Does Student Performance in a Blended Learning Environment Differ Based on Math Preparedness?

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Abstract - **University courses are gradually transitioning to blended learning formats. Many studies have shown that overall students not only like the blended learning environment, but they typically perform better. In the Fall 2014, we piloted blended learning activities in a first-year introductory engineering course. These activities primarily were used as course preparation: videos, quizzes, or demonstrations designed to prepare the students for what would be covered during the lecture portion of the class. Over 700 students and six instructors teaching 13 sections participated in the study. Blended learning was incorporated into the course in three groups: 1) Traditional format where all material was covered in class. 2) Pre-lesson videos were assigned by the instructors. This material was not covered in class. 3) Pre-lesson videos were required along with a short, on-line quiz. This material was not covered in class. Previous analysis indicates that overall student performance on homework and exams improved slightly as students watched more of the pre-lesson videos. Additionally, comparing student performance in 2013 and 2014 by instructor indicated that Group 3 instructors had the most significant increases in student performance. Anecdotally, the instructors have observed that the students in sections with advanced math skills (students placed into Calculus 2 or higher) typically perform better on homework and exams. In our previous comparison, part of the increase in student performance may be due to teaching a more advanced math section. This paper will explore the effect of incoming math placement on student performance in the engineering course along with student perceptions and participation in the blended learning activities in the three tiers for the Fall 2014 pilot.**

Index Terms – Blended Learning, First-Year Engineering, Math Requirements

INTRODUCTION

Each fall approximately 800 students enter the Michigan Technological University First-Year Engineering Program. With such a large program, the faculty are constantly looking for ways to engage the students. One such method is blended learning which has been defined as "the combination of traditional face-to-face and technology-mediated instruction" [1]. This method is appealing because it allows students more freedom in choosing when and how they learn the course material.

In Fall 2014, students in ENG1101 began having pre-lesson videos that they could view prior to class. The methods used to encourage student viewing differed between instructors. Blended learning was incorporated into the course in three experimental groups. These groups were compared to the traditional course offered in Fall 2013 (Comparison Group).

- Comparison Group Fall 2013: Traditional format; no pre-lesson videos available (5 instructors, 9 sections). All material was covered in class.
- Experimental Group 1: Traditional format; pre-lesson videos were available and recommended to the students, but not strongly encouraged; serves as a study control group (1 instructor, 3 sections). All material was covered in class.
- Experimental Group 2: Pre-lesson videos were assigned to the students (2 instructors, 5 sections). Pre-lesson material was not covered in class.
- Experimental Group 3: Pre-lesson videos were assigned to the students along with a short, on-line pre-lesson quiz (3 instructors, 5 sections). Pre-lesson material was not covered in class [2].

Previous work indicated that the more encouragement the students were given, the more students watched the pre-lesson videos. In Group 3, 74.4% of the students reported they watched all or most of the videos, followed by 46.4% and 5.7% of Group 2 and Group 1 students, respectively [2]. The increase in preparation time for students in Group 3 compared to the Comparison Group was, on average, only 1.5 minutes per class. Student performance appears to be equivalent or slightly improved when using pre-lesson videos. Other underlying factors may have contributed to these differences [2].

Anecdotally, the instructors have observed that the students in sections with advanced math skills (students placed into Calculus II or higher) typically perform better on homework and exams. The next question was: Is there a relationship between blended learning experimental groups and math placement and if so, does it affect student performance? This paper will analyze the differences in ENG1101 student performance with respect to college math level. The goal of this work is to determine if the students' math level and exposure to blended learning correlates with their performance in the course.

MATH LEVEL PLACEMENT

Much work has been completed on the retention and performance of engineering students based on their high school math courses [3]. Unfortunately, little research has been completed on student performance based on the university math course that first-year engineering students enroll in. Researchers at the University of Cincinnati found that some students who could have been successful in engineering are leaving engineering due to poor performance in Calculus I. Students at San José State University have had project based learning added to their first-year engineering courses. The purpose of this addition is to add content to the course that would be exciting to students and consequently increase retention [4]. This is similar to the work at Michigan Tech since the inclusion of pre-lesson videos allows for more time in class to complete activities. At Portland State University, they found that students with pre-college credits had lower grades than those without, when comparing the performance of high school and transfer students with respect to their pre-college credits and college credits, respectively. Also, the transfer students had higher withdrawal rates than those students with no college credits [5].

At Michigan Tech, first-year engineering students are cohort scheduled in groups of 20-24 students based on their math placement. Math placement has traditionally been determined on a student's math ACT score, but beginning Fall 2014, the online **A**ssessment and **LE**arning in **K**nowledge **S**paces (ALEKS) placement assessment was used to determine a student's math placement. ALEKS is an artificially intelligent assessment and learning system [6]. Students may retake the ALEKS placement assessment two more times but only after spending time in the Prep and Learning module. Based on their ALEKS placement assessment results, students are enrolled in one of the following math courses:

- MA1030, College Algebra, 3-credits
- MA1032, Precalculus, 4 credits
- MA1160, Calculus with Technology 1, 4-credits (Calc I)
- MA1161, Calculus Plus with Technology 1, 5-credits (Calc I+)

Students with AP, IB, CLEP or transfer credit may be placed into one of the higher math courses:

- MA2160, Calculus with Technology 2, 4-credits (Calc II)
- MA3160, Multivariable Calculus with Technology, 4-credits (Calc III)
- MA2320/MA2321, Linear Algebra, 2-credits (LA)
- MA3520/MA3521, Differential Equations, 2-credits (DE)

Students that begin in College Algebra (MA1030) are not placed in an engineering course, while students begin in Precalculus (MA1032) are placed into a three semester engineering sequence (ENG1001/ENG1100/ENG1102). For students that begin in Calc I/I+ (MA1160/MA1161) or higher, the students will be placed in a two semester engineering sequence (ENG1101/ENG1102). These students are cohorted as well, meaning they will be in the same math, engineering, and physics lab. There are two to three cohorts of students in each engineering class, and as a result, there are some sections that consist primarily of advanced math students (Calc II or higher). During the transition to ALEKS, a number of students retook the ALEKS placement assessment after the cohorts were assigned, requiring changes to math placement. This reduced the number of students in cohorts during Fall 2014 when compared to previous years.

ANALYSIS AND RESULTS

In Fall 2014, thirteen sections of ENG1101 were taught by five different instructors. Out of these sections, nine had students who were predominantly in Calc I/I+ (MA1160/1161), while the remaining sections were a mixture of students taking a number of different math courses. A one-way ANOVA with a Bonferroni Post-Hoc test was used to determine the effect of math level on student performance on course components (homework and exams) independent of the blended learning experimental group. Figure 1 shows student performance by math level on the overall course metrics (homework, exams, final grade). The LA/DE math level is defined as those students who were enrolled in Linear Algebra (LA) and/or Differential Equations (DE) concurrently with ENG1101.

As expected, students that were in advanced math classes (Calc II or higher) outperformed those that were in Calc I/I+. For Calc I+ students, these differences were statistically significant for the following course metrics and between Calc I+ students and students enrolled in the listed math courses:

- Individual Homework: Calc III ($p<0.05$)
- Exam 1: Calc I, Calc II, Calc III, LA/DE ($p<0.01$)
- Exam 2: Calc II, Calc III, LA/DE ($p<0.01$)
- Final Exam: Calc I, Calc II, Calc III, LA/DE ($p<0.01$)
- Final Grade: Calc II, Calc III, LA/DE ($p<0.01$)

For Calc I students, these differences were significant for the following course metrics and between Calc I students and students enrolled in the listed math courses::

- Exam 2: Calc II, Calc III, LA/DE ($p<0.01$)
- Final Grade: Calc II ($p <0.05$)

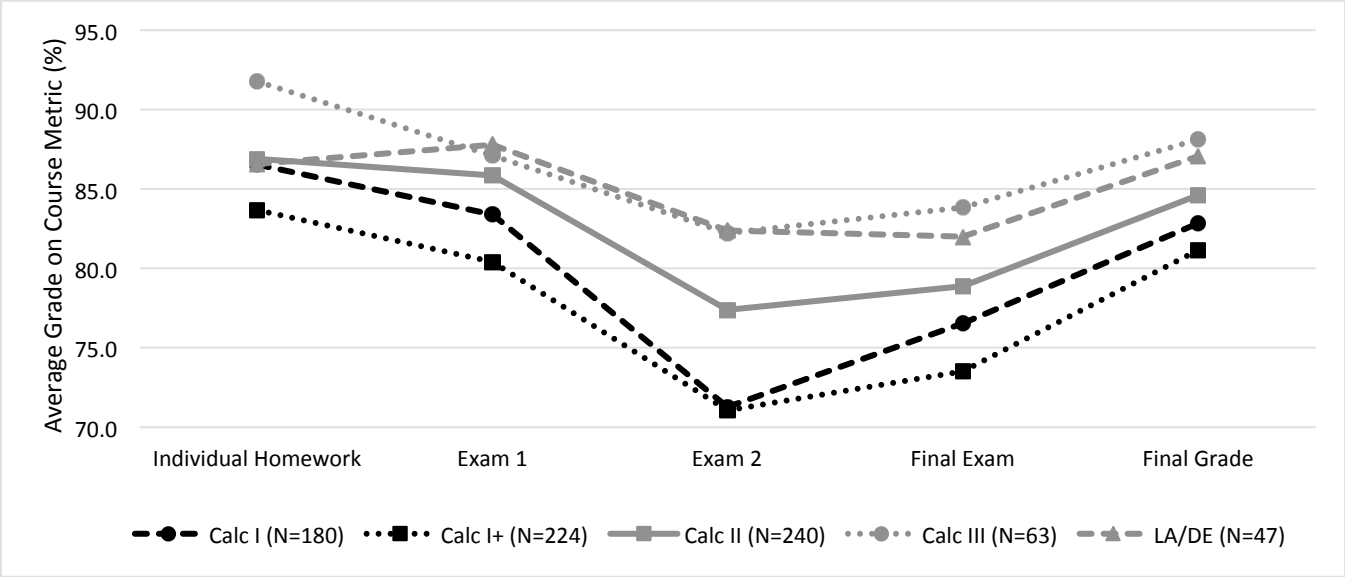
The performance of ENG1101 students in the various math courses also differed on the final exam topics. Figure 2 shows this performance on select final exam topics by math level. Again, those students in the advanced math classes (Calc II or higher) generally outperformed Calc I/I+ students, although there were a few exceptions. There were

no significant differences found in communication, spreadsheets, and spatial visualization topics on the final exam. This could be due to the low number of questions on the final for each topic, and the simplicity or complexity of the questions. For Calc I+ students, there were statistically significant differences in the following topics when compared to students in the various math courses:

- Unit Conversions and Problem Solving: Calc II ($p<0.01$)
- Statistics: Calc I, Calc II, Calc III ($p<0.01$)
- Empirical Functions and Graphing: Calc II ($p<0.05$)
- MATLAB: Calc III ($p<0.01$)

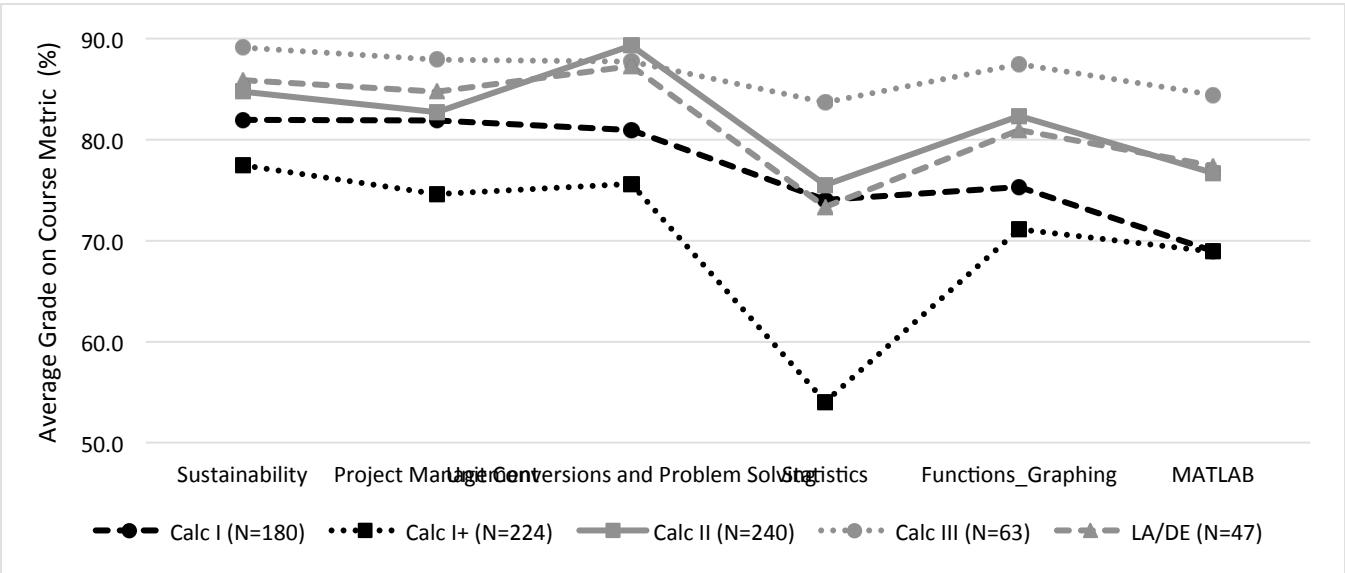
For Calc I students, there were significant differences in the following exam topics when compared to students in the various math courses:

- Unit Conversions and Problem Solving: Calc II ($p<0.01$)
- MATLAB: Calc III ($p<0.01$)



[1] Those students who were not enrolled in a math section concurrently with ENG1101 were not included in this analysis

FIGURE 1
ENG1101 COURSE PERFORMANCE BASED ON MATH LEVEL



[1] Those students who were not enrolled in a math section concurrently with ENG1101 were not included in this analysis

FIGURE 2
ENG1101 FINAL EXAM TOPIC PERFORMANCE BASED ON MATH LEVEL

Since there were two major effects on course performance occurring from a) blended learning experimental group [2] and b) math level placement, we wanted to determine if there is a cumulative effect from both. In other words, does a placement in a specific math level and a specific experimental group produce a different effect than other placements? Table I shows the distribution of the sections based on math level. All groups contained a majority of Calc I/I+ students. The number of ENG1101 students in each math level and blended learning experimental learning groups are shown in Table II. As shown, all math groups are represented across the different experimental groups.

TABLE I
ENG1101 COMPOSITION BASED ON THE NUMBER OF INSTRUCTORS AND STUDENTS' MATH COURSE

	Group 1	Group 2	Group 3
Number of Instructors	1	2	3
ENG1101 Sections with mostly Calc I/I+ students	2	3	4
ENG1101 Sections with mostly Calc II/III students	1	2	1

TABLE II
NUMBER OF ENG1101 STUDENTS ENROLLED IN INSTRUCTIONAL GROUP BASED ON CURRENT MATH COURSE

Math Course	Group 1	Group 2	Group 3	Total
Calc I+	67	72	85	224
Calc I	31	75	74	180
Calc II	53	111	76	240
Calc III	14	20	29	63
LA/DE	13	16	18	47
Not currently enrolled in math	5	13	9	27
Total	183	307	291	

We ran a two –way ANOVA with a Bonferroni post hoc test to determine the cumulative effects of math level and experimental group. Bonferroni was chosen as it is a very rigorous test and will not give a significant result unless one exists. However, if a result is close to significant, it may miss it. As expected, we saw the singular effects of instructional group and math level, but there were no cumulative effects found and no levels were close to significance. This means that the different instructional methods work equally well for each of the different math groups or, to put it another way, no math group is at a disadvantage with any of these instructional methods.

CONCLUSIONS AND FUTURE WORK

Previous work indicates that students who are enrolled in ENG1101 course sections that are required to watch pre-lesson videos and complete pre-lesson quizzes outperform students who do not. In addition, ENG1101 students concurrently enrolled in Calc II or higher significantly outperform students in Calc I+ and Calc I in several of the course metrics. While differences in performance exist between math levels and instructional groups, there is no cumulative effect. Therefore students in any math level will succeed equally well in any of our experimental groups. This lends support to the pre-lesson blended learning techniques, although the improvements observed in the blended learning experimental groups cannot be completely explained.

There are still several unanswered questions remaining regarding the relationship between math and how much/how many of the pre-lesson videos that were watched. Panopto will be used in the future to obtain the pre-lesson video viewing statistics as these are more inclusive than YouTube's options used in this and previous [2] work. Additional research is needed to further investigate the role math placement has on ENG course performance. Students placed into MA1032 are currently placed into a three semester engineering sequence, while those who are placed into CalcI/I+ or higher are placed into a two semester engineering sequence. These findings indicate that we need to investigate our current threshold for placement into our two semester ENG course sequence.

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