. Based on the past content of industry projects, various scenarios or problems are assigned to students to apply what they learn in lectures and labs to solve real world PLM-related problems. The first course focuses on the application of computer-based simulation in the four product lifecycle activities; design; planning; manufacturing; and sustaining. In contrast, the second course focuses on the production, storage, and retrieval of product document (or data) during the design and post-design periods; the possible interactions between PLM and ERP, SCM, or CRM are also discussed.

The ergonomics module reported here is part of the elective Simulation course; the other two modules of this course are design verification and process planning. The design and delivery of this course provides students authentic hands-on experiences by solving real life problems in a multidisciplinary environment. More information about this course can be found in this reference[6].

Learner analysis

This senior level course was fully redesigned in 2004, and in the Fall semester of 2005 seventeen students were enrolled. Students came from either Aeronautics and Astronautics Engineering or Computer Graphics Technology. Several students in this class had previous co-op or internship experiences from major manufacturing companies such as Boeing, Caterpillar, and Rolls-Royce. The knowledge and experiences brought in different industry practices and ways of thinking, which enriched the course content and authenticity of in-class discussions greatly.

Given that this course was offered for senior level students, the majority of them had taken at least two courses in Purdue's CGT Minor curriculum, Solid Modeling and Surface Modeling, which provided the necessary CAD skills. As the ergonomics module was the last one taught in the elective course, the students already had basic knowledge of design verification and process planning. Students met for two one-hour lectures and one two-hour laboratory section every week; and to work on assignments and projects, some students also met outside of class.

Design rationale

Since the principles of ergonomics can be very abstract and conceptual, it is not easy to teach those principles in a regular lecture-based environment[7], and the lack of hands-on experiences does not grant students opportunities for solid cognitive building. Today, the graduates from many well-known undergraduate engineering and technology programs are trained to concentrate on machines rather than the human user's well-being. Thus, one critical component in our teaching of ergonomics is to always bring students to the user, as other courses they have had in the past mainly emphasize the issues of product functionality and product manufacturability. The consequences of missing the human element in engineering and technology education could be the creation of mad scientists or evil engineers instead of a human-being with a balanced world view and the ability to respect life.

With the human-first idea in mind, the subjects covered in this module included both physical and cognitive ergonomics. The goal of this module was to help the students further engage the discipline of ergonomics and be able to apply what they have learned in their careers[8]. It was expected that the students would be able to reach all six levels of Bloom's Taxonomy of education[9]. They would learn the key domain knowledge, comprehend the context of information provided, apply theories to solve problems, analyze the given situations, synthesize the available resources, and evaluate the feasible solutions to find the best answer.

To reach our goal and the performance expectation, we adopted two popular educational strategies in our module design, active learning[10] and problem-based learning[11]. Students were asked to engage in various ergonomics problems by hearing lectures, reading the provided guidelines and case studies, discussing ideas in class, conducting design and analysis for given scenarios, and writing technical reports at the end. Rather than solving a well-defined textbook problem, students were given a real-world situation with intentionally vague description. They had to utilize and synthesize what they had learned to identify the real problems, define the problem scopes, and in the end solve them.

Exercise design

The details of the exercise design, is discussed in the following: Before the first regular lecture hour, students had to finish a reading assignment which was composed of an overview of what ergonomics is by UK's Ergonomics Society[12] as an attention catcher, and two case studies available online that addressed physical ergonomics in workstation design[13] and cognitive ergonomic in cockpit panel selection[14] respectively. The overview article gave the students an idea of what to expect in this course module, and the case studies were to bring them immediately to the ergonomic applications. Students would turn in reflection papers by answering given questions afterward. Two-hour lectures were then given as a review of their readings; and the activity of critical thinking was conducted in class through questioning and discussions among all the class participants.

Next, a laboratory assignment was designed to help students learn an ergonomics software package. In this assignment, students were asked to create a computer simulation of a simple manual operation often seen in our daily life. A manikin (e.g. the computer model of a human operator) would walk to the assigned location to pick up an object with one hand, carry this object up a flight of stairs, walk the cat walk, set the object down on a storage space and push the object inside, then walk back to the starting point. A similar exercise was repeated later but this time the operator would carry the object with both hands. The average time for creating this simulation was around eight hours with the help of step-by-step instructions. Through this exercise, students were exposed to a virtual human-being in an ordinary environment; they were able to move the parts of the body to create the intended movements. In the meantime, their new knowledge of physical ergonomics was reinforced by trial-and-error and comparing their simulation model with real human motions.

Following the laboratory assignment was the industry project mentioned earlier in this aticle[6]. In this project, the assembly line of a transmission valve body of a major automotive maker was studied. Students were divided into project teams and each team was responsible for simulating one portion of the assembly line that included both automated and manual stations. A text-based process plan describing the required assembly tasks was provided to students, who would then build the simulation models of manual stations with the ergonomic software package. Moreover, students were asked to consider to the following issues of workstation design; effectiveness of safety features, mental load of the operator, and the efficiency of the design. The time allotment of each operation would usually not mean much to the students in the beginning, but started making sense as soon as they plugged those numbers into their simulation model. For the automated workstations, not much ergonomic information was provided in the process plan, but students were asked to conduct a quick examination on the station's design to see if there were any design flaws that might cause safety problems.

In addition to the laboratory and project assignments, we also gave the students a quiz during the course to evaluate their learning of ergonomics. Rather than asking students to memorize the ergonomics design guideline, they were tested through a case analysis. The examination used the Sikorsky S70A as the subject of study; students served as ergonomics experts who worked for a major hospital in Los Angeles. To better serve their clients in this metropolitan area, this fictional hospital wanted to buy a crew of S70A for patient transportation. To customize this purchase, students were asked to give suggestions on the cabinet layout of the helicopter as well as the selection of the cockpit panel. The former task was the reflection of their first reading case on physical ergonomics of workstation design, while the later task was a mirror of their second reading case on cognitive ergonomics of pilot perception. A discussion section was given after the quiz; students were invited to present and defend their design recommendation. Based on the students' feedback and our observation, while this case analysis was given in the form of an assessment, it could actually be considered as part of their learning process.

Assessments

Formative and summative assessments were conducted throughout the process. By reading their written assignments and classroom interactions, we would be able to provide the students feedback on the learning outcomes in a timely fashion. A case analysis based final examination was used as a summative evaluation. One of the two scenarios in this examination was on functionality of a newly designed backhoe, while the other is on simulating the day-to-day operations for a fictional private airplane maintenance site over at Purdue's airport in West Lafayette, Indiana. Students were asked whether they grasped the intrinsic ideas of how to build computer simulation and what to pay attention to for design verification. As the scenarios were stated in an open-ended way, we were able to probe students' norms in the course topics and detect misconceptions and patterns of the learning process, as well as how certain knowledge was applied during the process.

The outcome of the final examination was interesting. For the airplane maintenance scenario, most students were able to address the ergonomics design issues in the operation and identified the information needed in order to create simulation models for verification purposes. However, for the backhoe scenario, while our intention was for students to pay attention to the kinematics of the machine arm and structure strength of the new shovel, more than two-third of students spent a lot of effort describing the necessity of ergonomics. Such a result could be because this subject area was the last one they learned in class, or they were so impressed by the exercises they completed that they were ready to care for the human well-being in their work.

In addition to what has been mentioned, we also did assessments on students' attitude toward ergonomics. A survey was given at the beginning of the semester and students were asked to evaluate their proficiency in ergonomics compared to other subjects such as CAD or PLM. Out of the fourteen responses we collected from the students, the average was around 1.5 out of a five-point scale where 5 being the best and 1 being the worst. A test was given at the end of the semester, and out of the fifteen responses, the average of students' self-evaluation in their ergonomics knowledge raised from 1.5 to 3.4, again out of a five-point scale. In addition, we also collected feedback on individual exercises used in the subject learning, including readings, lectures, labs, and projects. Thirteen out of the fifteen responses considered all those exercises were helpful for their learning, while one of them stated the readings were not useful and the other one did not indicate his thought on the effectiveness of the industry project in his learning.

Conclusion

Although we did not have a well-designed survey to test the significance of our exercise design along with long term data showing its impact on students' performance and attitude, overall speaking this course module was successful especially when considering that it was just the second time we offered it. Compared to the results from the first time we offered this course in 2004, the approaches of active learning and problem-based learning seemed to be very effective. The use of the computer simulation with the problem-based learning approach was especially the critical factor of our success as the students can link known and unknown content[15] by trail-and-error. In the future, we plan to bring in more information on the existing standards (such as the DOE handbook[4]) and design guidelines (such as Kodak's classical textbook[16]) for students' reference and at the same time, integrate these best practices of ergonomics into exercises. Furthermore, a polished assessment plan will help on test validity and provide appropriate interpretation of the assessment outcome for future improvement.

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