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Effectiveness of Traditional, Blended and On-Line Teaching of Electrical Machinery Course

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Abstract

With an 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programs focus too much on the transmittal of information through static lecture-discussion formats and routine use of outdated laboratory exercises.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, 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.

In this article we describe the development and implementation of three models of Electrical Machinery course offering: traditional, on-line, and blended. The traditional way of teaching of Electrical machinery course in Electrical Engineering Technology (EET) and Mechanical Engineering Technology (MET) majors has been conducted for years and therefore provides us with significant statistics on students' comprehension of the subject. 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. The blended version of Electrical Machinery course has been developed and implemented four times. During the first two offerings the blended approach was slowly introduced to the class to understand the students' perception and to capture any positive and/ or negative changes in the subject comprehension. The last three offerings of the Electrical machinery course taught in the Fall of 2012, 2013 and 2014 had fully integrated blended instructions. Rigorous assessment revealing interesting results has been implemented during the last offerings. The on-line Electrical Machinery course was offered during Track A of summer 2012-14 and is in the book for summer 2015.

In this article we discuss the structural details of all three course models, including the theoretical topics and experimental exercises of the course, the technology that has been used for the on-line materials development, implementation of the assessment tools to evaluate the students' progress, and perception of all three 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 the 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[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 6000 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. In 2010, U.S. Department of Education found blended learning courses produce statistically better results than their face-to-face equivalents[14]. Students also recognized the value of the blended course delivery. An Eduventures survey of 20,000 adult students found 19 percent of responders were enrolled in blended courses[15]. However, 33 percent of all respondents cited it as their preferred format[16]. This preference suggests student demand for blended and hybrid exceeds the number offered by institutions nowadays. In study[14], the aggregated results from surveys on the effectiveness of blended learning have been 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 United Kingdom participated in the survey. According to the key demographic data presented in this study[14] only 5% of participants were from engineering and 4% of computer science. The student’s response in this survey regarding the advantages of blended learning in comparison to traditional teaching methodologies was positively overwhelming. 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]. What remains less clear is the “gold standard” for pedagogical approaches that combine theory, hands-on, and active learning approach 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 on-line and/or blended versions to ensure effective students' comprehension of the subject taught.

Traditional, online, or blended learning?

The rapidly evolving technological world requires engineering skills being up-to-date and relevant. This applies to industry employed workers, as well as the students pursuing college degrees. To keep up with the rapid developments in technology, the industry representatives need to constantly update their knowledge base. Besides all the reasons mentioned above and related to the implementation of various teaching methodologies, 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 both groups: the university enrolled students and industry representative, the educational units must adequately adjust their curriculum, providing students with the opportunity to learn via traditional, blended or purely on-line class styles. Figure 1 depicts all three educational approaches. The first case represents a traditional model, in which the theory and hands-on activities are delivered in-person. We note that even the traditional approach branches into two distinctive models (not shown in the Figure 1). One model 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 commonly adapted by the engineering technology programs, in which the theoretical knowledge presented in the lectures is immediately reinforced with the laboratory hands-on activities.

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

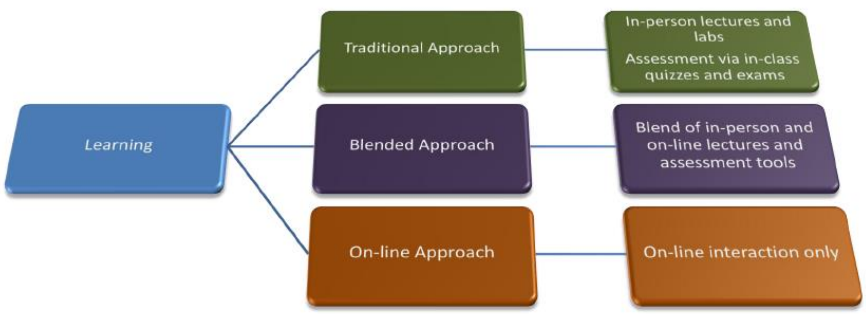

Figure 1: Educational approaches currently used in academia

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 on-line 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 for students. In addition to the flexibility and convenience to students, there is early evidence that a blended instructional approach can result in learning outcome gains and increased enrollment retention[17]. Blended learning is on the rise in higher education. As for now, 93% of instructors are using blended learning strategies and 7 in 10 expect more than 40% of their courses to be blended[18] by 2013.

The third, on-line approach is essentially the computer and network-enabled transfer of skills and knowledge. In on-line 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.[19] According to the Sloan Foundation reports, [20,21] there has been an increase of around 12–14 % per year on average in enrollments for fully online learning over the five years 2004–2009 in the US post-secondary system, compared with an average of approximately 2% increase per year in enrollments overall. On-line engineering education provides a flexible and accessible alternative for the 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[22]. However, studies show that student participation and motivation are different for an on-line course[22-29]. 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 material during the entire course[22, 30]. 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[22, 30]. 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[28].

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[31, 32]. 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 polyphase and single phase AC machines. Figure 2 depicts the course structure, including the learning and assessment tools.

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.

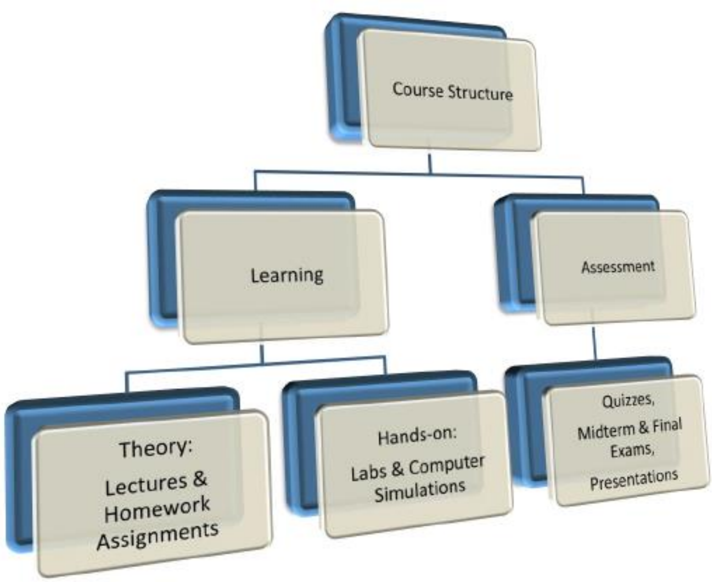

Figure 2: Electrical Machinery course structure

The theoretical part of the course is comprehended by the students via lectures and homework assignments. It is very common that homework assignments are used as an assessment tool 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 with the students to prepare for a follow up quiz given to the students in one week upon receiving the related assignment. This approach of assessing student's knowledge has been tested for several consecutive years and proved to be very effective in student's comprehension of a subject taught. The other assessment tools used in the EM course are the midterm and final examinations, and students' presentations. To make students more well-rounded engineers, the development of the student soft skills is becoming an integral part of the curriculum in most universities. In most of classes offered in the School of Technology 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 technical written report. The 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 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 course enrolled students have an opportunity to apply the knowledge they gain in the classroom to the 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 the 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 has been made. Utilizing the hybrid methodology, several lectures were converted into the online format and gradually introduced to the 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 last contribution was due to the fact that students were able to "re-take" the lecture if need it - this opportunity does not exist in the traditional, in-class teaching. To further conduct the research on the effectiveness of the hybrid model of offering, one more hybrid version of the EM course was introduced in the Fall of 2010 and 2011 to the class of 48 and 46 students respectively. The ratio of in-person to on-line lectures was kept at 60/40. The students' feedback collected at the end of the courses again indicated a great interest in the hybrid learning. Most of the students agreed that having part of the lectures in on-line format not only provides them with a flexibility to adjust their busy schedule, but also allows the students to better comprehend an advanced material by listening to the lectures at their own pace. Students also expressed their interest in the fully on-line and blended versions of the EM course. The students desire to have an on-line version of the course was specifically expressed in the course that could be offered during one of the Summer Track A or Track B sessions.

To further enhance and make the curriculum model more flexible, the authors developed an on-line version of the EM course for currently enrolled in Michigan Tech students and industry representatives looking to improve their knowledge in the subject. The on-line EM course was offered in Track A of summers 2012-14 and consisted of the online learning modulus, online quizzes and exams, and intense laboratories. Only few students participated in this pilot on-line course offerings in 2012-14 and completed it successfully fulfilling all the course requirements. The small number of students participating in the course does not allow the authors to statistically describe the success of the on-line model and therefore no conclusions will be drawn at this point. To collect necessary statistical data, allowing the authors to evaluate the on-line model of the course offering and to draw rational conclusions, the next on-line course is scheduled for Track A for Summer 2015.

To close the loop on different educational models of the EM course offered at Michigan Tech, the authors developed the fully blended version of the course. In this four credit hour blended version of the course, all the lectures were delivered online and comprised of 24 online modules ranging from 35 to 55 minutes covering the same amount of the theoretical material as in the traditional version of the course. Considering the blended nature of the course offering the "in-person" class time was spent to engage students in advanced learning experiences, review the material covered in the on-line lectures, and answer students' questions. Faculty teaching the course met at least twice a week during scheduled class times, which are Monday, Wednesday and Friday. Monday's class of "in-person" interaction provided the students with the opportunity to reinforce the key concepts introduced in the online learning modulus, ask the questions, and engage in the discussions relevant to the theoretical and practical topics revealed in the lectures. Lecture time during Wednesday's class was devoted to the student presentations - students were required to research and present a technical journal paper on topics related to the class subject followed by submission of a comprehensive technical written report. Friday class time was left open for the students with faculty being available for questions and discussions. The student performance was evaluated and graded by the faculty and classmates and was 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. The laboratory component is an integral part of any course offered in the SoT - every week, the course enrolled students have an opportunity to apply the knowledge they gain in the classroom to the 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 the computer projects utilizing MATLAB simulation software.

Echo 360 Lecture Capturing Technology

To create the on-line modulus of the course that could be further used in hybrid/blended, and online versions of the EM course, the authors utilized readily available at Michigan Tech Echo 360 lecture capturing system[33]. 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; 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 on-line modulus from the personal office. The equipment used for the personal capture was: the computer with installed Echo 360 license, the video camera for capturing the presenter, the microphone for audio capturing, and Adesso CyberPad Digital Notebook[34]. Utilization of the CyberPad in on-line lectures development serves the purpose of the white board in the classroom and allows the presenter to solve the numerical problems in real time. Every equation or expression written on the digital pad is transmitted to the computer screen and captured by the Echo 360 software in real time, which makes the on-line lecture to be 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 3-hour long laboratory activities. Students enrolled in on-line EM course participate in two intense laboratory sessions scheduled during two consecutive weekends. Considering the seven weeks duration of the Track A, the two laboratory sessions are conducted after the third and six weeks consecutively. Prior to each laboratory session, the participating students will be required to pass multiple quizzes specifically designed to test their knowledge in the subject matters being exercised in the laboratory activities. Upon completion all of the course requirements, students' knowledge is assessed using two hour on-line examination conducted via the Canvas learning environment.

Course Assessment

To effectively assess the course outcomes the direct and indirect assessment tools have been 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 is 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 another side of a coin - students may believe that they did not perceive a material well enough at the same time spending too much of their time learning the subject, but the direct assessment can indicate otherwise.

As an indirect assessment tool the authors developed and implemented the completely anonymous student survey. The survey was contacted at the end of the course during Fall 2012-14 offerings and was provided to the students with the following statement:

"The purpose of this anonymous questionnaire is to collect the student feedback on the effectiveness of various educational models. As you may know, the subject can be taught purely in person, purely online and utilizing a blended learning, 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 on-line 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 2012/2013/2014."

By starting the survey with the paragraph above, the authors intended to remove the student's bias towards online learning, commonly present among young students. Table 1 shows the results of the survey. We intentionally collected the participant's age, which averaged to 21.

5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1	Average	Average	Avera

= Strongly Disagree	2012	2013	ge 2014
Average student's age	21	22	22
I am a motivated person and can take on-line lectures on time without being reminded.	3.33	3.27	3.35
I prefer blended learning because it provides me with additional flexibility when and where to listen to the lectures.	3.25	2.62	3
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	3.31	3.8
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	2.42	3.5
Online lectures help me to better focus on the subject without being distracted by classmates, noise, etc.	2.08	2.11	2.2
The blended learning encouraged student-faculty interaction outside of a classroom (office hours, email, etc.)	2.75	2.19	2.9
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	2.54	3.3
Blended type of classes helps me to balance between school and work	3.09	2.73	3.55
Blended type of classes helps me earn higher grades	2.46	2.11	2.85
Blended type of classes help or would help me to take more classes	2.88	2.35	2.7
I would like to see more blended classes on campus	2.42	2.12	2.75
Overall the course was well designed and taught.	3.71	3.7	4.15
I gained significant practical experience in EET2233 blended course	3.33	3	3.85

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	3.04	3.5
I learned a great deal from this course	3.54	3.04	4.3

Table 1: Student's survey used as an indirect assessment tool

Analysis of the data represented in Table 1 reveals the fact that the students' responses to some of the questions regarding the blended version of EM course was slightly 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 2.08, 2.11, and 2.2 only. We attribute such a low output to the age of students-participants that at the age of 21-22 easily get distracted and are not very motivated to pursue learning on their own. There were two older 31 and 35 older students in the class of 2013 and 2014 and their response to the blended learning was very positive, averaging 3.93 out of 5 across all the questions in the survey. 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. What is interesting to observe is that the students indicated 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 EM course successful, we implemented the direct assessment tool. We used the average and standard deviation results of the final exam scores, as well as a final grade distribution as a rubric for this assessment. We also compared these data with the ones available from the 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 during the 2009-2014 time frame.

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)	Year 2013 (Blended Model)	Year 2104 (Blended Model)
Average	80	78	77	81	83	86
Standard Deviation	13.4	17	17	13.8	10	8
Number of Students	40	48	46	45	32	27

Table 2: The average and standard deviation results of the EM course

assessment for 2009-14 time interval.

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)	Year 2013 (Blended Model)	Year 2014 (Blended Model)
A	33.5	27.1	28.3	31.1	15.6	11
AB	20	31.3	23.9	15.6	37.5	40.7
B	25	8.3	26.1	11.1	22	26
BC	7.5	10.4	10.9	13.3	12.5	22.3
C	5	2.1	6.5	13.3	6.3	0
CD	0	0	2.2	4.4	3.1	0
F	0	4.2	0	6.7	3.1	0
Number of Students	40	48	46	45	32	27

Table 3: The final grade distribution of the EM course for 2009-14 time interval. Scores are given in the percentage.

The direct assessment of these data reveals very interesting results. Even though the students' perception of the blended version of the EM course was not exceedingly positive, the direct assessment demonstrates that the students' performance participating in the blended learning was either the same or even better compared to traditional and hybrid models. This fact almost looks like a negative correlation between the students' feedback and their actual performance in the class. During 2013 class offering there was more time devoted to the interactive activities between the faculty-students and students-students. This means that even less time was devoted to the theoretical material normally presented in the traditional lectures and students were "forced" to spend even more time studying. The reflection of this is the best students' performance - 83% average and 10% standard deviation in the final exam. The grade distribution demonstrates that the number of A and AB students is increased, and the number of C, CD, and F grades is reduced by 50% compared to 2012 class offering. The main conclusion based on these observations was very obvious: the more students study the better their performance and therefore their grades. The most difficult issue to address though is to how to continue implementing a "hard study" policy and at the same time keep students "happy".

Considering significant improvements in the students' performance due to increase of interactive activities performed during the Fall of 2013 offering, the authors took this approach to the next level. The number of interactive activities was increased with specific attention to the student-to-students interactions. The approach was taken such that the faculty member teaching the course would propose some intrigue question related to the current class material and provoke students to argue on the proposed topic. While observing the students' interaction, the faculty member would provide additional information on the topic to lead the students' argument in the right direction. Depending on the nature of the proposed by the faculty member topic, 3-4 interactive activities have been conducted during each class session. The open nature of the interactive activity drew the students' attention to the discussion and forced them to learn the proposed theoretical contact via student-to-student faculty supported interaction. Assessment of Fall 2014 offering revealed somewhat expected results with the overall improvement in students' performance: number of A and B grades was consistent with last year offering, the number of B grades was increased by 20% , while number of BC grades was nearly doubled. What interesting to observe is the fact that grades C and below completely disappeared in the Fall of 2014 offering which is a big achievement. In addition the average of the final exam score went up from 83 to 86 while the standard deviation went down from 10 to 8 – both of these metrics show positive progression.
Assessment of the students' responses to an anonymous survey conducted in the Fall 2014 also show the constructive nature of the applied course structure and teaching methodology. Comparison of scores for all the survey questions for 2013 and 2014 demonstrate that students' perception of the blended course offering is more positive in 2014. Most of the scores went up by at least 20% with some responses having 60-70% increase. All these positive attributes of currently developed teaching methodology provide significant promises in understanding of "gold standards" in educational models. Authors will continue their research on optimal teaching models for blended, online and traditional course offerings.

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 across in the SoT are developing and offering on-line courses in multiple disciplines. In this article we discussed the EM course development and implementation for currently enrolled in Michigan Tech students and industry representatives looking to improve their knowledge in the subject.

Due to current presence of blended learning in the academia and on-going research on its effectiveness, any input from academic units participating in online course 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. Availability of all the educational models in the curriculum derives multiple benefits 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 on-line summer session of the course will reduce the size of the class in the fall semester: the smaller the 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 the colleagues.
- Improve the STEM education by adopting the most effective learning techniques.

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

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