Effective Delivery of On-line Engineering Courses: The Nuts and Bolts of Success

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Abstract - This paper describes the web-based, asynchronous delivery of two industrial engineering courses, Industrial Safety and Human Factors in Engineering. These courses were developed and are taught using Blackboard by faculty of the University of Tennessee at Martin's Engineering Department for the University of Tennessee New College. Web-based instruction that combines homework, tests/quizzes, and discussion topics to successfully teach these two courses is described. Examples of the various evaluative instruments are presented along with a discussion of some of the practical issues associated with creating and maintaining this particular instructional delivery system. A brief background on the development of the courses is presented and the results of student evaluations of the courses are presented and discussed.

Keywords: on-line, Blackboard, industrial, asynchronous

Background

The Bachelor of University Studies (BUS) degree originally was offered as an area of concentration within the University of Tennessee at Martin's School of Arts and Sciences. With reorganization of the academic units in 2000, this program was developed into an independent degree program to be under the direction of the Assistant Vice-Chancellor of Academic Affairs. This new degree allowed undergraduate students increased flexibility in completing their bachelor's degree. The BUS degree was approved by the Faculty Senate in Spring 2000 and implemented in the fall of that year.

Within the same time frame, The University of Tennessee (UT) System offered The University of Tennessee at Martin (UTM) the opportunity to provide the initial degree program through UT New College. The BUS degree was selected as the conduit through which the UT New College could begin offering degrees off-campus to students at convenient times and places. The primary focus was to help Tennesseans complete a college degree.

The New College Committee, consisting of a group of UTM faculty and administrators, was appointed and directed to develop an implementation plan to offer BUS courses via the Internet. The committee was also charged with developing a budget and a selection process for the initial on-line courses to be offered in Fall 2001.

The UT System provided funding for the development of 10 courses each year for three years--a total of 30 courses. A faculty member was to be paid $8,000 to develop a course, $4,000 at the end of the summer months (course development and Blackboard training took place in the summer), and an additional $4,000 at the end of the first month of the first semester the course was offered. Courses were to be taught in-load unless the faculty member's department could not provide release time for the course. If no release time was available, the course would be taught as over-load assignments with funds provided by New College.

The UT System and the New College Office developed a survey to determine the courses and areas of interest that the target market of prospective on-line students expected and desired in Internet course offerings. This survey indicated the students' primary interests were in business, computers and information systems, and human resource development courses. The survey results were interpreted to include courses that supported these primary areas.

The New College Committee requested proposals from all UTM faculty for classes to be delivered via the Internet. Compared to development of conventional courses, these courses imposed two different policies on the faculty member: 1) faculty members would be paid to develop these courses, and 2) the University would own the courses after completion of development. These courses would normally be taught in-load and technical support would be

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supplied to the faculty to develop the online segments of the courses. The UT System specified three requirements for the courses: 1) they would be offered in an asynchronous environment, 2) the courses would not be new courses, but they would currently exist, and 3) the courses would be limited to 300- and 400-level courses. Additionally, in order to reduce the tendency to draw students from existing on-campus courses, the on-line classes would be restricted to students that were not currently enrolled on campus. The on-line courses were intended to develop new markets for UTM and create new enrollments. Eventually, on-campus students were allowed to enroll in the classes, but they were charged tuition even if the student previously paid full-time tuition for that semester.

Courses from all colleges across the UTM campus were received. The New College Committee first removed those courses that did not meet the requirements of the New College funding. Next, the courses were ranked relative to the ability of each class to meet the needs of the target market. The top 10 courses were then selected for development during the summer of 2001 for delivery during the fall semester.

Two courses have been developed by the UTM Department of Engineering. Industrial Engineering 402, Industrial Safety, was submitted and approved in the first group of 10 courses. Dr. Robert LeMaster developed the course and taught it through the Fall 2002. Engineering 381, Human Factors in Engineering, was developed in the third and final group of 10 courses. Professor Edward Wheeler developed the course, continues to teach it, and has taken over the Safety course. Both courses have been taught in each regular semester since their development.

The students who are attracted to the BUS degree are typically non-traditional students who have some college credits and need a flexible program to complete the bachelor's degree. Very few, if any, of these students have any background or credits in engineering. These courses traditionally have attracted students interested in management, work place safety, or both. The challenge has been to maintain the rigor associated with these courses and still be able to provide a meaningful learning experience for the typical non-engineering student.

Developing the Courses

Even though the courses were developed independently and three years apart, the same objectives were used to develop both courses. The most important objective was not only to present a course that was rigorous, but also not overwhelm the non-engineering student. Additional objectives were to give the students assignments that would be meaningful to their life situations, be easily delivered on-line, and be accommodated in a 15-week semester.

One of the biggest challenges in the development of both courses was the choice of an appropriate textbook. The choice for the safety course was not very difficult. Hammer and Price's *Occupational Safety Management and Engineering* was chosen for the course because it is relatively easy to read, covers the required material, and contains 29 chapters. The number of chapters makes for easy pacing of the course over the 15-week semester. Choosing a text for the human factors course was more difficult. Wickens' *Introduction to Human Factors* and Kroemer's *Ergonomics* were both considered for use in the course. Without the classroom lecture time to explain the material as presented in these texts, each of them was determine to be too difficult for on-line use. Pulat's *Fundamentals of Industrial Ergonomics* was found to be an acceptable text. It is relatively easy to read and understand and is fairly comprehensive. A couple of drawbacks to using the text are its age and, in some areas, it's lack of depth. Pacing in the course was also an issue with this text. The appropriate chapters to assign on-line were determined by the typical coverage in an on-campus class-not all chapters in the text are used.

The usual forms of evaluations used in the classroom setting are available on Blackboard. Quizzes/tests can be composed of the multiple choice, multiple answer, true/false, matching, or short answer questions. The computer does the grading of objective questions; however, the instructor must grade subjective questions. In both courses, a quiz/test was developed for each chapter. The safety course does not use time limits on the quizzes, although the mid-term and final are timed examination. Each quiz/test in the human factors course is timed.

In the safety course, two chapters are assigned each week (with the exception of the last week when three must be assigned). The additional week is used for a mid-term examination. Associated with each chapter is a short quiz, usually eight to eighteen points in value. Each week the students receive immediate feedback with the immediate grading provided by Blackboard. Making assignments in the human factors course was more difficult. Twelve of the books 14 chapters are covered in the course. Most weeks, a single chapter is assigned with an associated quiz/test. Chapters dealing with physical ergonomics and industrial safety are assigned over two-week periods. There is no mid-term or final examination in this course. In both courses, students are allowed to retake each quiz/test any number of times until they are satisfied with their score. One interesting observation is that most students do not avail themselves of this opportunity.

Each course also makes use of homework assignments that must be submitted by e-mail or through Blackboard's digital drop box. The homework is intended to provide the students' experience in web searches, procedure description, anthropometric design, capacity calculations, and work environment design. Examples of homework assignments are presented below.

Safety Examples:

- The company you are employed by uses a variety of compressed gases in the manufacture of its products. Gas cylinders are used throughout the factory and are stored in a "tank" farm in back of one of the buildings. Specific gases used are chlorine, acetylene, propane, oxygen, and nitrogen. Management is concerned that all of the tanks are not properly stored, marked, or used by employees. You are asked to develop a plan that establishes requirements for the proper use and handling of the cylinders and then to conduct an inspection to determine if these requirements are being met. Your assignment is to review OSHA requirements for gas cylinders and develop a plan for conducting the inspection. Your plan should contain a checklist that references appropriate OSHA documents.
- Beryllium is a metal that has many desirable features. It is lightweight and has good dimensional stability (it does not distort much when subjected to mechanical and thermal loads). One of its applications is in satellite construction. At one time, beryllium was heralded as a miracle metal. Unfortunately, beryllium dust is very toxic and special precautions must be taken to protect workers. Your assignment is to investigate the hazards of beryllium (specifically its dust) and write a short paper that discusses precautions that should be taken when working with it.

Human Factors Examples:

- Please indicate all variable values and equations used to solve the following.
    1. Consider a 42-year-old female performing a task that requires 6 kcal/min. Determine the rest time required for 45 minutes of activity.
    2. A worker standing nine inches from the conveyor lifts boxes off a conveyor that is located 28 inches above the floor at the rate of 4/min. The boxes are placed on another conveyor that is 40 inches above the floor. Using the 1981 lifting guidelines, determine the action limit and the maximum permissible limit for this task for a person performing this task continuously.
    3. Boxes weighing 25 pounds are lifted from a position on the floor and placed on an overhead conveyor 62 inches above the floor every 30 seconds. The worker must twist in order to accomplish the task. The box is classified as a 20-inch box and has handles. Determine the capacity of 70 percent of the female population to perform this task on a full-time basis, five days a week. Assume the knuckle height is 24 inches above the floor.
    4. A job requires the worker to move boxes from an unloading chute to a conveyor at a rate of about 5 boxes per minute. Each box weighs 10 pounds, and the worker performs this task for approximately 4 hours of a typical 8-hour workday. The worker stands approximately 10 inches from the chute as the boxes are lifted off. A twist by the worker of 90° is required to move the boxes from one conveyor to the other. The unloading chute is located 24 inches off the floor, and the conveyor is located 40 inches above the floor. Using the 1991 NIOSH guidelines, determine if this job is acceptable or should be redesigned.
- Using the Illuminating Engineering Society's procedure for minimum lighting, determine the minimum lighting for the problem presented below. Your solution should include a step-by-step explanation.

  The average age of workers in a newly designed work is 42 years. Assembly of high quality watches will take place in the area. This work will include using magnifiers and very small tools to perform the assembly. The area is designed to have a background reflectance of 15%. Determine the minimum illumination value for the work area.
- Using your text and any other resource, provide the answers to the following design questions.
    1. Design a crawl space to gain access to a repair area for electrical equipment located under the production floor of your plant. Also determine the ceiling height for the repair area.

2. Design a square opening that a worker must reach through to replace a bulb. Also, how far from the opening can the bulb be placed? Assume a gloved hand.
3. An adjustable seat is to be designed to accommodate your workforce. The average popliteal height for your workers is 41.2 cm with a standard deviation of 2.3. What range of values would you use for seat pan height and why?

In order for the students enrolled in each course to develop a sense of community, discussion topics are assigned throughout the semester. The safety course makes use of 14 topics, and 10 topics are assigned in the human factors course. The topics are chosen in an attempt to generate exchange of ideas among the enrolled students. The students have approximately 10 days to post their discussion, and the postings are then graded. Examples for the topics used in each class are presented below.

Safety Examples

- Employees may have personal problems that they bring with them to the workplace. Some of these problems can place the employee and his/her co-workers at the risk of injury. Alcoholism and drug abuse are two problems that employers are particularly concerned about. Employers to screen potential or existing employees, particularly in high-risk jobs, sometimes use drug testing. I have also seen a few restaurants stating that prospective employees will be subjected to a drug test. Discuss this issue considering both the employer's need to minimize risk and to provide a safe work environment and the employee's right to privacy.
- You are the manager of a facility that requires employees to wear safety glasses, steel toed shoes, and earplugs. You make it a point to have your safety officer conduct random safety inspections on a weekly basis to verify that all workers are using these safety devices. What should you do to employees who are identified as not wearing the required devices? How tolerant should you be? After how many occurrences should you fire the employee? What if an employee is an excellent employee in all other areas of job performance, and his/her particular skill would be hard to replace.

Human Factors Examples

- The manufacturing facility where you work experiences a great deal of worker turnover in its metal cutting and bending work area. It has also been noted that the production rate is consistently below standards. As the industrial engineer, you have been asked to investigate the situation. How would you go about the investigation?
- Recently there have been several lawsuits filed on behalf of employees seeking compensation for cumulative stress disorders (sometimes referred to as repetitive stress disorders) caused by working conditions and methods. As the industrial engineer for your company, what can you do to minimize the possibility of such a lawsuit being filed by your employees?
- A colleague recently commented to me about a job he had as a youth; he worked in a frozen food storage facility 'pulling' orders. The rules stated that anyone working in the freezer must take a 10-minute break outside the cold storage area for every 20 minutes worked inside it. I was also told that because he was paid by the number of orders pulled, he rarely took the required breaks. As the manager of such a facility, what could you do to insure that the freezer workers took their required breaks?

One of the challenges with the discussion topics was developing a grading system that was fair and meaningful. The grading system developed for discussion board participation seeks to reward both the quality and quantity of a student's input. In this context, the following formula is used to assign a grade for each week's discussion topic.

$$Grade = \frac{1}{3}\sum Q_f \times 100$$

The weighting factor of 1/3 is based on the instructor's desire to have each student make a minimum of three contributions to each discussion topic. The factor of 100 simply converts a rational number to a percentage. When a student submits more than three contributions (containing at least one high-quality input), he/she may begin to accumulate additional points that can raise his/her grade for a particular discussion topic. The average of all the weekly grades is used in the calculation of the course grade.

The parameter, Q_f, is the factor used to assess the quality of an input. The quality factor can have values of 0.7, 0.8, 0.9, and 1.0, as shown in the table below.

0.7	A response that simply expresses agreement or disagreement with what someone else has written. The author has at least read the other responses, but has not demonstrated independent thought in this particular case.
0.8	An input that contains an independently developed argument. The basic point of the argument is not clear, the argument shows little depth of thought, or the communication of the argument is not very effective.
0.9	An independently developed input. The basic point of the argument is well thought out and is effectively communicated. The author cites personal experience related to the topic.
1.0	An independently developed input. The basic point of the argument is well thought out and is effectively communicated. The author may cite personal experience related to the topic, but also includes material from authoritative sources (outside publications, OSHA standards, journal articles, etc.) that are cited in the argument.

Table 1: Quality Factor Definition

Several examples are given to show how this formula works. Consider the case where a student makes four inputs to a discussion topic. One of the inputs is of exceptional quality and receives a quality factor of 1.0. Another response is above average, but does not contain material from outside sources-it receives a quality factor of 0.9. The other two responses express agreement or disagreement with what another student submitted. These last two responses do not contain much of an explanation or defense of the disagreement/agreement-these inputs receive a quality factor of 0.7. The student's discussion topic grade for this week would be computed as follows:

$$Grade = \frac{1}{3}(1.0 + 0.9 + 0.7 + 0.7) \times 100 = 110$$

The student will receive a grade higher than 100 for this discussion topic. This high grade will offset a lower than 100 grade that may be received for another week's discussion topic. At the end of the course, a student can receive a grade greater than 100 for participation in the discussion topics.

As another example, the student in the above example submits only the second, third, and fourth inputs. In this case, the grade would be computed as follows:

$$Grade = \frac{1}{3}(0.9 + 0.7 + 0.7) \times 100 = 77$$

As demonstrated by these two examples, the formula rewards both quality of input and quantity of input.

Only two inputs having a quality factor of 0.7 will be included in the formula to prevent a student from trying to "beat-the-system" by flooding it with low quality responses. For example, if a student submits five responses that receive a quality factor of 0.7, his/her grade would be computed as follows:

$$Grade = \frac{1}{3}(0.7 + 0.7) \times 100 = 47$$

In this case, the student will receive a failing grade for this discussion topic because there was not at least one high quality input. If the student were to submit an input that received a quality factor of 0.8 in addition to the two 0.7 quality inputs, his/her grade would be 73. This reflects a significant improvement because of the increased quality of at least one submittal. If a student makes no input to the discussion topic during the week that it is assigned, he/she receives a zero for that week's participation.

The workload involved with the development of the courses was eased by the assignment of a graduate assistant to the instructor during the summer that the course was developed. The graduate assistant was trained on Blackboard and was helpful with inputting the evaluations, discussion topics, and homework assignments. This greatly reduced the menial work that was required of the instructor.

Conducting and Maintaining the Courses

Once the courses were developed, running them was not terribly time consuming. The majority of the work involved was grading the discussion topics each week. In an average class of 12 to 15 students, there will often be 65-70 posts. Approximately 60 to 90 minutes is required each week to grade the work. Another time consuming aspect is downloading and grading the homework. Students submit their homework through Blackboard's digital drop box feature. Individual homework must be retrieved and printed. Many students inadvertently leave their name off the homework assignment, and this consumes more time, as you are required to determine who turned in the assignment. The posting of weekly activities is very easy once the course has been established. Initially, posting the activities consumes a moderate amount of time, as you must determine the pacing of the course. Once the course is established, you can simply use the cut and paste features if the previous course is not deleted. There is a minimal amount of time that will be required in e-mailing the students with homework critiques and the occasional phone call.

Maintaining the course is a relative simply exercise on the UTM campus. Information Technology Services (ITS) copies the courses from semester to semester at the request of the instructor. Also, ITS builds the class roster at the beginning of each semester for each course. As students adjust their schedules, the instructor has the capability to drop students from the roster.

From a technical viewpoint, the major problem with Internet delivery is the occasional Internet service provider (ISP) timeout. Students will often not input information into their computer for several minutes while they take a quiz/test. Many ISP's will automatically disconnect the computer when a certain time passes with no activity. The quiz/test that the student was attempting is then 'locked' by Blackboard and cannot be retaken until the instructor clears the aborted attempt.

Student Comments

The students that have taken one or both of the courses have reported very positive feedback on the course organization, content, and Blackboard. A sample of the comments taken from recent student evaluations is presented below.

- Are there specific positive characteristics of the COURSE you would like to mention?
    1. Great course for those who will be working in an industrial or commercial setting.
    2. I think that I learned a lot of worthwhile stuff in this class that I can apply to my job.
    3. The presentation and format is great.
    4. Relevant material in today's working environment.
- What do you specifically LIKE about Blackboard?
    1. The opportunity to complete my degree while continuing full-time employment.
    2. I like the flexible format. I can work almost anytime day or night.
    3. It's functional, and I find it to be easy to use.
    4. The ability to learn and converse without leaving your home.
    5. Easy to navigate and accessible anytime!
    6. I like being able to interact with teachers and other students from my home.
    7. Blackboard is extremely user friendly. I like the fact that each class is set up with a ready to click format, so accessing assignments and course grades etc. has become very efficient.
    8. I like being able to share topic discussions with the other students.
- What do you specifically DISLIKE about Blackboard?
    1. It's difficult at times when I don't understand something, and I can't just raise my hand and ask the teacher in person.
    2. The fact that it goes down occasionally. Also, when you need an answer from a professor, they do not give an immediate answer.
    3. Teachers have different designs and schedules on the site-for instance, week 15 is week 13 for another teacher and course documents and assignments are different.
    4. Navigation is not as facilitated as it could be. Need more applications to open in Blackboard.

- What about the online course experience do you particularly like?
    1. Flexibility in time.
    2. The opportunity for discussion board interaction.
    3. I like it all.
    4. Everything but the price.
    5. Being able to complete my degree at my pace when I have the time to devote to it...the way I work plus the family activities...I would never be able to finish my degree by actually going to class...this is a lifesaver for me...my company is requiring me to finish my degree and without online I simply could not do it!
    6. The ability to work at my own pace.
- What about the online course experience do you NOT particularly like?
    1. This has nothing to do with the course or course content, but computer problems and ISP connections are a definite concern at times.
    2. Cost.
    3. Not having one-on-one interaction with other students except on the discussion boards.
    4. At times the inability to discipline myself
- General Comments
    1. The site is very organized and easy to move around in. The instructor makes the materials covered interesting and fun for everyone, even us non-techies.
    2. Make sure the students have a good math background prior to taking this course. The formulas can be hazardous to your health!

Students have also been asked to rate the difficulty of these courses. On a scale of 1 to 10, with 10 being the most challenging (difficult), 55% rated the safety course an eight on a recent evaluation. The average rating was 7.73. This indicates that the rigor requirement is being met. The human factors class was evaluated on a scale of 1 to 5, with five being the most challenging (difficult). The average rating was 4.67 with 67% rating the course a five. This reflects the higher degree of difficult in the course material. The rating also is evidence that the course is meeting the rigor requirement.

The following statement can summarize the on-line experience. Students enjoy the freedom and flexibility of the on-line class, but do not like the isolation. Other concerns expressed dealt with the technical inadequacies of Blackboard and the differences in instructors' policies and schedules.

Conclusion

The success of an on-line course and its value lies in the content. It is very important to maintain the quality and rigor that is expected by all the constituents of an engineering program. By being creative when developing assignments for the on-line students, this quality and rigor can be established and maintained.

Not all engineering courses can be set-up for on-line presentation. Care must be taken when selecting and developing courses for this delivery methodology. Any course with heavy computational requirements and emphasis would likely not work in this environment. Courses that allow the student to navigate through the information with only the text and minimal interaction with the instructor are the most appropriate candidates for on-line presentation. Engineering management, quality, project management, and engineering economy are examples of engineering courses that are currently being offered on-line.

Based on the continuing popularity of the courses, consistently positive student comments, and the experiences of both the instructors, the courses have been a success. This success is offered as proof that engineering courses when selected properly and developed with creativity, can be offered on-line.

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