A Review of Online Instruction in Introductory Engineering Mechanics Courses

Hodge E. Jenkins[1]

Abstract – The demand for distance learning by students and the flexibility afforded to both students and faculty via asynchronous, online instruction has increased the number of engineering courses offered online. A review of current approaches in the development and delivery of course content for online instruction of introductory, sophomore engineering mechanics courses, focusing on statics and dynamics courses is presented. The challenges, failures, and successes of providing an online, self-paced learning experience that is an equivalent to (or better) than a face-to-face lecture/recitation format are discussed. Formats and structures of the course are discussed. Introductory mechanics courses face additional challenges over many currently offered, online courses engineering courses, which tend to be at a higher undergraduate or graduate level. These hurdles include the graphical nature of the materials and the enrollment demographics of primarily sophomores and some freshman students, who may be less mature and less disciplined for self-paced nature of courses, than upper classmen and graduate students. As the first engineering course for many students, many concepts and visualization techniques will be novel to these students. Where possible, assessment results or a discussion of learning outcomes are presented to evaluate the effectiveness of the methods and technology, especially in comparison to tradition classroom versions of these courses. Technology, materials and resources available for instructors through publishers, universities and other sources are also reviewed. Considerations of costs, faculty time, and student retention question the value of teaching early engineering courses in an online format.

Keywords: online, instruction, statics, dynamics, mechanics.

INTRODUCTION

The direction of improving learning has been shown to be effective when it is learner-centered [1]. The use of computer technology in this learner-centered mode has been widely and successfully implemented outside of the traditional educational structure through popular no-cost websites such as YouTube and Google. Videos and associated discussion forums exist on a wide range of instructional topics at these and other popular websites. Although, it must be noted that instruction via this approach is generally more passive with primarily one-way communication through videos. While these sources of instruction serve a variety of needs, the implementation of online education at institutions of higher education requires more structure for the providing security, testing, limiting access to those paying, providing feedback as well as interaction amongst the students and the coordinating faculty.

Graduate engineering courses were the first online courses developed in engineering education. This naturally followed from distance learning programs that have long been part of graduate engineering education at many institutions. Online instruction for undergraduate engineering education is relatively new. [11] Many of the first undergraduate online courses were upper-level courses, or those with less visual interactions (e.g., programming, economics).

[1] Mercer University School of Engineering, Macon, GA 31207, Jenkins_he@mercer.edu

Engineering mechanics courses (statics and dynamics) present a special challenge to the engineering educational community to create online versions that satisfy desired learning outcomes for a greater variety of learners. The number of engineering educational papers related to online teaching of engineering statics and dynamics to date has been, not surprisingly, limited. This may be explained by the limited number of universities offering online sections of these courses. Clearly, the focus of most creating online engineering course work has been distance learning at the graduate level. At the graduate level, students have greater grasp for absorbing fundamental concepts, owing the maturity and higher attained achievement of these students. Graduate students may have a greater desire to learn and generally have lesser need for continuous communication and feedback, as compared to undergraduate students. At the sophomore level of engineering education, student profiles are quite different. Students are generally younger, with a range of talents and skills is broader than in graduate school. Study and work habits of many sophomore engineering students may not be well-formed. Visualization skills are required and must be developed by students to understand basics concepts in statics and dynamics. There will most certainly be less capable students in the sophomore introductory engineering classes, as compared to graduate courses. Also, the mechanics courses (especially statics) may be the very first contact a student has with engineering faculty. Of significant concern is the retention and nurturing of these sophomore students in engineering. (This might indeed provide a reasonable argument why most engineering programs do not desire an online engineering statics course.)

Despite these challenges, online instruction applied as a supplemental or pre-class learning vehicle in early mechanics courses such as statics, as noted by Dollar and Steif, has shown measureable benefits. [7]

ONLINE INSTRUCTION FORMATS

Implementation of online course instruction varies greatly at colleges and universities. For some institutions this consists of live web-casting to a remote location. While at the other end of the spectrum an online course may provide a total pre-recorded learning experience with no physical classroom and significant student time independence. Many institutions provide online course components to supplement regular classroom instruction [2], [7]. While other instructors run hybrid courses formats of varying degree of online instructions. A hybrid course is defined as providing both online and traditional classroom instruction, expanding the classroom to those unable to attend the all classes or labs.

Probably the largest decision in the development of an online course is "how asynchronous should the course be?". [3] The literature, as well as reason, indicates that a successful course (online or in-class), especially at sophomore level, must have synchronous components as well as asynchronous ones. A totally asynchronous course has appealing characteristics to both faculty and students. The advantages include flexibility of schedules, allowing more time for a quality discussion, students can work at their own pace, all course materials are available all the time. Disadvantages of a purely asynchronous course include the need for students to be self-disciplined to complete it on time, delays in responses from faculty to questions, as well as a lack of a perception of a community of learners. Synchronous courses also have some appealing attributes and educational (if not flexibility) advantages. Live communication (chat, video, phone, etc.) can occur with no time delay. Students may form and perceive a community more readily. At the live session students can more readily communicate with the professor and each other. Disadvantages of these sessions include scheduling, possible technical problems, and the need for additional equipment (depending on the format). The blending of the synchronous and asynchronous parts to a course appears to be a better online format, for all types of students especially those taking their first engineering course. Indeed, the blended approach is arguably more learner-centered, providing more feedback for the student (and structure), while allowing some flexibility in schedule and location. In these instances the lectures and materials are still provided asynchronously, with the due dates of the assignments and quizzes and providing a live communication media held synchronously.

Important structure of the synchronous course includes weekly deadlines for completing quizzes and homework assignments. Some online formats also have time-release on the availability of materials for the course. [3] A recent example of an online statics instruction is one that blended synchronous and asynchronous instruction components of the course. Specifically related to statics instruction, one study found that the length of time for a course did not impact the student performance, thus the possibility of completing online courses in shorter time than a semester interval appears plausible. [10]

TECHNOLOGY

A key element of online instruction is technology. Transitioning from traditional chalkboard to the latest technology can be a challenge for faculty new to these resources. The necessary technology tools depend on the instruction formats to be presented and school resources. The primary focus of the online instruction is providing learning resources for students to learn independently and asynchronously, whether or not the course is asynchronously or not. Thus, videos, presentations, images, and documents for web media distribution comprise the bulk of the content presented. Live instruction or simultaneous webcasting a traditional lecture will pose other challenges.

Presentation Formats

Statics instruction relies on visualization using graphics for geometry and physics concepts as well as presenting the associated mathematics. Several forms of media and technology exist to present the course materials. It is interesting to note that the technology required to provide online content is readily available and has been implemented by a variety of individuals. This technology can be somewhat of an impediment to a large section of the current higher educational faculty, who are unfamiliar with it, have had little time to use it or limited access. For some instructors many aspects of online instruction are time and resource problems not a technology issue. Many (if not most) engineering courses are comprised of handwritten notes. Conversion of these notes to digital media requires substantial effort and time. While much of the time involved in developing this digital content could be recouped in subsequent course offerings, current faculty teaching loads make this effort unpalatable for many instructors. Alternatives to creating original material content in digital form have been addressed by publishers of textbooks. Many publishers offer PowerPoint slides to parallel their textbooks. But quality and content of this available material varies.

Technical considerations for distribution of materials must account for the possibility of students using a variety of computers and software to view the materials provided. Thus, it was found necessary by some authors to avoid distribution of word processing and spreadsheet files, owing to different versions and software that could be used, that may either change the appearance, function, or prevent used of such files.[4] Portable document format (Pdf) files appear to be a preferred means of publishing documents.

A significant effort may be required to obtain the copyright permissions for materials to be shown in online class. Availability on the web of materials affects the “fair use” status. New illustrations had to be created in some situations where the copyright could not be attained. Hand-out materials not in a digital form had to be scanned. [5]

Some instructors have created their own technical approaches to converting existing courses into an online form. A low cost method for converting a “blackboard and chalk” course has been presented by Lipscomb [4]. A webcam fixture for a clipboard was built by the user and to record the presentation materials for online instruction. The authors used free or low-cost software for creating and editing of videos and images.

While all lecture materials may be available to students at all times in an online course, there is no method for guaranteeing that student will watch, understand, and absorb the information presented. One course even randomly dispersed several bonus grade points in the lecture video, and yielded a surprisingly low number of students finding these bonus points. [3]

Video Instructions

Several papers have highlighted technology approaches for the creation of video presentations for course content. [12]   Much has been discussed on the development of videos for online classes. A few instructors have created videos specifically for online courses. [18] [4] However, the approach taken by most instructors is to create videos from actual course lectures in a previous semester, requiring significant editing. [12][3] Creating videos of staged lectures requires substantial time in capturing, editing, and retakes. Good planning is also needed to capture live lectures in semesters prior to online course offerings.

Another concern is the video format used for distribution. Common video formats include Audio Video Interleaved animation file (AVI), Flash video file (FLV), QuickTime Movie (MOV and QT), multimedia container format (MPEG MP4), Video object (VOB), Windows Media Video (WMV). Flash video format (FLV) requires additional software not available on all types of computers and internet devices, and are not recommended. There is a trade-off between video quality and file sizes. Web hosting and web traffic limitations are also considerations. Some authors [4] have limited image/video resolutions to 640 x 480 pixels to reduce files sizes and improve the speed of accessing materials.

Online Environments/Learning Management Systems

Most online courses at institutions of higher education are conducted via commercial classroom learning management systems (LMS). Two of the most popular of these systems are Blackboard (includes the acquisition of WebCT) and Desire2Learn (D2L).   These systems provide a secure online gateway and course framework allowing the timing of materials (files, movies, and documents), administering quizzes and tests, providing students with grade information and serve as a forum/threaded conversation location for student interaction with each other, as well as with the professor.

Many publishers offer similar courseware services to faculty adopting their books. Services provided by the publishers range from supplemental education materials to entire online courses even providing the LMS. For example Pearson Publications has developed an online course environment, CourseCompass [14]. This environment provides a pre-configured site for a limited number of courses, which does include both Statics and Dynamics.

It should be noted that YouTube videos, using live streaming connections to the internet, have been a popular environment for learning in general, they are also suitable as vehicle for distribution of course video materials, and in fact my ease the web traffic problems at some universities [19]. Controls on use and statistics are not available for this means of providing video content. Podcasts provide a similar mechanism with the added benefit of students being able to download and view videos while not online.

Open Courses and Materials

Another source of web-based materials for engineering mechanics and many other engineering courses are the open course initiatives. Two institutions, Carnegie Mellon University (CMU) and

Massachusetts Institute of Technology (MIT) provide substantial free online course content, and entire courses. MIT has long provided the OpenCourseWare (OCW), while the CMU Open Learning Initiative (OLI) is more recent. [15], [16]

MIT OpenCourseWare (OCW) is a web-based publication with the goal of providing course content for virtually all MIT courses. OCW is free and available via the internet. While the goal OCW at MIT is to provide all course materials, online for free, providing an MIT education free to the world, the reality of this effort is less useful. Unlike current educational approaches for online courses using multimedia with interaction, OCW courses provide mostly scanned or digital documents. The potential content available documents for courses is 1) Lecture notes, 2) Projects and examples, 3) Image Galleries, 4) Online textbooks, 5) Assignments and solutions, 6) Exams and solutions, and 7) Multimedia content. Most OCW course do not provide all forms of content. In fact some courses have very little content provided.

The CMU Open Learning Initiative (OLI) paradigm is more typical of what one might expect if seeking to learn a subject independently. The courses in the OLI website provide some interactive course environment (although much content is text). It should be noted that the OLI program has limited courses presently included. However, engineering statics is one of those courses included in OLI. A unique aspect of this effort is that courses in OLI may potentially be taken for credit. Several institutions around the world are using OLI courses as part of their curricula. The instructor at a partner institution may provide students with a course key for access. Credit for course completion is to be provided by the student's home academic institution, not CMU. Academic courses include all (or part) of the materials plus a grade book and tests. In OLI the Statics course offering is comprised of a set of units, each broken into modules with interactive content including simulations and video clips of devices. Videos of instructors or narrations have not been included. Much of the instructional web pages are text with images. Simulations are also part of the instruction. Significant attention has been given to pedagogy in the development of OLI course modules and assignments directly relating to learning concepts and objectives.

Noted Problems and Concerns

Several authors have stated that the development of the of online courses has revealed unexpected costs and scheduling problems. Some of these costs relate to the technology, while other hidden costs are the time requirements of faculty preparing these courses. [2, 3, 4, 5, 9] Preparation time for each hour of web presentation content, require 4 to 10 hours of preparation and administration. [4]

Tests and quizzes must be designed with the understanding that students will have access to their texts as well as other materials, so a time-limited exam is essential. Also the uniqueness of each examination is also desired for instances where students may be together when completing the exam materials.

Timing of information is a concern. Solutions to quizzes or exams cannot be released prior to all students completing them. This is less of a concern for distance learning of scattered individuals, as opposed to groups of students either on campus or in remote locations.

FINDINGS AND RECOMMENDATIONS

From the reviewed literature an online course for sophomore statics or dynamics must have synchronous aspects (Deadlines for assignments and completion of quizzes, Time limited exams, Live communication sessions) to engage and structure work for younger college students to succeed. Weekly quizzes, for example, were found to encourage student to not get behind in the course or put off too much material until the end.

Grades of students were similar for online and face-to-face versions of courses, including statics [3], [5], [11]. Students reported online classes were easier to complete. Some instructors have used technology to enhance a traditional introductory engineering course, rather than the sole means of content delivery [9]. This may be the best application of the online media to enhance existing classroom learning, not replace it. Statistically significant gains in student performance with web-enhanced learning have been reported [2]. These improved student results in statics are attributed to using technology engaging students more, increasing instructor interest, as well as the causing students to spend more time on task.

It has been shown that benefits for the instructor are also possible, when data from the online instruction is used to assess learning difficulties. In the OLI tools developed at CMU, the statics instructor can display student performance in all course concepts, as modules and assessments are linked to learning objective and concepts. Instructors can elaborate on problem concepts or provide remedial instruction. [7]

Even ignoring the faculty preparation time required for online courses, the cost of developing, hosting, and executing online courses has been found not be cost effective by some institutions [11]. Retention and career choice issues associated with students taking introductory mechanics courses online have not been addressed. Thus, the value of teaching early engineering courses in an online format remains unanswered.

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Hodge Jenkins

Dr. Hodge Jenkins is an Associate Professor in the Department of Mechanical Engineering at Mercer University in Macon, Georgia. Prior to coming to Mercer in 2002, Dr. Jenkins was employed in optical fiber product development with Bell Laboratories of Lucent Technologies. He is a registered professional engineer, and with over 20 years of design and development experience in high-precision machine design, dynamic analysis, process automation, control, and robotics. Dr. Jenkins holds a Ph.D. in Mechanical Engineering from Georgia Institute of Technology (1996), as well as the BSME (1981) and MSME (1985) degrees from the University of Pittsburgh. He is a member of ASEE.