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**AC 2009-1770: ASSESSING LEARNING OUTCOMES IN A BROADCAST  
LEARNING ENVIRONMENT: APPLICATION OF THE DYNAMICS CONCEPTS  
INVENTORY**

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# **Assessing Learning Outcomes in and Student Attitudes toward Engineering Mechanics: Dynamics in a Live Interactive Broadcast Class Environment**

## Abstract

This study investigates the effectiveness of the live interactive broadcast method of delivering engineering content *into* a standard university classroom. The Dynamics Concepts Inventory, a standardized quantitative assessment, has been administered as a pre-test and final assessment for the broadcast section of dynamics for four semesters. Student attitudes toward the non-standard learning environment were assessed through an instructor-developed survey, third party interviews, and anecdotal evidence. Results of the DCI indicate that outcomes from the broadcast section are similar to national average for lecture style classes. Attitude surveys revealed a persistent sense of student isolation and frustration with lack of personal contact with the instructor, but little difficulty with the broadcast and technology assisted class room environment.

Purpose:

The purpose of this study was twofold: 1) test the hypothesis that the primary influence on learning outcomes in a live interactive broadcast class of Dynamics was the broadcast technology, and 2) explore the factors governing the hypothesis that traditional lecture content delivery style needs to be adapted to the technology assisted classroom environment to be successful.

A unique learning environment has made this study possible. To serve industry needs for ABET accredited engineering graduates in a growing population center of approximately one million, remote from the servicing state university, a hybrid engineering program was inaugurated in Fall semester 2004. The program, the Antelope Valley Engineering Programs (AVEP), combines synchronous live interactive broadcast lecture classes with direct-contact laboratory instruction for the upper division engineering coursework, while lower division work is provided by the local junior college. No core coursework is available asynchronously. The existence of this remote program has created an environment where several traditional lecture-style classes are broadcast *into* the main campus of the degree-granting institution *from* faculty at the remote site. Student populations at the course-generating remote site are small, between zero and four maximum during the study. Student populations on the receiving main campus are significantly larger for this course, between 15 and 33 during the study. Courses broadcast into the main campus are not designated on the schedule as being generating off-campus. So, many students enroll in the broadcast section not knowing that the instructor will be remote from the on-campus class. This reversed broadcast environment creates a unique 'laboratory' for studying the influences of the broadcast technology on student learning outcomes and satisfaction of engineering students in a standard university classroom.

A 1999 meta study examined 355 comparative research efforts that found "no significant difference" between broadcast (Russell, 1999)<sup>1</sup> and direct-contact instruction in students obtaining the learning objectives of the class. One conclusion from the meta-study is the persistence of the belief, within the educational community, that broadcast technology somehow interferes with content assimilation. That persistent prejudice was the foundation of the first hypothesis in this study: that the primary influence on learning outcomes in a live interactive broadcast class of Dynamics was the broadcast technology. The broadcast learning environment in this study is distinct from either the standard University classroom or the asynchronous distance learning environment (Rybarczyk, 2007)<sup>2</sup>. Students in a standard university classroom have an expectation of direct, and potentially non-verbal, interaction with their professor. This level of interaction can be transparent to students involved in the learning process. However, students knowingly enrolling in on-line or asynchronous Distance-Learned courses have an expectation of an alternative classroom environment and therefore expect interaction to require more effort (Lesniak & Hodes, 2000)<sup>3</sup>. Since this study brings a broadcast instructor into a standard university classroom in real time, factors affecting just the broadcast technology and class pedagogy can be insulated from factors having to do with the collegiate lifestyle and student motivation to participate in alternative learning environments.

Student learning outcomes for the Engineering Mechanics: Dynamics course can be assessed objectively through the Dynamics Concepts Inventory (DCI) developed by

Dr Gray, Et al. and the Foundation Coalition (Gray et al. 2003)<sup>4</sup>. Results of the DCI along with course grades for both direct-contact students at the remote site and broadcast students in the standard university classroom over four semesters allows the influence of the broadcast technology on student learning outcomes to be tested. An instructor-designed survey and informal discussions explore the factors influencing student satisfaction and pedagogical changes.

#### Theoretical Framework:

The division of engineering curriculum content into lecture and laboratory classes study was established by the mathematician Gaspard Monge with development of the L`Ecole Polytechnique in Palaiseau, near Paris, France in 1794<sup>5</sup>. Many of the assumptions created with the X's<sup>6</sup> program of study about foundational mathematics and science coursework and suitability of content for lecture or laboratory delivery styles have become entrenched in American university engineering programs and propagated through the ABET accreditation standards for engineering programs<sup>7</sup>. The development of computational and tele-presence technologies and their application to engineering education has not changed traditional division of engineering content into lecture (student passive) and laboratory (student interactive) delivery. The remote site engineering programs in this study are ABET accredited under the main campus programs and rely on traditional engineering content and delivery methods.

The traditional lecture style of content delivery is the style most easily adapted for broadcast since it does not rely on physical interaction between students, experimental equipment, and the instructor. However, the Foundation Coalition<sup>8</sup> has found it to be ineffective in changing students misconceptions about dynamics concepts (Gray et al., 2005)<sup>9</sup>. That Dynamics is a difficult subject for students to learn is well documented in the engineering educational literature (Valiotis, 2008)<sup>10</sup>. The difficulty students have assimilating dynamics concepts has engendered the development of the Dynamics Concepts Inventory as an objective measure of student comprehension of the basic translation of physical principles into a mathematical vocabulary. It is the documented ineffectiveness of the traditional lecture-style delivery along with realities of content delivery through a technological medium that engendered the second question of this study.

Cognitive Theory literature indicates that effective teaching methods elicit and explore student preconceptions of the course material and develop metacognitive skills (Donovan, Et al. 1999)<sup>11</sup>. While the traditional lecture style of content delivery does not preclude development of metacognitive skills, in its simplest form, it only relates knowledge at the lowest level of Bloom's taxonomy<sup>12</sup>. Problem-solution activities and student explanation tasks are necessary to develop higher level critical thinking skills necessary to master dynamics content. The lecture style adopted by the remote instructor for this class began as an emulation of the style of a tenured faculty member who was judged by student course evaluations to be successful in teaching dynamics, along with suggestions from the instructor's manual for the course text. During this study, the pedagogy for this dynamics class became more interactive and more illustrative of concepts. The early pedagogy presented Dynamics material as though it were new to the students without exploration of common misconceptions or preconceptions. As the

pedagogy progressed, discussion of commonly misconceived physical relations came to include in-class demonstrations and conceptual discussions.

“One of the main factors that determine the success of a university is the interaction between students and instructors” (Cosman-Ross & Hiatt-Michael, 2005)<sup>13</sup>. While interaction can be fostered through many mechanisms, for the broadcast section of Dynamics, there is always a layer of technology between the main campus students and the remote instructor. In class, the television and audio system is two-way so students can interact with the instructor, and with each other, in real time, but camera angles and limitations on camera movement means body language and facial expressions are not clear. Students can also ‘hide’ from the instructor by sitting off-camera. Similarly, at the beginning of this study, the instructor necessarily ‘hid’ from the students because the sending of a document image precluded simultaneous sending of the instructor’s image. At the end of the study, a third monitor was added to the classroom that continuously broadcasts the instructor camera view. Just as in a direct-contact classroom, the students can now see both the instructor and what the instructor is writing at the same time. Out-of-class interactions occur through telephone, e-mail, and through synchronous on-line multi-media communication. However, for the students to make full use of all the multi-media capabilities available on-line they must use a dedicated computer system in the computer technician’s office. The full capabilities including video camera, document camera and scanner are not available in a student-accessed portion of the computer laboratory on campus.

“Active learning” and other methods that engage students in confronting misperceptions are considered effective in learning literature (Donovan et al., 1999). Student participation, feedback, and student-led discussions are characteristics of active learning styles (Valitotis, 2008). Since the broadcast lecture style of content delivery places a layer of technology between the instructor and student, active learning strategies that require physical participation by the instructor are limited. Discussion must be verbal or written, since body language, facial expression, and other non-verbal means of communication do not broadcast effectively. In this way, an interactive broadcast course encounters some of the same difficulties as asynchronous courses, without the student expectation of a restricted communications environment. In-class demonstrations by the instructor can be modified for broadcast. Forcing interaction and metacognition by having the students present example problems to the class is also possible. However, student participation in impromptu “laboratory exercises”, like folding paper footballs and observing their motion in the classroom, is sometimes problematic if the broadcast students do not recognize the value of participating in the exercise.

#### Inquiry Techniques:

The first hypothesis of this study was tested through examining student grades and quantitative techniques employing a standardized content assimilation assessment, the Dynamics Concepts Inventory (DCI). The DCI is a multiple choice assessment, developed through the Delphi technique, designed to test student understanding of the basic principles governing the unbalanced forces that cause motion. The instrument was validated by focus group and beta testing. Reliability was verified by the Cronbach  $\alpha$  being greater than 0.7. The 29 question inventory covers 11 fundamental concepts of force application, angular, and linear motion. No calculations are required and detractor

answers for every question indicate common misconceptions about forces and motion. The Inventory is available through Dr Gary Gray at the Pennsylvania State University, or through the Dynamics Concepts Inventory Website: <http://www.esm.psu.edu/dci/> (Gray Et al. 2003). The DCI was administered pre and post course as a timed assessment online through the Dynamics class Blackboard website.

Each semester, the instructor also administered a self-developed exploratory survey of 15 questions to assess that semester's broadcast environment and pedagogy via the class Blackboard website. While the survey was reviewed by a learning expert and another faculty at a different university to remove bias and determine appropriateness of the questions, a focus group of students was not employed to validate the survey. Approximately 10% of the questions on the survey changed each semester to reflect the exact circumstances of that semester's class. Questions on the survey probed the student reaction to the broadcast technology itself: "The quality of the DL signal did NOT interfere with my ability to learn the material in this course", and "the quality of the broadcast signal was good", interaction with the instructor: "I liked the virtual office hours in the Blackboard chat room," "emailing my instructor with questions was frustrating for me" and course pedagogy: "doing homework in groups helped me learn the material." With the exception of one question asking specifically which information students found most useful on the class Blackboard website, responses were five point Likert scale with a sixth option of not applicable. To incentivize student response, extra credit points were offered for completion. The survey was administered on-line through Blackboard the final week of classes for the semester. Analysis of the responses was not conducted until after semester grades were submitted. The purpose of the survey was to inform the instructor of student attitudes towards technological and pedagogical changes.

Data:

The class average scores from the pre-course DCI agree generally with what is to be expected from the 9.3 value reported by Gray, et al. (Gray et al. 2005). However, with an average of average scores of 8 correct responses to the 29 questions and a standard deviation in responses of 4.3, these average scores are not significantly outside the range of results expected for random guessing of 5.8 correct responses. While post-course averages show an improvement in scores of 1.7 correct answers, this improvement is not outside of one standard deviation. Therefore, no improvement in student assimilation of dynamics concepts has been measured in this study. There was no difference in results between the remote and direct-contact student populations.

Examining the detractor answers to the Inventory questions across about one third of the questions on the inventory, a fewer number of the available answer selections were chosen on the post-course Inventory than on the pre-course Inventory. This convergence to a select group of the available answers may indicate fewer students randomly guessing on about a third of the questions. However, while student responses converged, they did not converge to the correct answer. They tended to converge to specific detractor answers indicating that common misconceptions about the material taught in Dynamics class were reinforced, rather than being corrected, during the course.

Like the DCI results, student grades for the semesters do not indicate a difference between the direct contact and broadcast populations. Studies of broadcast classes using only grades to assess effectiveness report no difference in grades between student

populations (Salisbury, Pearson, Miller, & Marett, 2002)<sup>14</sup>. The grade distributions are generally Gaussian with a long tail at the low end. Since the assessments used to generate grades are generally calculation-based problem solutions, difficulty with dynamics concepts that do not involve mathematical calculations cannot be assessed through student grades.

Student grades appeared to correlate with DCI results only for those scoring above class average on the DCI. The few students who scored more than one standard deviation above average on both the initial and post-course DCIs were also among the top scoring students on the graded assessments. However, average scores or a lack of improvement from the initial to the post-course DCI did not correlate with student grades. Many students earning “B” grades did not show significant improvement on their DCIs. This lack of correlation between grades and DCI improvement may indicate the ineffectiveness of calculation-style assessments for monitoring concept development in Dynamics student learning. However, by design, the concepts inventory does not measure the importance of calculation-style problem solution techniques to overall engineering education. Most Dynamics text books emphasize calculation style problems. This lack of correlation may indicate a broader disconnect between understanding of physical concepts and the ability to apply appropriate mathematical solution techniques.

Survey results have shown consistently that over 60% of students who have taken Dynamics by broadcast would *not* choose to take another class by the same method. While grades and DCI results do not indicate a difference in the direct contact and broadcast student populations, students in the broadcast class were dissatisfied with their experience. Forty-six percent of respondents would not recommend to a friend to take a broadcast class.

Technological improvements aimed at improving the quality of the broadcast signal have been effective. In spring 2006, over 43% of respondents reported that the quality of the broadcast was poor enough to interfere with their ability to assimilate course content. In Fall 2007, only 16% of Dynamics students felt that the broadcast quality interfered with their ability to learn. The technological improvements included: continuously broadcasting the instructor camera view on a third monitor and improving the resolution of the content screen image. Eighty percent of respondents in spring 2006 liked the way the Blackboard website was used in class. Class notes, some previously used assessments with solutions, the syllabus, and announcements are posted to Blackboard. That level of Blackboard use has been consistent throughout the study. While 4% of students responded that they did not like having to e-mail questions to the instructor, 12% of students admitted that they had not tried to e-mail the instructor and another 12% appreciated the e-mail interaction. These results appear to indicate students are comfortable with the technology-enhanced classroom. However, a small percentage of students perceive that the technology interferes with their learning process.

Overall, the class surveys indicate that students appreciate instructor feedback, whether in class or by e-mail. However, while 16% of students in the Fall 2006 semester responded that Blackboard chat room “office hours” worked well for them, 37% responded that the on-line, real-time, chat room “office hours” were unacceptable. Real-time chat room “office hours” were discontinued after the following spring semester. That the instructor can not be followed into the hall after class frustrates students with over half of the students responding that they wished there was another method of

contacting the instructor. Only one student out of the over 90 in broadcast sections over the four semesters studied used the multi-media on-line contact method to interact with the instructor. For the one semester in which the instructor allowed text-messaging to her personal cell phone, two students from the broadcast section used the service for simple questions like confirming the homework problems due that week. These results appear to indicate that student comfort level with a variety of technologically enhanced communication techniques is individual and course pedagogies that include significant feedback from the instructor are appreciated by students.

When asked at the end of the semester about alternative broadcast delivery modes, 78% of respondents felt that real-time streaming video to their personal computers would be just as effective as the real-time broadcast to the classroom, 46% agreed or strongly agreed that an asynchronous (taped) lecture would be effective as long as there was in-class problem recitation. Thirty-two percent disagreed with the question of asynchronous delivery. However, 66% felt that a totally on-line class with no in-class portion not acceptable. These results appear to indicate two things. First, students value direct-contact and organized problem recitation in Dynamics class. Second, some students are open to alternative methods of content delivery. The results on questions of alternative delivery mode also appear to reinforce the conclusion that student comfort levels with broadcast technologies are individual, not common to a cohort.

#### Conclusions:

The similarity in DCI results and grades earned between the direct-contact and broadcast student populations indicate that the broadcast technology does *not* strongly influence student learning outcomes in a core engineering class. Problems with the technology frustrate students. But, many students in a standard university environment are willing to try alternative delivery modes for key classes.

The lack of improvement in class performance on the DCI over four semesters indicates that the unobtrusive changes in the traditional lecture style implemented over three semesters have been ineffective in improving student assimilation of dynamics concepts. Similarly, improvements in the broadcast lecture environment and increasing methods of instructor contact have not been effective in improving DCI results. Changing textbooks, changing lecture content to include more conceptual discussions of Dynamics as suggested by Gray, et al.<sup>6</sup>, implementing math skill assessments for intervention of poorly prepared students, increasing the percentage of homework scores in the semester grade calculation, and improving support from outside tutors have had no effect on the post-course DCI scores. Major improvements in the quality of the broadcast and homework handling procedures have had no effect on the post-course DCI scores. These results appear to indicate, as suggested in the Foundation Coalition research for traditional direct-contact instruction, that it is the traditional lecture delivery method, not broadcast technology that primarily influences learning outcomes in Engineering Mechanics classes.

Survey results, second hand student interviews, and other discussion indicate that student perception of the broadcast delivery method is unsatisfactory even though the delivery method does not appear to influence student grades. Students report frustration with lack of feedback from instructors, feelings of isolation and forced independence in completing coursework, along with difficulty maintaining classroom discipline and

focusing on broadcast lectures (Brian Barker, Erik Newell-Lavigne, Claudia Heflin, and Edgar Felix, personal communication, 2007/2008, Interviews with main campus Dynamics students, Loscutoff, December 2007)<sup>15</sup>.

While test results indicate that the broadcast method of delivery is as effective as direct contact in creating student learning outcomes, students do not like it. The reasons students do not like broadcast classes were not directly probed in this study. However, discomfort with the technology or technologically assisted communications do not appear to be significant factors in the student dislike. Future investigations in this area should probably focus on student expectation and motivation, the importance of the classroom environment and student-to-student interactions on creating learning outcomes, and the convenience of alternative delivery mode as it influences student satisfaction.

Overall, having an objective measure of student understanding of the concepts required to master dynamics course material was essential to the conduct of this research. In one semester, determining that about a third of the students in the remote class had difficulty completing basic algebra and calculus calculations would not have been possible without the initial Dynamics Concepts Inventory results to rule out conceptual difficulties with the course material. Having a standardized method, other than grades, on instructor-generated assessments, to study two distinct student populations taking the same class in similar classroom environments ensured there was no instructor bias toward one of the student populations due to proximity.

As expected from the literature, this study also found “no significant difference” in student learning outcomes between broadcast and direct-contact content delivery modes. While the prejudice against broadcast classes is persistent, it does not appear to be engendered by the broadcast technology itself.

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