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Impact of Mastering Engineering on Student Learning and Perceptions in a Strength of Materials Course

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Abstract

In recent years, web-based learning systems have become more available for inclusion in engineering and technology courses. The purposes of these learning systems can vary, but they are often promoted as enabling and enhancing student learning inside and outside of the classroom, as well as helping reduce faculty time devoted to labor-intensive tasks such as grading homework. Although research has been performed to investigate the effectiveness of some of these systems, there is a continuing need to evaluate their effects on student learning and perceptions. The study discussed in this paper explores the impact of one of these learning systems, Mastering Engineering by Pearson Education Inc., on student performance in a strength of materials course at Rochester Institute of Technology (RIT).

In this study, the web-based Mastering Engineering learning system component for the textbook Mechanics of Materials, 10th Edition, by R. C. Hibbeler, was used together with that textbook in the strength of materials course for civil engineering technology students at RIT. Mastering Engineering was implemented in a limited fashion in this course by assigning one or two tutorial problems a week from Mastering, along with four to six standard textbook problems. The tutorial problems in Mastering are similar to textbook problems with the exception that the tutorial problems are web-based and provide hints to help students move forward, if they are uncertain how to proceed. Students in this study were required to complete the tutorials prior to gaining access to the required textbook problems and they submitted hard copy paper solutions for both to the course instructor. In addition, they submitted tutorial answers into the Mastering Engineering system for immediate feedback. Besides having students complete the required tutorial and textbook problems, one or two optional videos available in Mastering were recommended each week. These videos provided step-by-step instructions for solving the problem types covered that week. Other than the use of some tutorials and videos in Mastering Engineering as part of weekly homework assignments, all other aspects of the strength of materials course remained unchanged.

The impact of Mastering Engineering on student learning of key concepts in strength of materials has been assessed in this study by comparing homework and examination grades received by students who used Mastering to those from prior years when it was not used. Student perceptions of the effectiveness of Mastering for helping promote learning were obtained through weekly surveys that students completed about their use of the tutorials and videos. In addition, student ratings of teaching effectiveness and the accomplishment of course learning outcomes were evaluated to see if there were any impacts on student perceptions of the course. From all of these evaluations, an assessment is made concerning the educational benefits of using Mastering Engineering in a strength of materials course.

Background and Purpose of Study

Over the last 10 to 15 years there has been an increase in the development and use of web-based learning systems in collegiate science and technology courses. Some of these systems can be used in conjunction with traditional course delivery methods, such as lectures, with the purpose of supplementing and reinforcing concepts learned in lecture and/or offering an on-line approach for completing and submitting homework assignments. One such system that has grown in use for engineering and engineering technology courses is Mastering Engineering, which has been developed and marketed by Pearson Higher Education, Inc. Pearson's website[1] states: "Mastering is the world's leading online homework, tutorial, and assessment system for science and engineering, designed to improve results and increase student engagement before, during, and after class." In regards to the effectiveness of Mastering, the Pearson website states: "Used by more than 4 million students each year, Pearson's Mastering delivers consistent, measurable gains in student learning outcomes, retention, and subsequent course success."

The purpose of the study described in this paper is to assess the impact of Mastering Engineering on student learning and perceptions in a strength of materials (mechanics of materials) course in the undergraduate civil engineering technology program at Rochester Institute of Technology (RIT). The web-based Mastering Engineering learning system for the textbook Mechanics of Materials, 10th Edition, by R. C. Hibbeler, was used together with that textbook for the course. Different educational components in the Mastering system available for use included:
1) coaching activities in the form of instructional videos regarding how to solve problems,
2) tutorials consisting of problems to be solved that provided a stated learning outcome and intermediate, optional hints to help students if they got stuck, and 3) end-of-section problems that provided no intermediate hints and were similar to the textbook homework problems. In addition, a "Continuously Adaptive Learning" feature could be specified that looks at student performance on the main homework assignment given in Mastering and provides the student with additional problem sets to work based on ascertained weaknesses. In this study, the "Continuously Adaptive Learning" feature was not utilized due to concerns about the additional time that students would be required to spend on assignments. End-of-section problems were also not assigned due to their similarity to standard textbook problems.

Case studies dealing with the impact on student learning of Mastering Engineering and Mastering systems for other disciplines can be found in the literature as well as on the Pearson Higher Education website. Pearson's website[2] has 26 documents and videos about the positive impact of Mastering on student learning, some of which provide statistical data showing improvement in examination and/or course grades. A study published in the literature by Arora et al.[3] (includes two co-authors from Pearson) in 2013 looked at the changes in examination grades in a statics course when students completed Mastering Engineering online homework problems that provided hints, rather than traditional textbook problems on paper. The study showed there was a statistically significant improvement in the midterm and final exam scores of the cohort that used Mastering Engineering for homework compared to students who completed traditional textbook problems during the same semester. In addition, students who completed the statics course using Mastering Engineering also had improved exam scores in the strength of materials course that followed, when compared to the students who did not have statics with Mastering.

A similar study was done by O'Neill et al.[4] where Mastering Engineering online homework was used instead of paper homework for a mechanics (statics and dynamics) course. In this study, a statistical analysis showed there was no difference in the exam performance of students who used the online Mastering homework compared to students who did not use it the year before. Student feedback on surveys was mixed concerning how they liked Mastering. The authors note they only used end-of-section problems in Mastering that did not provide any hints. Elizandro et al.[5] conducted a study where Mastering Engineering on-line homework was incorporated with traditional lectures to permit the teaching of larger numbers of students in statics and strength of materials classes in the University of Tennessee system, while reducing the amount of outside class assistance that students needed. The study showed this hybrid model of using traditional lectures with the Mastering online homework had no adverse effects on the percentage of students receiving grades of A, B, and C.

There are also some studies reported in the literature concerning the use of Mastering for courses other than statics, dynamics, and strength of materials. Maheswaran[6] implemented Mastering Physics in a Physics 2 course by having students complete pre-chapter problems, which consisted of tutorials and coaching videos in Mastering, prior to the relevant lecture. He then had them complete post-chapter problems in groups of four or five students during an interactive learning session. Survey information collected from students indicated they did not feel the pre-chapter problems were helpful for preparing them for the lectures in advance, although the instructor felt otherwise, and they did not feel the hints provided in problems were particularly helpful. However, 75 percent of them responded "yes" to the statement "Do you think Mastering Physics helps you master engineering physics concepts?". Maheswaran[7] conducted a similar study in an electrical circuits course using Mastering Engineering demonstrations (videos), tutorials, and end-of-section problems. In a survey, students rated the Mastering videos and tutorials 2.75 out of 5 (5 being high, 1 being low), and the Mastering Engineering homework 3.6 out of 5, in regards to helping them learn electrical circuit concepts. Seventy-eight percent of them chose "yes" when asked if Mastering Engineering helped them master electrical circuit concepts.

The conclusions from these previous studies regarding the effectiveness of Mastering Engineering for enhancing student learning in engineering-related courses taught using more traditional approaches, such as a lecture, are somewhat mixed. In addition, some of these investigations did not collect any hard data on changes in student performance on homework, exams, or the course overall. There are two studies in the literature by Gordon[8] and Le et al.[9] that look at the incorporation of Mastering Engineering in a flipped classroom approach, but they focus more on the flipped classroom effect on student learning, as opposed to the direct impact of Mastering. Therefore, we decided to conduct a study investigating the impacts of Mastering Engineering in a traditional strength of materials course by collecting and analyzing fairly extensive survey and student performance data from a variety of sources in the course. The purpose was to determine if a limited implementation of Mastering in a traditional lecture and textbook homework class would result in improved student learning and perceptions for strength of materials.

Details of Study

The current study investigating the impacts of Mastering Engineering on student learning and perceptions in undergraduate strength of materials was conducted by the authors using the Strength of Materials course sections they taught in Fall 2014/15 (one author was on sabbatical in 2015 and therefore information will be used from Fall 2014 for him) and Fall 2016 in the civil engineering technology program at RIT. This 15-week-long course is typically taken in the second year of the five-year-long undergraduate program (program includes one year of co-operative education work experience). Each author taught their own course section in Fall 2014/15 without Mastering Engineering implemented in the homework (referred to as control groups) and taught another section again in Fall 2016 with Mastering included in the homework (referred to as experimental groups). Each course section had anywhere from 21 to 34 students enrolled. Hibbler's Mechanics of Materials, 9th edition textbook was used in Fall 2014/15 and the 10th edition with Mastering Engineering was used in Fall 2016.

The components of Mastering Engineering used in Fall 2016 were the tutorials and coaching videos. A tutorial typically consisted of a three- to four-part problem on a particular strength of materials topic that had to be solved. The students submitted their answers in Mastering for immediate checking so they could go back and correct mistakes before moving on. Each tutorial had an introductory learning objective stated in writing and, if a student was unsure how to solve the problem, there were hints they could access that specified intermediate calculation steps to help them. Answers to the intermediate steps were also input in the system by the student for immediate checking. Students had up to six tries to get each answer correct. If a submitted answer was incorrect, the system provided some written feedback concerning potential issues causing the incorrect answer. Each weekly homework assignment included one or two required tutorials along with four to six standard textbook problems. In addition to submitting answers to tutorials in the Mastering system, students also had to submit handwritten work for both the tutorials and textbook problems to the instructor. Grades for the tutorials, as well as the textbook problems, were based on the supporting handwritten work. The homework assignments were set up so students had to complete the on-line tutorials before the related textbook problems were released to them by the system.

As part of each homework assignment, one or two coaching videos from the Mastering system were suggested for students to view if they were uncertain how to approach solving a particular problem type or were having other difficulties. Each coaching video provided a step-by-step solution approach to a given problem type, with the solution being written out on the screen as the instructor in the video verbally explained what was being done and why. The video simulates an instructor explaining the approach to solving a problem to a student in their office or in the classroom. Use of the videos was optional and did not carry any credit towards the homework score. The instructors opted to make use of the videos optional because they reinforced what was already covered in lecture and therefore would not likely be needed by all students.

In addition to Mastering Engineering tutorials and standard textbook problems, most weekly homework assignments also included one or two web-based MecMovie modules (developed and described by Philpot et al.[10]) that students were required to complete for credit. MecMovies are animated movies that explain different strength of materials concepts and include on-screen learning drills and problems for students to complete. For each MecMovie module, a student progresses through a series of screens that explains a particular topic and a solution approach. Graphics are included to visually reinforce the phenomena being discussed and at the end of the module a problem related to the topic is presented for the student to solve and submit answers. If the student's first answer is incorrect, they are given two additional tries to correct their mistake. If it is still incorrect, the correctly worked solution is shown and the student given an opportunity to start over on the same type of problem with different values. MecMovies have been incorporated in the homework for strength of materials at RIT since 2007. They were included in Fall 2016 to provide consistency between the experimental and control groups in this study, as well as check whether experimental group students had any preference for Mastering Engineering or MecMovies.

Table 1 provides a list of the weekly topics covered in the Strength of Materials course along with the number of Mastering Engineering tutorials, optional coaching videos, textbook problems, and MecMovies assigned to the experimental groups. The length and content of the homework assignments completed by the experimental groups were very similar to the control groups, but not identical. The experimental groups' homework had one or two fewer textbook problems to compensate for the Mastering tutorials that were added. The tutorials covered the same type of material/content as the textbook problems that were dropped. In addition, since there was a change in the edition of the textbook, some problems used for the control group that were discontinued had to be replaced with similar problems for the experimental group.

Other than introducing and using Mastering Engineering as part of the course homework in Fall 2016, and the change in the textbook editions from the 9th to 10th, the course components were the same for students in the 2014/15 and 2016 Strength of Materials classes. Both cohorts attended three 50-minute-long lectures per week where topics were presented and explained, and one two-hour-long recitation session at the end of the week that focused on problem solving. The cohorts also completed a total of fourteen weekly homework assignments, four 60-minute-long examinations, and one two-hour-long comprehensive final examination. Five 30-minute-long lab experiments were also performed in recitation during the semester using desktop equipment.

Data on the impacts of Mastering Engineering on student learning and perceptions were obtained in a number of different ways including surveys completed by students about Mastering, end-of-semester teaching evaluations, intended learning outcome ratings, and student grades for homework, exams, and the overall course. As mentioned earlier, each of the authors taught a section of Strength of Materials in 2014/15 and again in 2016. When looking at data from this study, course sections taught by the different instructors are typically kept separate from each other. Students taught by Instructor/Author 1 in 2015 and 2016 will be referred to as Control Group 1 and Experimental Group 1, respectively, and students taught by Instructor/Author 2 in 2014 (on sabbatical in 2015) and 2016 will be referred to as Control Group 2 and Experimental Group 2, respectively. This approach provides two separate sets of data for assessing the impacts of using Mastering Engineering.

Table 1 – Strength of Materials Course Details

Week	Topics	Homework Components: # of Tutorials/Videos/Text Problems/MecMovies
1	Statics review; Stresses in members (normal, shear, bearing)	2 / 1 / 4 / 2
2*	Stresses on oblique planes; Axial stress-strain behavior (Hooke's law); Shear stress and strain	2 / 1 / 6 / 1
3*	Axial deformation (PL/AE); Superposition; Statically indeterminate axial loading problems	2 / 2 / 6 / 0
4*	Shear and bending moment diagrams – algebraic equations and area method	2 / 1 / 5 / 2
5*	Centroids and moment of inertias; Normal (bending) stresses from internal moments in beams	1 / 3 / 6 / 1
6*	Shear stress and shear flow in transversely loaded beams	2 / 3 / 5 / 1
7	Torque in stationary and rotating shafts; Internal shear stresses and angle of twist in shafts	1 / 2 / 6 / 0
8	Selection of beam size based on internal bending and shear stresses; Combined axial load and bending	1 / 3 / 3 / 1
9*	Stress transformation (2-D) for plane stress conditions – equations and Mohr's circle	1 / 1 / 4 / 2
10	3-D stresses (out-of-plane stress effects) and strains – equations and Mohr's circle	1 / 0 / 6 / 1
11	Strain transformation (plane strain) – equations and Mohr's circle; Strain rosettes	0 / 0 / 5 / 1
12*	Deflection of beams – integration approach and beam table approach along with superposition	1 / 2 / 5 / 2
13	Statically indeterminate beams – evaluation of reactions and deflections	1 / 1 / 5 / 0
14*	Column buckling – Euler's theoretical approach and AISC method	2 / 1 / 5 / 0

Note: * denotes weeks when experimental group students completed surveys about Mastering Engineering

When checking to see if there was an improvement in the performance of an experimental group (used Mastering Engineering as part of homework in 2016) relative to a control group (did not use Mastering Engineering in 2014/15), a statistical evaluation was conducted. The Ryan-Joiner goodness-of-fit test was first used to check the plausibility of assuming a normal distribution for the performance data (exam or homework scores) for each group. If the data for each group fit a normal distribution, a one-sided t-test was performed using the null hypothesis that the difference between the mean scores of the two groups equals zero (experimental and control group mean scores are the same) at the usual $\alpha = 0.05$ significance level (or 95% confidence level). A computed p value greater than 0.05 caused the null hypothesis to be accepted whereas a p value of less than 0.05 caused the null hypothesis to be rejected in favor of the alternative hypothesis that the difference between the mean scores is negative (experimental group mean score is higher than the control group mean score). For cases where the performance data did not fit a normal distribution, a one-sided Mann-Whitney test was performed using the same basic approach with median scores instead of mean scores.

A comparison of cumulative grade point averages (GPA) for the students in the experimental and control groups at the time they entered the Strength of Materials course was also performed. The thirty-four students in Control Group 1 had a mean GPA of 3.02 and the twenty-one in Experimental Group 1 had a mean of 3.20. A two-tailed t-test performed between these mean grade point averages gave $t = -1.21$ and $p = 0.232$ (for 58 degrees of freedom) indicating no significant difference. The twenty-five students in Control Group 2 had a mean GPA of 3.05 and the twenty-two in Experimental Group 2 had one of 3.02. A two tailed t-test performed between these mean grade point averages gave $t = 0.20$ and $p = 0.839$ (for 33 degrees of freedom) indicating no significant difference. These results imply the experimental and control groups entered the Strength of Materials course with similar abilities.

Student Perceptions of Mastering Engineering

Student perceptions on the usefulness of the Mastering Engineering tutorials and coaching videos incorporated in the Fall 2016 Strength of Materials homework assignments were primarily obtained by having the experimental groups fill out surveys for eight of the fourteen weekly homework assignments they completed, as denoted by the asterisks in Table 1. Survey data were only collected for eight weeks to reduce the chance of survey fatigue. The eight weeks selected focused on the more significant topics in the course. Although space was provided on the surveys for students to include their name, doing so was voluntary and most of them did not do so. Therefore, it was not possible to evaluate whether specific students responded in the same way from week to week.

Most of the data collected from each weekly survey consisted of subjective, quantitative feedback to the eight statements shown in Table 2. Students responded to the survey statements using responses (equivalent five-point Likert scale rating given in parentheses) of either strongly disagree (= 1), disagree (= 2), neutral (= 3), agree (= 4), or strongly agree (= 5). If students did not make use of any hints when solving a tutorial, then they did not respond to statements 3 through 5 and if they did not view any of the optional coaching videos they did not respond to statements 6 and 7. Other information collected in each survey included:

- asking each student whether they completed at least one Mastering Engineering tutorial before starting the normal textbook problems;
- checking whether they preferred the Mastering tutorials or MecMovies modules, liked them both the same, or liked neither one; and
- requesting an estimate of how much time they spent on the homework assignment.

In addition, separate sections were provided on the surveys for students to write comments regarding things they liked and/or disliked about the tutorials, hints provided for the tutorials, coaching videos, and the homework assignment in general. At the end of the semester,

Table 2 – Mastering Engineering Survey Responses

Survey Statement	Number and Percentage of Students Selecting Likert Rating 1 – 5*					Mean Response
	1	2	3	4	5	
1. I liked solving the Mastering Tutorial problems better than textbook problems.	27 9%	61 22%	88 31%	92 33%	14 5%	3.02
2. Learning goals stated in each Tutorial problem helped me to better understand the purpose of the problem.	18 6%	30 11%	98 35%	114 41%	18 7%	3.30
3. Hints provided in Tutorial problem were useful for helping me solve that Tutorial problem.	5 2%	17 7%	42 17%	136 56%	44 18%	3.81
4. I thought a sufficient number of hints were provided in a Tutorial.	10 4%	19 8%	51 21%	131 54%	31 13%	3.64
5. Solving Tutorial problems with hints helped to better prepare me to solve textbook problems.	11 5%	28 11%	65 27%	104 43%	33 14%	3.50
6. Explanation of how to solve problem presented in Video was clear and helpful to me.	0 0%	2 4%	23 42%	28 51%	2 3%	3.55
7. Watching Video helped to better prepare me to solve problems in homework assignment.	0 0%	1 2%	29 54%	21 39%	3 5%	3.48
8. I found material presented in MecMovies modules to be helpful.	7 3%	26 13%	55 26%	98 47%	24 11%	3.50

*Note: In rating system 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

experimental group students were asked to complete one short survey in class to solicit their overall impression of the Mastering Engineering and MecMovie components of the course homework assignments.

Responses to Eight Statements in Weekly Surveys

The responses to survey statements 1 through 8 in Table 2 were first compiled on a weekly basis for the eight weekly homework assignments (Weeks 2, 3, 4, 5, 6, 9, 12 and 14) where surveys were given, with the data for the two different course sections taught by Instructors 1 and 2 compiled separately from each other. For each survey statement the number of students who selected particular responses (strongly disagree, disagree, neutral, agree, strongly agree) were tabulated and then the mean responses (based on the 5-point Likert scale rating) were calculated. Figure 1 shows the variation in the mean response of Experimental Groups 1 and 2 for statement 1 (liked solving tutorial problems more than normal textbook problems) for the eight weekly

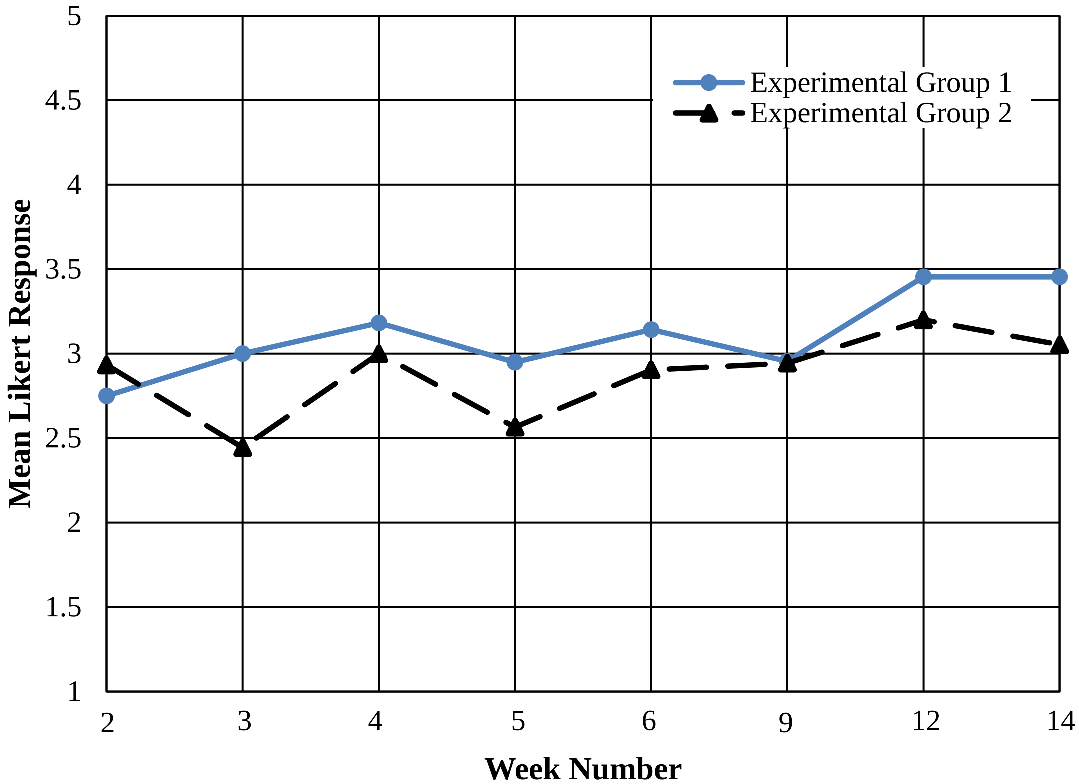

Figure 1 – Weekly Mean Response to Survey Statement 1

homework assignments where surveys were given. As seen from Figure 1, the weekly mean responses for each group fall within a relatively narrow band around a rating of about 3 (neutral), with the band having a range of about 0.75 and the rating from Experimental Group 1 typically slightly above that from Group 2.

The mean responses for statements 2 through 8 differed somewhat from statement 1, but the variation of the mean for each statement from week to week was relatively small and the mean response of Group 1 just slightly higher than Group 2. For this reason a single mean response was developed for each statement that combined together all of the weekly ratings from both groups of students for that statement. Table 2 presents a summary of that combined data including the number and percentage of students who selected each Likert-scale rating for a statement and the combined mean response.

As seen from Table 2, the student response was neutral (3.02 rating) for statement 1 pertaining to liking Mastering Engineering tutorial problems better than standard textbook problems and it was just above neutral on the agree side (3.30 rating) for statement 2 pertaining to the written learning goals in each tutorial helping students better understand the purpose of the associated problem. In regards to the hints provided in tutorials, students were roughly halfway between neutral and agree (rating of 3.50 to 3.81) when responding to statements 3 through 5 about the hints being useful, sufficient numbers of hints being provided in tutorials, and the tutorials with hints helping better prepare them to solve textbook problems that had no hints. For the limited number of students who opted to watch the optional coaching videos, their mean responses for statements 6 and 7 concerning the helpfulness and clarity of the videos were roughly halfway between neutral and agree. It should be noted that the variability of the weekly mean responses to statements about the videos were higher than the other statements, with the means varying anywhere between 3 and 4.5 from week to week. For statement 8 concerning the MecMovie modules being helpful, the overall mean response was 3.5 putting it halfway between neutral and agree.

Other Feedback in Weekly Surveys

Other useful feedback was obtained from students on the eight weekly surveys. Key observations for those eight weeks are summarized below.

- 90 to 95 percent of the survey respondents indicated they completed at least one tutorial before starting the standard textbook problems.
- 75 to 95 percent of the weekly respondents said they used at least some of the hints provided in tutorial problems.
- 5 to 50 percent of the weekly survey respondents indicated they used a coaching video when completing the homework, with the percentage moving to the lower end in the later homework assignments.
- Individual students spent anywhere from 1 hour to 9 hours on homework assignments, with the weekly means ranging from 3.5 to 5.6 hours and the overall mean for the entire semester being 4.6 hours.

Figures 2 and 3 summarize information regarding whether students preferred Mastering Engineering tutorials or MecMovies modules, liked both equally, or did not like either one for the six weekly assignments where both were used and survey data was collected. The data are presented for Experimental Groups 1 and 2 separately in Figures 2 and 3, respectively, and are based on the number of students who indicated a particular preference. As seen in the two figures, students in Group 1 had an overall preference for the MecMovie modules on a week-to-week basis, whereas students in Group 2 were more evenly split between liking Mastering, liking MecMovies, and liking both. The exceptions are week 5 when both experimental groups show a strong preference for MecMovies for the topic of bending stresses due to internal moments and week 12 when both groups show a strong preference for Mastering Engineering for beam deflection. It should be noted for those six weekly assignments that anywhere from one to four students, representing five to twenty-five percent of respondents in each experimental group, indicated they did not like Mastering or MecMovies.

In the eight weekly surveys, roughly 260 written comments were received from students in the two experimental groups on things they liked and disliked about the Mastering Engineering tutorials, hints that were provided in the tutorials, coaching videos, and the homework assignments in general. Table 3 presents a numerical breakdown of the written comments received from both experimental groups (combined together), including the number of comments that were received for each comment category and a breakdown of key comments that were repeated by students under that category. As seen from Table 3, one of the predominant written comments students provided regarding things they liked about the Mastering tutorials (31 of 59

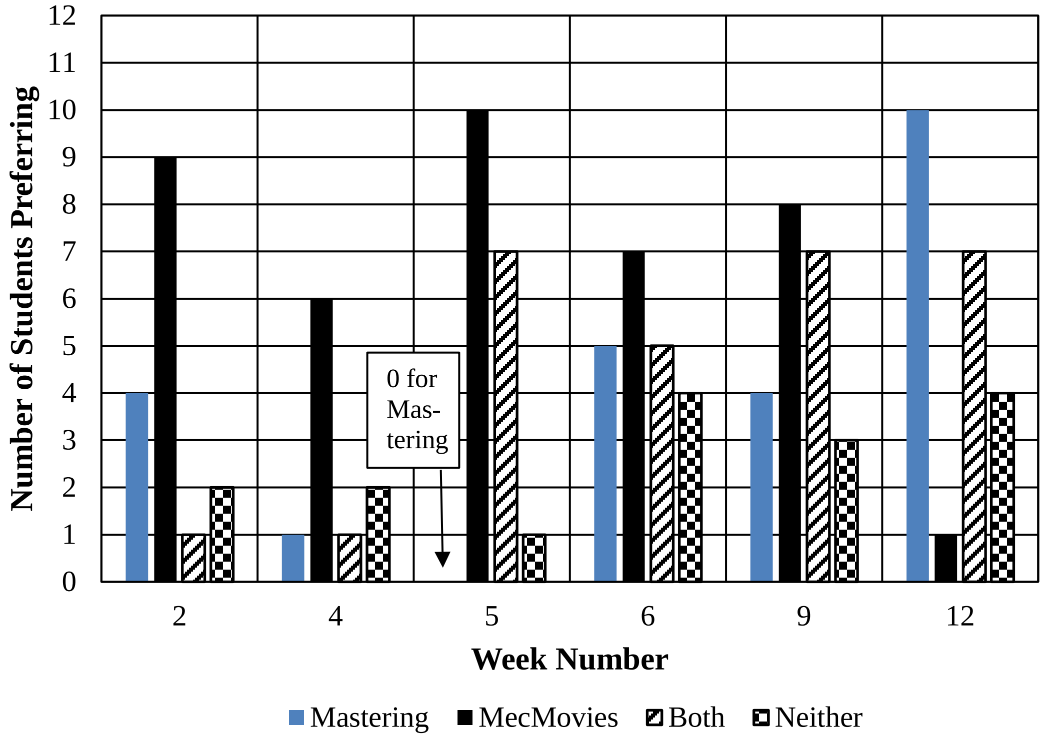

Figure 2 – Online Component Preferences of Experimental Group 1

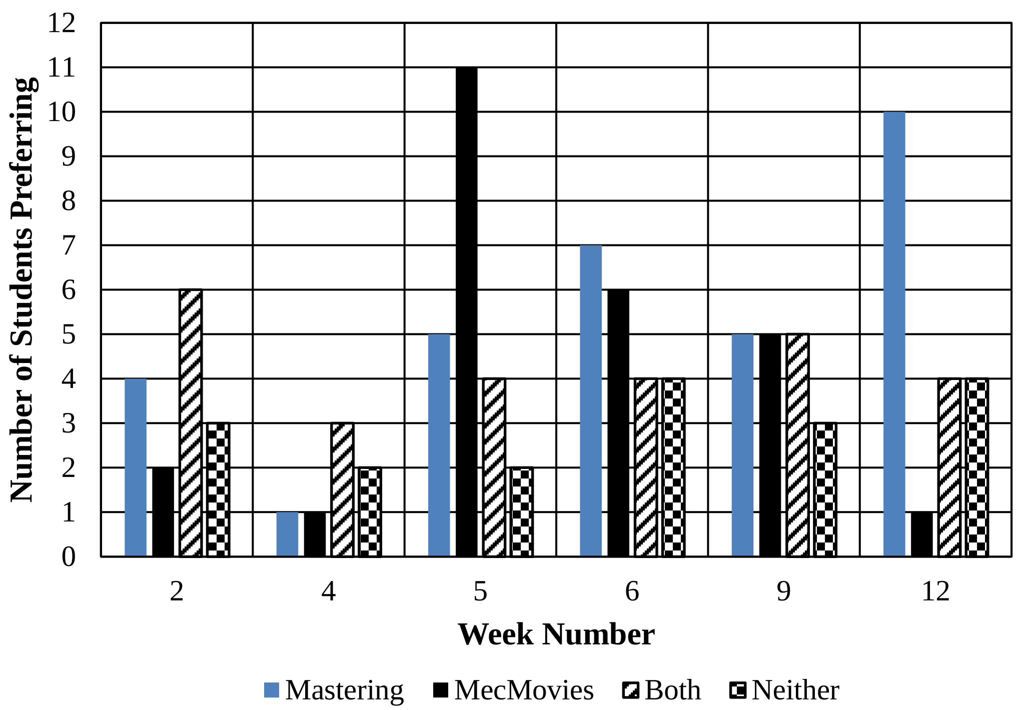

Figure 3 – Online Component Preferences of Experimental Group 2

Table 3 – Summary of Written Comments

Comment Category	Total Number of Comments	Breakdown for Repeated Comments – Number (Percent of category)
Liked about tutorials	59	31 of 59 (53%) – liked hints
Disliked about tutorials	51	6 of 51 (12%) – couldn't move onto other problems if stuck[1]
Liked about hints	33	20 of 33 (61%) – got me going in the right direction
Disliked about hints	19	9 of 19 (47%) – better hints are needed
Like about videos	9	2 of 9 (22%) – provided good/clear explanations 2 of 9 (22%) – helped improve my understanding
Disliked about videos	3	-
Liked about overall homework	34	5 of 34 (15%) – liked textbook problems 5 of 34 (15%) – liked MecMovies[2]
Disliked about overall homework	58	16 of 58 (28%) – disliked MecMovies[1] 8 of 58 (14%) – disliked Mastering Engineering tutorials[2]

Total comments: 266

Notes: 1) Comment only came from Experimental Group 2.
2) Comment only came from Experimental Group 1.

comments or 53%) were the hints provided in the tutorials. Twenty of the 33 comments (61 percent) received from students regarding things they liked about the hints mentioned that the hints helped get them going in the right direction when solving a problem. One thing students disliked about the tutorials were they had to complete the tutorials first before they could move onto the textbook problems. A few of them also indicated the tutorials did not always help prepare them for the textbook problems. Of the 19 written comments students provided regarding things they disliked about the hints, nine of the comments (47 percent) indicated that better hints should be provided. There were nine positive comments received about the coaching videos. Some of these comments mentioned that the videos provided clear explanations and helped students to further understand the material. In regards to things students liked about the homework in general, 10 comments out of the 34 received mentioned liking the textbook problems or MecMovies modules. Under the "disliked about homework" category, 16 comments were received from students in Experimental Group 2 indicating a dislike for the MecMovies modules and eight comments were received from Experimental Group 1 indicating a dislike for the Mastering Engineering tutorials. A few students commented the homework was too long and some disliked having homework components from three different sources (Mastering Engineering, MecMovies, and textbook).

End-of-Semester Survey

In the end-of-semester survey about Mastering Engineering, students responded to two statements (using the 5-point Likert scale described previously) regarding whether they found the Mastering tutorials helpful and if they would recommend continuing the use of the tutorials in the course. They then responded to the same two statements for the MecMovie modules. The responses to these statements from the two experimental groups are provided in Table 4. Students in Experimental Group 1 agreed that the Mastering tutorials and MecMovies modules were helpful (mean responses of 3.95 and 4.09, respectively). On the other hand the students in Group 2 agreed to a lesser extent about the usefulness of these two components, particularly in the case of MecMovies where the mean response was only 3.18. Both groups were just above neutral (on the agree side) in regards to recommending that the Mastering tutorials be used again in the course. The students in Group 1 agreed (mean response of 3.95) that the MecMovies modules should continue to be used whereas those in Experimental Group 2 were just above neutral (mean response of 3.31).

Students were given the opportunity in the end-of-semester survey to provide any written comments they had regarding the Mastering tutorials and MecMovies modules. Twenty-two written comments were received and most of these were the same as those provided in the weekly surveys. However, one new comment about MecMovies indicated it would be helpful if the modules provided user-specific feedback when wrong answers were submitted. Two

Table 4 – End-of-Semester Survey for Mastering Engineering

Survey Statement	Percentage of Students Selecting Likert Rating[1] Row 1: Experimental Group 1[2] Row 2: Experimental Group 2[2]					Mean Response
	1	2	3	4	5	
1. Overall I found the Mastering Engineering tutorials assigned in homework to be helpful.	0% 4%	5% 14%	10% 18%	71% 59%	14% 5%	3.95 3.45
2. I would recommend continu-ing the use of Mastering Eng. in Strength of Materials.	10% 5%	19% 18%	29% 45%	33% 18%	9% 14%	3.14 3.18
3. Overall I found the MecMovies modules assigned in homework to be helpful.	0% 5%	0% 27%	19.0% 23%	52.4% 36%	28.6% 9%	4.09 3.18
4. I would recommend continuing the use of MecMovies modules in Strength of Materials.	0% 5%	5% 18%	14% 27%	62% 41%	19% 9%	3.95 3.31

Notes: 1) In rating system 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.
2) Group 1 has 21 student respondents and Group 2 has 22 respondents.

students noted that a few MecMovies modules were too long and repetitive. One stated the MecMovies gave them great visuals that helped with the problem solving.

Student Perceptions of Course

No data or feedback were collected in this study directly addressing whether the use of Mastering Engineering, as a component of homework, improved student perceptions of the Strength of Materials course. However, information from seven statements on the standard teaching evaluations (SmartEvals) completed by students on-line at the end of a semester may indirectly provide insight into this issue. The seven statements to which students respond are given in Table 5 along with the mean ratings received by the instructors for each statement in 2014/15 and 2016 when Mastering Engineering was not and was used by students, respectively. The mean ratings are based on the number of students who select responses (equivalent five-point Likert scale rating given in parentheses) of either strongly disagree (= 1), disagree (= 2), neutral (= 3), agree (= 4), or strongly agree (= 5). An overall average rating is also provided for each instructor based on the seven means.

As seen in Table 5, while the ratings for Instructor 1 went up by 0.3 to 0.6 for the seven teaching-related statements and his overall average increased from 4.5 to 4.9 between 2015 and 2016, the ratings for Instructor 2 went down by 0.4 to 0.8 and his overall average decreased from

Table 5 – Student Rating of Teaching

Survey Statement	**Mean Ratings for Instructor 1**[1,2]		**Mean Ratings for Instructor 2**[1,3]	
The course instructor:	**2015**	**2016**	**2014**	**2016**
1. enhanced my interest in this subject.	4.2	4.8	4.2	3.6
2. presented material in organized manner.	4.5	4.8	4.6	4.2
3. communicated the course material clearly.	4.3	4.8	4.6	4.0
4. established positive learning environment.	4.6	5.0	4.6	4.2
5. provided helpful feedback about my work.	4.6	4.9	4.4	4.0
6. supported my progress towards achieving objectives.	4.6	5.0	4.6	4.0
7. was an effective teacher.	4.6	5.0	4.5	3.7
Average rating:	**4.5**	**4.9**	**4.5**	**4.0**

Notes: 1) In rating system 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.
2) Survey completion rate of 41 out of 46 in 2015 by Control Group 1 and 20 out of 22 in 2016 by Experimental Group 1.
3) Survey completion rate of 12 out of 27 in 2014 by Control Group 2 and 11 out of 23 in 2016 by Experimental Group 2.

4.5 to 4.0. Mann-Whitney analyses of these changes indicate most of the changes for Instructor 1 were statistically significant while only one of the changes for Instructor 2 was significant (lower number of significant changes for Instructor 2 may be due to the lower survey response rate for him). Given that the student ratings went up for one instructor and down for the other, it is difficult to ascertain if any of the rating changes were due to the introduction of Mastering Engineering. Although the students in the course section taught by Instructor 2 in 2016 typically did not rate Mastering Engineering quite as high as those in the section taught by Instructor 1 (for Instructor 2 there was one student who entered a "strongly disagree" response for all statements regarding the benefits of Mastering Engineering in many weekly surveys), it seems likely there were other factors that contributed to the decrease in the ratings of Instructor 2. Such factors could include Instructor 2 missing a year (2015) teaching this course, a change in the daily time slot he taught the course in 2016 putting it much closer to other courses, less of a rapport between the Instructor and students, and/or the low survey response rate.

A second potential indicator of student perceptions of the Strength of Materials course are the Intended Learning Outcome surveys that students complete at the end of the course. Using a scale of 1 to 5 (1 being lowest and 5 being highest) students are asked to rate how well the nine key topics and skills associated with the course were covered, as well as rate their confidence in each of those topics/skills. Table 6 presents the mean ratings received by each instructor concerning the coverage of topics and student confidence in the topics.

As seen from Table 6, the mean student ratings for coverage remain more or less constant at about 4.86 for Instructor 1 between 2015 and 2016 while there is a minor increase for Instructor 2 from 4.45 to 4.59 between 2014 and 2016. In terms of student confidence, there is a minor increase for Instructor 1 from 4.35 to 4.41, while that rating remained constant for Instructor 2 at 4.02.

Overall, there is a lack of substantial size and/or consistency in the changes observed in the student evaluations of teaching and the intended learning outcome ratings between 2014/15 and 2016. Given these mixed results, it is not possible to conclude that using Mastering Engineering

Table 6 – Intended Learning Outcome Ratings

Rated by Students:	**Mean Ratings for Instructor 1[1, 2]**		**Mean Ratings for Instructor 2[1,3]**	
	2015	**2016**	**2014**	**2016**
Coverage of topics in class	4.85	4.87	4.45	4.59
Student confidence in topics (self-rated)	4.35	4.41	4.02	4.02

Notes: 1) Ratings based on a scale of 1 to 5 with 1 being the lowest rating and 5 being the highest.
2) Ratings from 2015 by Control Group 1 and from 2016 by Experimental Group 1.
3) Ratings from 2014 by Control Group 2 and from 2016 by Experimental Group 2.

as a component of the homework produced consistent positive change in student perceptions of the Strength of Materials course.

Student Learning

One of the ultimate objectives of introducing the Mastering Engineering component to weekly homework assignments was to improve student learning of concepts in the Strength of Materials course. If the Mastering Engineering tutorials and optional coaching videos produced improved student learning, then it was expected there would be improvements in student grades on the weekly homework assignments where the Mastering material was directly integrated with the standard textbook problems and MecMovies modules. Likewise, some improvements in examination grades and overall course grades were anticipated.

Homework

A plot of the median scores for the fourteen (weekly) homework assignments completed by Control Group 1 in 2015 and Experimental Group 1 in 2016 is presented in Figure 4 and the same type of data are presented for Control Group 2 and Experimental Group 2 in Figure 5. Median homework scores are presented and used because a majority of the homework data did not fit a normal distribution.

As seen in Figure 4, the median homework scores of Experimental Group 1 were numerically higher than Control Group 1 in only three of fourteen weeks (Weeks 8, 9, and 12). None of the differences observed in those three weeks were statistically significant per the Mann-Whitney test. On the other hand there were eleven weeks where the median scores for Experimental Group 1 were actually lower than those for Control Group 1 and the differences in the scores were statistically significant for seven of those eleven weeks. It should be noted that the upper-level student grader used for Experimental Group 1 in 2016 was different than the one used for Control Group 1 in 2015, which could potentially explain the fairly consistent lower scores for the Experimental Group.

Experimental Group 2 (2016) had median homework scores that were higher than Control Group 2 (2014) for six of the fourteen weekly homework assignments (Weeks 1, 2, 5, 8, 9, and 13). However, none of the differences in the medians were statistically significant for those six weeks. For the remaining eight weeks the Experimental Group had median scores that were lower than the Control Group, but none of those differences were significant. The homework grader for both groups was the same course instructor, which should have provided some consistency and may explain the differences observed between these groups versus what was observed for Group 1.

Overall, the homework score data suggest that incorporating Mastering Engineering as a component of the homework caused no obvious improvement in student understanding and learning of strength of materials concepts during the completion of the homework assignments.

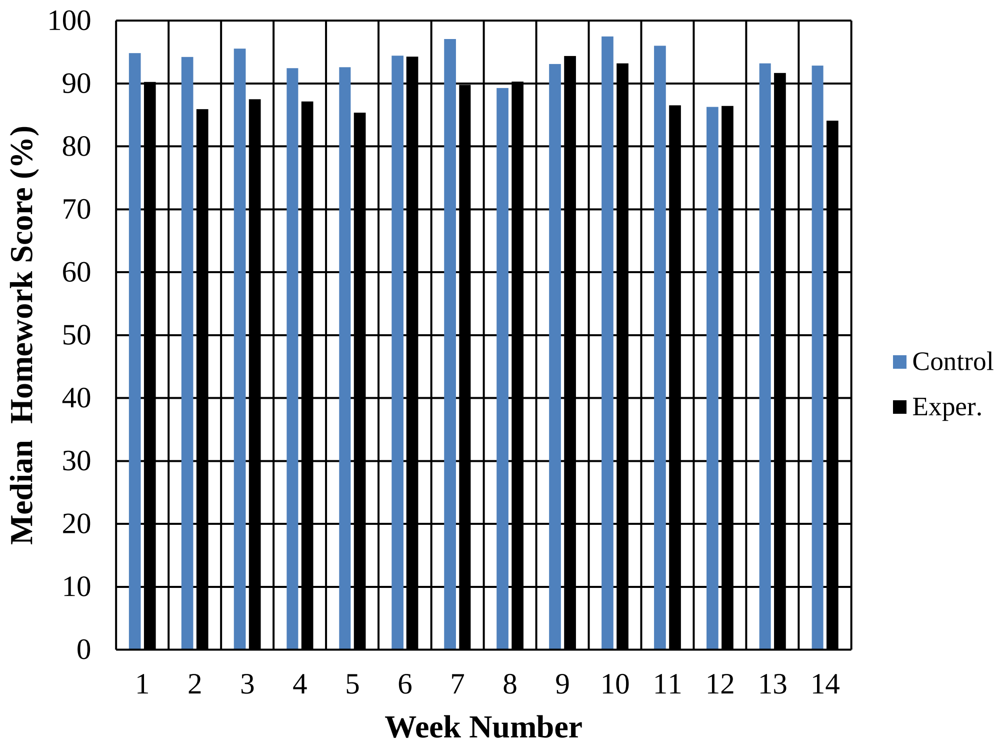

Figure 4 – Weekly Median Homework Scores for Control and Experimental Groups 1

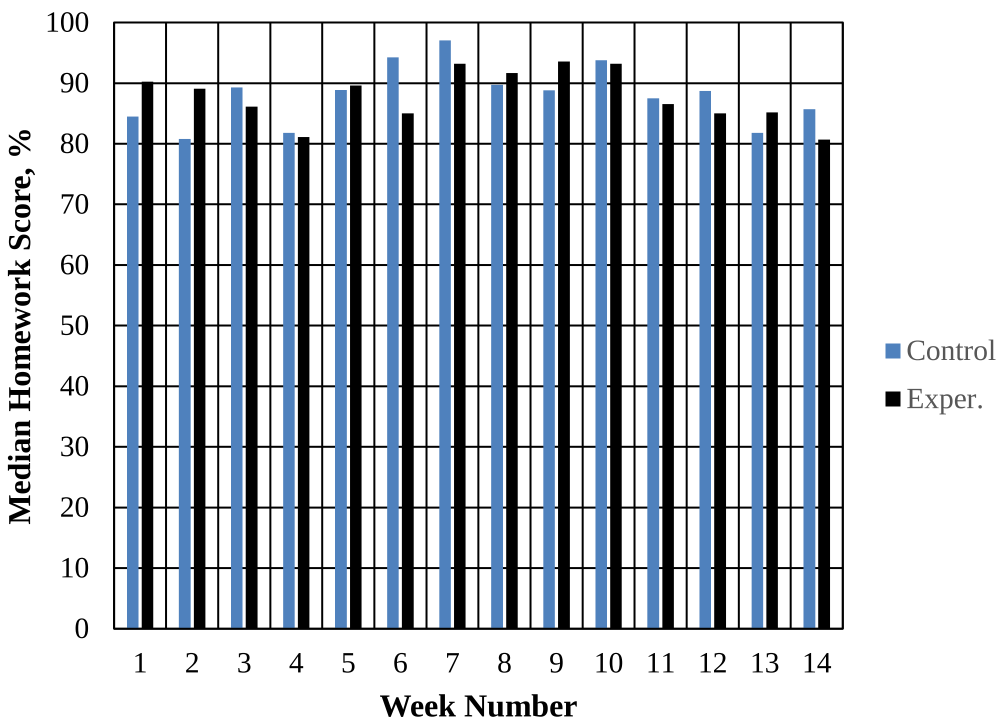

Figure 5 – Weekly Median Homework Scores for Control and Experimental Groups 2

Examinations

In order to evaluate if Mastering Engineering caused any long term improvement in student learning of strength of materials concepts, the mean and median exam scores of the experimental and control group students are directly compared to each other in Table 7. As seen from that table, Experimental Group 1 (2016) had mean and median exam scores that were higher than Control Group 1 (2015) on two (exams 1 and 4) of the four 60-minute-long exams taken during the semester, but only the change in the exam 4 score was significant based on the Mann-Whitney test (exam 4 data did not fit a normal distribution). A closer look at exam 4 showed that the median score for Experimental Group 1 on a statically determinate beam deflection problem was higher than Control Group 1 and the difference was statistically significant. This better performance on the beam deflection problem for Experimental Group 1 happens to coincide with the fact they strongly preferred the Mastering Engineering tutorial over the MecMovies modules for beam deflection in Week 12, as shown in Figure 2. The mean and median final exam scores for Experimental Group 1 were lower than Control Group 1, but the difference was not statistically significant. It should be noted that all of the problems given on the exams taken by these two groups were essentially the same because Instructor 1 retains all exams.

Experimental Group 2 (2016) had mean and median exam scores that were higher than Control Group 2 (2014) on all four of the 60-minute-long exams they took, as well as the final exam. T-tests or Mann-Whitney tests performed between the Experimental Group 2 and Control Group 2 scores indicate there is a statistically significant difference between the scores for exams 1 and 4,

Table 7 – Performance on Exams

Exams	**Group 1 Scores**			**Group 2 Scores**		
	Mean │ Median		**Statistical Values[1]**	**Mean │ Median**		**Statistical Values[1]**
	Control	**Experimental**		**Control**	**Experimental**	
Exam 1	82.7 │ 86.5	86.0 │ 87.0	W = 1528 p = 0.22	66.7 │ 69.7	76.5 │ 77.4	t = -2.81 p = 0.004
Exam 2	82.9 │ 85.0	83.0 │ 82.0	t = 0.04 p = 0.969	75.1 │ 77.1	79.2 │ 79.7	t = -0.93 p = 0.177
Exam 3	81.1 │ 82.0	77.0 │ 78.0	NI[2]	74.2 │ 76.2	76.7 │ 76.8	t = -0.71 p = 0.241
Exam 4	85.9 │ 88.5	92.7 │ 98.0	W = 1457 p = 0.045	77.8 │ 82.8	88.7 │ 91.7	W = 539.0 p = 0.002
Final Exam	88.1 │ 93.0	84.3 │ 88.0	NI[2]	69.4 │ 69.6	78.1 │ 78.0	t = -1.95 p = 0.029

Notes: 1) W is statistical value from Mann-Whitney test based on medians and t is statistical value from Student t test based on means. p is probability for accepting null hypothesis of no difference between control and experimental group scores. p value < 0.05 signifies the null hypothesis is rejected and the alternative that the experimental group scores are higher is accepted. 2) NI means there was no improvement in scores from control to experimental group and therefore a statistical analysis was not performed.

as well as the final exam. However, it is important to note that although the exams taken by Experimental Group 2 and Control Group 2 covered the same material, the exam problems were not identical because Instructor 2 returns exams 1 through 4 to students and therefore has to change problems from year to year. Therefore the difference in exam scores might be due in part to changes in the details of the problems, as seemed evident for the final exam. On the final exam, three questions (axial loading, bending stresses, and shear/moment diagrams) for Experimental Group 2 and Control Group 2 were essentially the same, whereas the other two questions (statically indeterminate beams and column buckling) varied somewhat. When the means of the combined scores for the three questions that were the "same" on the final exam are compared for the experimental and control groups no statistically significant difference is found.

In summary, the examination score data suggest there could have been an improvement in "longer term" student learning of strength of materials concepts primarily for one of the two experimental groups that used Mastering Engineering, but the impact appears to be limited.

Course Grades

The mean course grades for Experimental Group 1 and Control Group 1 were 85.7 percent and 85.0 percent, respectively, and the median course grades were 86.7 percent and 88.4 percent, respectively. The course grades of Experimental Group 1 and Control Group 1 were not statistically different. The mean course grades for Experimental Group 2 and Control Group 2 were 81.7 percent and 76.8 percent, respectively, and the median course grades were 81.3 percent and 78.4 percent, respectively. The difference in the means (the course grades fit a normal distribution) was statistically significant for Group 2, with the t-value equaling -1.79 and a p-value of 0.04.

The course grade results for Group 2 suggest there was some overall improvement in student performance and learning in 2016, which could partially be attributed to the introduction of Mastering Engineering. However, the lack of a statistically significant improvement in the course grades for Group 1 makes this conclusion tenuous.

Conclusions

This particular study has collected data to assess whether incorporating Mastering Engineering in a limited fashion into a strength of materials course taught using a traditional lecture/recitation and textbook homework format leads to improvements in student learning and perceptions for the course. It also has obtained student feedback on their perceptions of the tutorials and coaching videos in Mastering, as well as their preference, if any, for completing Mastering Engineering tutorials or MecMovie modules. Some of the key conclusions from this study are summarized below.

1) Overall student response was just above neutral, on the agree side of the spectrum (typically somewhere between 3.0 and 3.5 on a 5 point Likert scale), in regards to preferring Mastering Engineering tutorials over standard textbook problems and finding those tutorials to be helpful in preparing them to solve textbook problems. Although

some students found the hints embedded in tutorials to be helpful, others indicated that the hints provided did not match their needs.

2) The impact of Mastering Engineering on student perceptions of the Strength of Materials course was mixed. The student ratings of one instructor went up when compared to the previous year when Mastering was not used, while the ratings of the other instructor went down. Student ratings of the degree of coverage of the key topics in the course and their confidence in understanding those topics went up slightly in some cases, but not a substantial amount.
3) Improvements in student learning from incorporating Mastering Engineering in the strength of materials course were not consistent. The statistically significant improvement in homework grades that was expected by the authors did not occur. Some statistically significant increases in examination and overall course grades did occur, but those improvements were not consistent between the two sets of experimental and control groups used in this study, suggesting they could have been due to other factors.

Overall the results of this study do not strongly support the idea that a limited implementation of Mastering Engineering in a traditional strength of materials course will produce consistent positive changes in student learning and perceptions. In addition, students did not express a strong preference for the Mastering components that were introduced. There are a few studies that suggest substantially or completely replacing traditional textbook problems in homework with a robust configuration of Mastering Engineering learning system components can have a more substantial impact on student performance and that using Mastering in conjunction with the "flipped" classroom can also have beneficial effects. More studies investigating the impacts of these approaches should be performed. Although the results of this study indicate that adopting Mastering Engineering in a limited fashion does not produce substantial or consistent improvements in student learning and perceptions, such an approach does provide a means of gradually transitioning from the more traditional textbook homework format to the online Mastering Engineering format.

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