TRADITIONAL, BLENDED, AND ONLINE TEACHING OF AN ELECTRICAL MACHINERY COURSE IN AN ELECTRICAL ENGINEERING TECHNOLOGY PROGRAM

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Abstract

With increasing emphasis on student learning outcomes and assessment, educators constantly seek ways to effectively integrate theory and hands-on practices in inventive course design methodologies. Critics of engineering education argue that educational programs focus too much on the transmittal of information through static lecture-discussion formats and routine use of outdated laboratory exercises. On the other hand, active learning, the learning that involves hands-on experience, significantly improves student comprehension and proficiency. It is clear that understanding and retention are greatly enhanced when students engage in active learning. While theoretical knowledge remains a fundamental component of any comprehension process, the underpinnings of proficiency development seem to increase best through active learning practices. What remains less clear is the "gold standard" for pedagogical approaches that combine theory and hands-on learning.

The Electrical Engineering Technology (EET) program in the School of Technology (SoT) at Michigan Tech is constantly revamping the curriculum to meet the expectations of industry by supplying qualified technicians and technologists who have extensive hands-on experience. To further enhance and make the curriculum model more flexible, all programs across the School of Technology are developing and offering online courses in multiple disciplines. In this paper, authors emphasize the development and implementation of three models of an Electrical Machinery (EM) course offering. The traditional way of teaching of an EM course for EET and Mechanical Engineering Technology (MET) majors has already been offered several times, allowing the authors to collect data on student comprehension. The goal of a blended approach is to join the best aspects of both face-to-face and online instruction: classroom time can be used to engage students in advanced learning experiences, while the online portion of the course can provide students with content at any time of the day allowing for an increase in scheduling flexibility for students. A 70/30 hybrid of traditional and online versions of the EM course has been offered three times, which in turn has triggered the development of fully online and fully blended versions of this course. The online EM course was offered in the summer of 2012 for a class of four students, and the blended version of the course was conducted in the fall semester of 2012 for a class of 45 students.

In this paper, the authors present the structural details of all course models, including the theoretical topics and experimental exercises, the technology being used for the online materials development, implementation of the assessment tools to evaluate student progress, and student perception of all educational models.

Introduction

With a growing emphasis on student learning outcomes and assessment, faculty and educators constantly seek ways to integrate theory and research in innovative course design methodologies [1-5]. Critics of engineering education argue that educational programs focus too much on the transmittal of information through static lecture-discussion formats and routine use of outdated laboratory exercises [6], [7]. This educational approach often results in graduates who do not have a full range of employable skills, such as the ability to apply knowledge skillfully to problems, communicate effectively, work as members of a team and engage in lifelong learning. As a result, engineers and engineering technologists often enter the workforce inadequately prepared to adapt to the complex and ever-changing demands of the high-tech workplace [8]. Research [9-11] shows that active learning, learning that involves hands-on experience, significantly improves student comprehension and proficiency. In a study by van and Spencer [12] where researchers compared learning outcomes in a management class, taught using lecture-based methods versus active learning methods, an improvement of one standard deviation was demonstrated with regard to long-term memory and use of concepts over time for the active learning group [8]. Similarly, in a study of over 6,000 participants enrolled in an introductory physics class [13], students who engaged in active learning scored two standard deviations higher on measures of conceptual understanding of Newtonian mechanics than did students in a traditional lecture-based course.

Recent studies reinforce the importance of blended learning due to its impact on students. Students also recognized the value of the blended course delivery. An Eduventures survey of 20,000 adult students found that only 19% of responders were enrolled in blended courses [14]. However, 33% of all respondents cited it as their preferred format [15]. This preference suggests that student demand for blended and hybrid courses exceeds the number offered by institutions nowadays. In another study [14], the aggregated results from surveys on the effectiveness of blended learning were presented. The survey was issued at 17 institutions during the 2010 academic year [14]. A total of 1,746 students in the United States and the United Kingdom participated in the survey. According to the key demographic data presented in the study, only 5% of the participants were from engineering and 4% from computer science. The students' responses on the survey, regarding the advantages of blended learning compared to traditional teaching methodologies, was positively overwhelming.

It is clear from these studies that understanding and retention are greatly enhanced when students engage in active learning. While theoretical knowledge remains a fundamental component of any comprehension process, the underpinnings of proficiency development seem to flourish best through active learning practices [8], [13-15]. What remains less clear is the “gold standard” for pedagogical approaches that combine theory, hands-on and active learning approaches in various fields of engineering. The question that needs to be addressed is whether or not any course in engineering can be converted to its online and/or blended versions to ensure effective student comprehension of the subject taught.

Traditional, Online, or Blended Learning

The rapidly evolving technological world requires engineering skills be up-to-date and relevant. This applies to industry-employed workers as well as students pursuing a college degree. To keep up with the rapid developments in technology, industry representatives need to constantly update their knowledge base. On the other hand, the current economy impacts the college students in a way that many undergraduates have to work to secure the funds for their education which, in turn, requires a more flexible class schedule. In order to accommodate the needs of university students and industry representatives, the educational units must adequately adjust their curricula in order to provide students with the opportunity to learn via traditional, blended or purely online class styles. Figure 1 depicts all three educational approaches. The first scenario represents a traditional model in which the theory and hands-on activities are delivered in-person. Note that even the traditional approach branches into two distinctive models (not shown in the figure). One branch represents the traditional engineering curriculum in which the theory of the subject is presented first, followed by the hands-on activities. There is an alternative model, the second branch of the traditional approach, commonly adopted by engineering technology programs, in which the theoretical knowledge presented in lectures is immediately reinforced with laboratory hands-on activities.

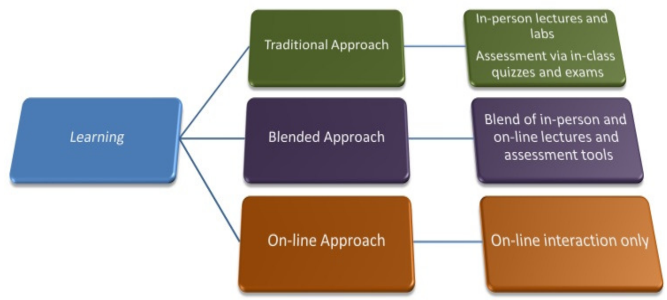

Figure 1. Educational Approaches Currently used in Academia

The second scenario represents blended learning, which combines face-to-face classroom methods with computer-mediated activities to form an integrated instructional approach.

The goal of a blended approach is to join the best aspects of both face-to-face and online instruction. Classroom time can be used to engage students in advanced learning experiences, review the material covered in the online lectures, and answer students questions, while the online portion of the course can provide students with content at any time of the day allowing for an increase in scheduling flexibility. In addition to the added flexibility and convenience to students, there is evidence that a blended instructional approach can result in learning outcome gains and increased enrollment retention [16]. Blended learning is on the rise in higher education. As of now, 93% of instructors are using blended learning strategies, and 7 in 10 expect more than 40% of their courses to be blended [17] by 2013.

The third, online approach is essentially the computer- and network-enabled transfer of skills and knowledge. In online learning, content is delivered via the Internet, audio or video tape, etc., and includes media in the form of text, image, animation, streaming video and audio. By 2006, 3.5 million students were participating in online learning at institutions of higher education in the United States [18]. According to Sloan Foundation reports [19], [20], there has been an increase of around 12–14 % per year on average in enrollments for fully online learning over the five years from 2004 to 2009 in the U.S. post-secondary system, compared with an average increase of approximately 2% per year in enrollments overall. Online engineering education provides a flexible and accessible alternative for students and people who want to pursue higher education at their own pace. Because of this, more online courses are being offered as part of traditional programs [21]. However, studies show that student participation and motivation are different from an online course [21-28]. Positive attributes of online learning include: increased productivity for independent learners; diminished fear of public speaking, which increases class participation; efficiency in assignment completion; and, easy access to all lecture materials during the entire course [21], [29]. However, critics of online learning claim that it diminishes the active process of learning and, as a result, limits development of high-level thinking skills [21], [29]. Other research has focused on the benefits of online learning for certain demographics. In particular, older students have significantly higher final course graders than their younger, 24-year-old and younger peers, and do better than counterparts who learn the same material in a class lecture style of learning [27].

Revamping the Electrical Machinery Course

The EET program in the SoT at Michigan Tech has already successfully developed and implemented several blended and online courses in the field of Robotics Automation [30], [31]. Being a core course, the EM course has been traditionally taught for years in the SoT serving electrical and mechanical engineering technology students. The EM course covers the fundamental steady-state analysis of electrical machinery, including transformers, DC machines, AC poly-phase and single phase AC machines.

Upon successful completion of this course, students should have the knowledge to:

- Analyze single- and three-phase circuits.
- Understand the principles of magnetic circuits.
- Test and model single-phase and three-phase transformers.
- Understand and predict the behavior of DC generators and motors.
- Test and model AC induction motors.
- Gain an extensive hands-on experience working with laboratory equipment.

Figure 2 depicts the course structure including the learning and assessment tools.

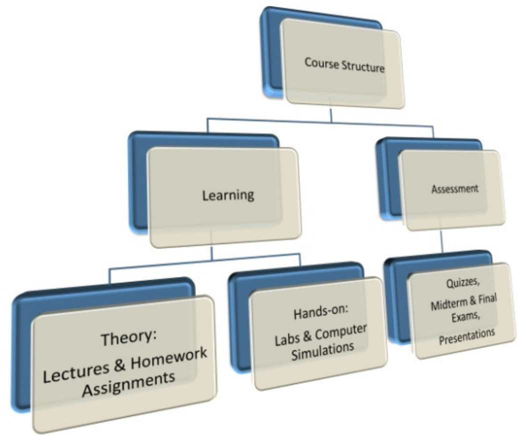

Figure 2. Electrical Machinery Course Structure

The theoretical part of the course is conveyed to students via lectures and homework assignments. It is very common that homework assignments are used as assessment tools only. In the authors' approach, the homework is assigned weekly and the solutions to the problems are provided. Homework assignments are not graded but must be worked thoroughly by the students to prepare for follow-up quizzes given one week after receiving the related assignment. This approach of assessing student knowledge has been tested for several consecutive years and has proven to be very effective in student comprehension of a subject. The other assessment tools used in the EM course are the midterm and final examinations, and student presentations.

Due to globalization, the development of student soft skills is becoming an integral part of the curriculum at most universities. In most classes offered in the SoT at Michigan Tech, students are required to research and present a technical journal paper on topics related to the class subject, followed by submission of a comprehensive written technical report. Student performance is graded based on several factors such as: the ability to extract the key technical concept of the paper, the technical knowledge of the subject matter, proficiency and confidence in presenting, and the quality of the written report. Due to the hands-on nature of the educational strategy, the laboratory component is an integral part of any course offered in the SoT, and the EM course is no exception. Every week, the students have an opportunity to apply the knowledge they gain in the classroom to industrial equipment. By the end of the course, students have at least 33 hours of hands-on activities. The knowledge gained via theoretical and practical exercises is reinforced by computer projects utilizing MATLAB simulation software.

In 2009, the first attempt at converting the existing traditional model of the EM course into the blended version was made. Utilizing the hybrid methodology, several lectures were converted to an online format and gradually introduced to a class of 40 students. Feedback collected from the students showed an interest in the hybrid/blended version of the course. A standard assessment model, previously conducted for traditionally taught EM courses, demonstrated an increase in comprehension of the subject. The students were able to re-take the lecture if needed, an opportunity that does not exist in traditional, in-class teaching. To conduct further research on the effectiveness of the hybrid model, one more hybrid version of the EM course was conducted in the fall, 2010 and 2011, semesters for classes of 48 and 46 students, respectively. The ratio of in-person to online lectures was kept at 60/40. Student feedback collected at the end of the courses again indicated a great interest in hybrid learning. Most of the students agreed that having part of the lectures in an online format not only provided them with a flexibility to adjust their busy schedule but also allowed them to better comprehend advanced material by listening to the lectures at their own pace. Students also expressed interest in the fully online and blended versions of the EM course. The students’ desire to have an online version of the course was specifically expressed in the course that could be offered during summer sessions.

To further enhance and make the curriculum model more flexible, the authors developed an online version of the EM course for students currently enrolled in Michigan Tech and for industry representatives looking to improve their knowledge in the subject. The online EM course was offered in the summer of 2012 and consisted of the online learning modulus, online quizzes and exams, and intense laboratories. Only four students participated in this pilot, online course offering and completed it successfully, fulfilling all of the course requirements. The small number of students participating in the course did not allow the authors to statistically describe the success of the online model and therefore no conclusions were drawn. To collect necessary statistical data allowing the authors to evaluate the online model of the course offering and to draw rational conclusions, the next online course is scheduled for summer of 2013.

To close the loop on different educational models of the EM course, the authors also developed the fully blended version of the course. In this four-credit-hour blended version of the course, all of the lectures were delivered online and consisted of 24 online modules ranging from 35 to 55 minutes covering the same amount of theoretical material as in the traditional version of the course. Considering the blended nature of the course, the in-person class time was spent engaging students in advanced learning experiences, reviewing the material covered in the online lectures and answering students' questions. Faculty teaching the course met at least twice a week during scheduled class times on Monday, Wednesday and Friday. Monday's class for in-person interaction provided the students with the opportunity to reinforce the key concepts introduced in the online learning modules, ask questions, and engage in discussions relevant to the theoretical and practical topics revealed in the online lectures. Lecture time during Wednesday's class was devoted to student presentations. Students were required to research and present a technical journal paper on topics relevant to the class subject followed by submission of a comprehensive written technical report. Student performance was evaluated and graded by the faculty and classmates. Evaluations were based on several factors including the students' ability to extract the key technical concept of the paper, their technical knowledge of the subject matter, their proficiency and confidence in presenting, and the quality of the written report. Friday's class time was left open for the students with faculty being available for questions and discussions. The laboratory component is an integral part of any course offered in the SoT. In the EM course, students have an opportunity every week to apply the knowledge they gain in the classroom to industrial equipment. By the end of the course, students have at least 33 hours of hands-on activities. The knowledge gained via theoretical and practical exercises is reinforced by computer projects utilizing MATLAB simulation software.

Echo 360 Lecture Capturing Technology

To create the online learning modulus for hybrid, blended and online versions of the EM course, the authors utilized an Echo 360 lecture-capturing system readily available at Michigan Tech [32]. The Echo 360 system combines a view of the presenter, with a capture of the screen output, automatically making the results available shortly after a lecture is delivered. There are two options to utilize the Echo 360 capturing system at Michigan Tech: 1) to use a designated classroom equipped with a computer, cameras, microphones and digital boards; and, 2) to request the installation of a standalone Echo 360 license on the office computer. The authors utilized the second option, due to the convenience and flexibility of creating online modules from one's office. The equipment used for the in-office approach was the computer with the installed Echo 360 license, a video camera for capturing the presenter, a microphone for capturing audio and an Adesso CyberPad Digital Notebook [33]. Utilization of the CyberPad in online lecture development serves the purpose of the whiteboard in the classroom and allows the presenter to solve numerical problems in real time. Every equation or expression written on the digital pad is displayed on the computer screen and captured by the Echo 360 software in real time, which makes the online lecture very similar in appearance to the one taught in-person.

Students enrolled in the traditional or hybrid/blended versions of the course are engaged in weekly three-hour-long laboratory activities. The students enrolled in the online EM course participate in two intense laboratory sessions scheduled during two weekends. Considering the seven-week duration of the course, the two laboratory sessions were conducted after the third and sixth weeks. Prior to each laboratory session, the participating students were required to pass multiple quizzes specifically designed to test their knowledge of the subject matter being exercised in the laboratory activities. Upon completion of all of the course requirements, student knowledge was assessed using a two-hour online examination conducted via the Canvas learning environment.

Course Assessment

To effectively assess the course outcomes, direct and indirect assessment tools were implemented. In general, **direct** assessment involves looking at actual samples of student work produced in the course. These may include homework, quizzes and midterm and final examinations. **Indirect** assessment involves gathering information through means other than looking at actual samples of student work. These include surveys, exit interviews and focus groups. Each serves a particular purpose. Indirect measures can provide an evaluator with the information quickly, but may not provide real evidence of student learning. Students may think that they learned well or say that they did, but that does not mean that their perceptions are correct. It may also represent the other side of a coin—students may believe that they did not perceive some material well enough, while at the same time spending too much of their time learning the subject, but the direct assessment may indicate otherwise.

Table 1 shows the results of the survey. The authors intentionally collected the participant's age, which averaged 21. The group of students that was assessed on the perception of various learning models consisted of sophomore, junior and senior students with more weight on junior-level students. The majority of the assessed students were men with very few women, and the average age was 21 years old. An indirect assessment tool the authors developed and implemented was the completely anonymous student survey. The survey was contacted at the end of the course and was introduced to the students with the following statement:

Table 1. Student's Survey used as an Indirect Assessment Tool

5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree	Average
Average student's age	21
I am a motivated person and can take online lectures on time without being reminded.	3.33
I prefer blended learning because it provides me with additional flexibility when and where to listen to the lectures.	3.25
I prefer blended learning because I can listen to the lectures several times, if needed, resulting in better understanding of the presented material.	3.33
I prefer blended learning because I can comprehend the material on my own and still have one class a week devoted to questions	2.83
Online lectures help me to better focus on the subject without being distracted by classmates, noise, etc.	2.08
The blended learning encouraged student-faculty interaction outside of a classroom (office hours, email, etc.)	2.75
Blended learning free up class time that can be used for student presentations, which I consider to be an important tool for broadening my scope and developing my presentation skills.	2.96
Blended type of classes help me to balance between school and work	3.09
Blended type of classes help me earn higher grades	2.46
Blended type of classes help or would help me to take more classes	2.88
I would like to see more blended classes on campus	2.42
Overall the course was well designed and taught.	3.71
I gained significant practical experience in EET2233 blended course	3.33
The amount of time that I have to spend on the EET2233 blended course is more than the time I usually spend on a regular on-campus class.	3.54
I learned a great deal from this course	3.54

The purpose of this anonymous questionnaire is to collect student feedback on the effectiveness of various educational models. As you may know, the subject can be taught purely in person, purely online and by utilizing a blended learning approach, which is the mix of in person and online instructions. Please complete this survey without being biased by the fact that you may not like the online learning for whatever reason and try to base your answers only on the effectiveness of your comprehension of the material taught in EET 2233 in the Fall 2012.

Analysis of the data represented in Table 1 reveals that students' responses to some of the questions regarding the blended version of the EM course were just above average. The question *Online lectures help me to better focus on the subject without being distracted by classmates, noise, etc.* appeared to be relatively low at only 2.08. The authors attribute such a low output to the age of student participants at the age of 21 are easily distracted and are not very motivated to pursue learning on their own. Students also indicated that the amount of time they have to spend on the EET 2233 blended course is more than the time they usually spend on on-campus, traditionally taught classes. It is interesting to observe the students indication that "*they learned a great deal from the course*" at the same time stating that they "*had a hard time*" earning high grades.

To further evaluate the blended version of course success, the authors implemented the direct assessment tool. The average and standard deviation results of the final exam scores, as well as a final grade distribution were used as a rubric for this assessment. The authors also compared these data with those available from previous years when the course was taught utilizing traditional and hybrid models. Table 2 shows the average and standard deviation results, and Table 3 demonstrates the final grade distribution for the courses taught between 2009 and 2012.

Table 2. The Average and Standard Deviation Results of the EM Course Assessment for 2009-2011

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)
Average	80	78	77	81
Standard Deviation	13.4	17	17	13.8
#Students	40	48	46	45

Table 3. The Final Grade Distribution of the EM Course for 2009-2011

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)
A	13	13	13	14
AB	8	15	11	7
B	10	4	12	5
BC	3	5	5	6
C	2	1	3	6
CD	0	0	1	2
F	0	2	0	3
#Students	40	48	46	45

The direct assessment of these data reveals very interesting results. Even though student perception of the blended version of the EM course was not exceedingly positive, the direct assessment demonstrates that the performance of students participating in the blended learning course was either the same or better when compared to traditional and hybrid models. The grade distribution demonstrates that the number of A and AB students is consistent; however, there is an increase in CD and F students. This can again be attributed to the maturity stage of the students that at the age of 21 not always can be well organized without being "pushed" by the instructor to study, which results in poor performance at the end.

Conclusion

Academic programs in the School of Technology at Michigan Tech are designed to prepare technical and/or management-oriented professionals for employment in industry, education, government and business. The EET program in the SoT is constantly revamping the curriculum to meet the expectations of industry by supplying qualified technicians and technologists who have extensive hands-on experience. To further enhance and make the curriculum model more flexible, all programs in the SoT are developing and offering online courses in multiple disciplines. In this paper, the authors discussed the EM course development and implementation for students currently enrolled in Michigan Tech, and industry representatives looking to improve their knowledge of the subject.

Due to the current prevalence of blended learning in academia and on-going research on its effectiveness, any input from academic units participating in online courses, development and implementation will increase the knowledge database. Introduction of blended and online versions of the EM course will complement already existing hybrid and traditional educational models of the EM course. The availability of all of the educational models in the curriculum produces multiple benefits as indicated below:

- Time flexibility for all students.
- Flexibility in learning preferences: some students may prefer in-person learning and some may choose the purely online approach.
- Introduction of the online summer session of the course will reduce the size of the class in the fall semester. The smaller class size allows the faculty to have a more individual approach during lectures and laboratories.
- Faculty will be able to assess the effectiveness of each approach and share this knowledge with colleagues.
- Improve STEM education by adopting the most effective learning techniques.

The authors strive to improve the quality of education at the University and will continue researching the "gold standard" for pedagogical approaches. The data collected during this study will be shared with the educational community with the overall goal of improving STEM education.

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