2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33880

Stimulating Student Preparation in Introductory Engineering Mechanics

Major Brad Gregory Davis, United States Military Academy

Major Brad Davis is an Instructor in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, NY. He received his BS in Civil Engineering from the United States Military Academy, MS in Engineering Management from the Missouri University of Science and Technology, and MS in Civil Engineering from the University of Texas at Austin. His research interests include the impact response of structural materials, design of protective structures, and engineering education.

Dr. Kevin Francis McMullen, United States Military Academy

Kevin McMullen is an Assistant Professor in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, NY. He received his B.S. and Ph.D. in Civil Engineering from the University of Connecticut. His research interest areas include bridge engineering, protective structures, and engineering education.

Mr. J. Adam Pegues, United States Military Academy at West Point

Mr. Pegues is an instructor in the Department of Civil and Mechanical Engineering at West Point, and has served in various engineering and management roles in both the public and private sectors. He graduated with distinction from the United States Naval Academy, and served for more than a decade as a naval aviator in the Navy, flying F/A-18s from aircraft carriers. Mr. Pegues hails from rural Virginia and is married to the former Kathryn Kennedy of Olympia, Washington.

Stimulating Student Preparation in Introductory Engineering Mechanics

Abstract

Engineering mechanics is the foundation for an engineering curriculum. It is crucial to comprehend and retain this knowledge to be successful in advanced courses such as structural analysis and machine component design, as well as to pass the fundamentals of engineering (FE) exam. The study presented in this paper details the approach taken to replace in-class quizzes with regular out-of-class homework assignments in an introductory engineering mechanics course. The objectives of the study were to: 1) provide students with a variety of problems to apply both new and previous knowledge; 2) encourage engagement with the course material outside of in-person lessons; and 3) teach students to reflect and self-assess their own learning. Eighteen homework assignments were added throughout the thirty-lesson course. Each assignment consisted of two parts; practice problems from previous lessons and conceptual responses based on preparation for the next lesson. At the beginning of each class, students were given the opportunity to assess their own work and clarify any points of confusion. Instructors also provided focused, frequent, and timely digital feedback on these assessments. Instructors graded each assignment based on a holistic evaluation of the students' comprehension in four domains: 1) approach to problem solving, 2) demonstration of engineering concepts, 3) application of fundamental math concepts, and 4) accuracy and presentation of the final answer. The effectiveness of the assignments was evaluated based on time students engaged with the material outside of class, historical performance on mid-term and final examinations, and student and instructor feedback. The results of the study showed frequent out-of-class assessments allowed students to spend a consistent amount of time with the course material per lesson and reduced the reported study time for midterm and final examinations. Students' time spent preparing for each lesson increased by 22%, but time spent preparing for examinations decreased by 29%. Student feedback showed regular assessments were a useful tool when preparing for examinations and assisted in learning the material. However, the students' performance on historical examinations showed negligible impact on comprehension of course topics. Further research is required to evaluate long-term retention.

Introduction

All fundamental courses struggle with the same key question: *"How can we structure the course so that students retain the knowledge required to be successful in the succeeding curriculum* [1]?" One reoccurring theme is the student approach of using the *"cram and dump"* method [2]. The cram and dump method for students involves performing massed practice before an assessment, displaying adequate mastery on the graded event, but promptly losing the skills learned soon afterwards. Often, when previously learned topics are brought up in subsequent courses, students cannot even recall having learned them, but these courses cannot be expected to re-teach prerequisite topics.

The goal of this study is to improve the structure of assignments in a combined introductory statics and mechanics of materials course to increase student engagement with the material prior to each lesson, build connections between topics to improve retention and understanding, and interleave practice on fundamental concepts over the course of the semester [3]. As cognitive researchers argue in *Make it Stick: The Science of Successful Learning*, *"The simple act of spacing out study and practice in installments and allowing time to elapse between them makes both the learning and the memory stronger, in effect building habit strength* [4]." This study intends to build *"habit strength"* by replacing in-class quizzes with graded, nightly homework assignments specifically designed to improve understanding and retention.

This approach has been used in previous studies for math, science, and engineering courses with differing results [5], [6]. Student feedback has indicated targeted assignments focused on reading comprehension and representative example problems would be a valuable learning tool. In a recent course assessment, students highlighted the necessity of frequent assessment:

> *"I felt that my class should have allotted more time to complete individual board problems. We did complete a board problem as a class each lesson, but I felt that I was lost when it came time to complete lessons on my own"*
>
> *"I learned the most during the beam lab when [the instructor] had us go to the boards in groups and went to help each group work through the problems to completion. I learned a lot from my peers that way. Going to board by myself doesn't help at all if I don't know what I'm doing"*

Students also struggled differentiating different types of problems, with one student writing:

> *"Sometimes I feel there is a gap between conceptual understanding and using mathematics to solve problems. From time to time, I would be asked to solve a problem that differed slightly from a homework or in-class problem and couldn't. The way to fix this is to either give us more diverse HW/in-class problems or explain in class how we might go about solving problems and explain the process"*

Nightly homework assignments provide students with ample opportunity to engage with the course material and complete example problems. Interleaving previous concepts benefit future learning by refreshing topics and building connections [7]. Homework assignments can increase in complexity to stretch students' ability to recall course material [8]. Conceptual and reflection questions may be used to test students problem-solving process and their ability to differentiate problem types.

However, mass practice is not enough to achieve the goal of this study. Previous researchers have identified focused, frequent, and timely assessments are critical to improving students' understanding. Mullen noted that students need to be engaged with the material and receive constant feedback on their performance [9]. Several alternative methods have been proposed to provide more impactful feedback. Self-grading has been used to encourage students to assess their own work. Unfortunately, researchers found grade inflation was a common problem [10]–[12]. Textbook publisher developed web-based systems are becoming popular to provide immediate feedback; though, students should be prompted to annotate their mistakes in addition to reviewing the solution [13]–[15].

Reflection exercises are also valuable for engaging students with course material prior to class. Research has shown pre-class preparation has a strong correlation to positive student performance

[16], [17]. Scheduling in-class, written and oral presentations are an effective technique to encourage student preparation for class and provide an active learning environment [18]. Nevertheless, a key factor necessary to promote student preparation is emphasis by the instructor about the importance of class preparation [19].

Design of the Study

MC300 - Fundamentals of Engineering Mechanics and Design is an introductory level, three credit-hour course, which covers the basics of statics and mechanics of materials. This course is taught to both engineering and non-engineering majors, primarily second- and third-year undergraduates. Approximately 450 students are enrolled each year. The course is divided into three blocks: 1) Statics; 2) Axial Loaded Members; and 3) Flexural Members. The topics covered are shown in Table 1.

Table 1: Lesson topics and assessments for MC300

	Assessments by Topic			
Topics	**Lessons**	**Homework**	**Problem Set**	**Design Project/Lab**
STATICS	**(9)**	**(7)**	**(2)**	**(1)**
Vectors & Forces	2	2		
Equilibrium & Reactions	3	2		
Truss Analysis	2	1		
Frame Analysis	2	2		
AXIAL MEMBERS	**(9)**	**(6)**	**(1)**	**(1)**
Stress & Strain	4	2		
Buckling	2	2		
Connections	2	1		
Design	1	1		
FLEXURAL MEMBERS	**(9)**	**(5)**	**(1)**	**(1)**
Shear & Moment Diagrams	2	1		
Normal Stress	2	1		
Deflection	1	1		
Shear Stress	1	1		
Design	3	1		
EXAMINATIONS	**(3+1)**			
Midterms	2			
Review Lesson	1			
Final	1			
Total:	**(30+1)**	**(18)**	**(4)**	**(3)**

The overarching goal of this study was to increase student out-of-class preparation in an introductory mechanics course through the implementation of regular out-of-class homework assignments. The objectives were to encourage and incentivize students to:

1) *Practice* an increased number and variety of fundamental problems.
2) *Engage* with the material outside of class.
3) *Reflect* on their own learning.

The out-of-class homework assignments were designed to assess two primary focus areas: preparation and comprehension. Each problem was uniquely designed by the course instructors to address specific topics and skills to achieve the lesson and course objectives. Conceptual and/or reflection questions based on the reading encouraged lesson preparation and allowed students the opportunity to connect lesson material to their problem solving process [16], [17]. Basic and intermediate problem-solving questions assessed prerequisite material and content from prior lessons. The assignments allowed instructors to provide focused, frequent, and timely assessment of a students' learning. Students were rewarded for engaging with class material through the successful completion of homework assignments in their final course grades [20].

The graded requirements for the course included homework assignments, comprehensive problem sets, a laboratory report, two engineering design projects, two midterm examinations, and a final examination. The number of assessments by topic are shown in Table 1. A full breakdown of the graded requirements for the previous and new versions of the course are shown in Table 2. Previous studies indicated out-of-class assignments increased student engagement with the material more than in-class exercises [18]. Therefore, the reading quizzes in the previous version of the course were replaced with out-of-class homework assignments focused on both problem solving and self-learning.

Table 2: Graded requirements for the two versions of MC300

	MC300 Versions	
Requirements	***Old*: Reading Quizzes**	***New*: Homeworks**
Reading Quizzes	10%	--
Homeworks	--	15%
Problem Sets	25%	22.5%
Laboratory Report	7.5%	7.5%
Design Projects	12.5%	10%
Midterms	20%	20%
Final	25%	25%

As part of this study, no modifications were made to the course content or lesson topics. However, in 2020, the course was delivered with a hybrid structure due to the COVID-19 pandemic. The hybrid format consisted of half of the lessons taking place in-person and half of the lessons taking place remotely. The authors recognize the learning environment during the COVID-19 pandemic was unique relative to previous semesters.

<u>Implementation</u>

Eighteen homework assignments were integrated in the new course format. The homework assignments were designed to be completed out-of-class within 60 minutes. A graded event was due 27 out of 30 lessons including homework assignments, problem sets, laboratory report submissions, engineering design projects, and examinations. The frequency of assignments fostered nightly engagement with the course material and spread student practice out over a longer, more engaged period of time [21].

The homework assignment average grade accounted for 15% of the final grade, which encouraged completion of the assignments [20], [23]. Each homework was scored out of a maximum 20 points accounting for 1% of the course final grade. The lowest three homework assignment grades were dropped. The homework assignments were incorporated into the students' daily routine prompting them to engage with the course material prior to class. Students submitted their work digitally through the course learning management system. This allowed instructors to grade more efficiently and provide more detailed feedback. Instructor feedback was generally received by the student within two lessons of submitting the assignment. A standardized holistic grading approach was used to assess comprehension in four domains: 1) approach to problem solving, 2) demonstration of engineering concepts, 3) application of fundamental math concepts, and 4) accuracy and presentation of the final answer. The students also received immediate feedback during self-assessment of their work at the beginning of each in-person class. Students spent five minutes self-assessing their solution and reflecting on the material. Self-assessment was included to increase student retention of the material [10]–[12].

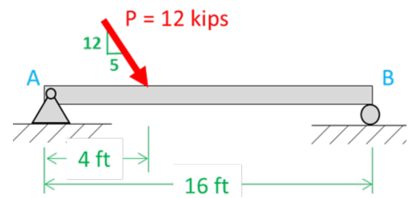
Generally, the homework assignments were divided into two parts worth 10 points each: conceptual reading questions and problem-solving questions. All homework assignments consisted of original questions created by the instructor team. The questions focused on desired lesson and course objectives. The questions included basic and intermediate problems with a one to two step simple solutions. Students could easily solve the problems based on the course material, i.e., in-class practice problems, textbook, notes, etc. Creating original problems facilitated interleaving of course topics by connecting the problem description to multiple assignments. Original problems dissuaded students from accessing solutions online from textbook publishers or study websites. Students were required to acknowledge and cite all external resources used to complete the assignment and self-reported the amount of time spent on the reading and homework assignments.

The reading questions focused on the learning objectives for the next lesson. These questions familiarized students with equations, terminology, and variables, reinforced precision of language when discussing lesson topics, and connected lesson topics to real-world applications [19]. Most answers were taken directly from the reading incentivizing engagement with the textbook prior to class but requiring some synthesis of the material to receive full credit. Examples for the reading-based questions are shown below:

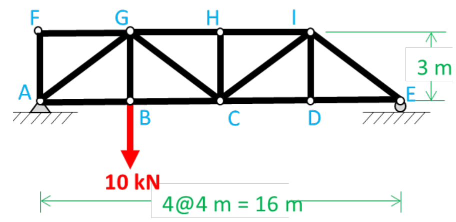
1) Equilibrium: "Describe the principle of transmissibility using a real-world example of your choosing."
2) Frames: "Describe the frame/machine solving process. How is solving a truss different from solving a frame/machine? How is solving a machine different from a frame?"
3) Axial: "Describe how deformation, initial length, and stress are related through Hooke's law."
4) Connections: "Define three different modes of failure for simple bolted or pinned connections."
5) Flexure: "Explain the steps for determining the flexural stress in a beam. Identify one way to increase the strength of a beam in bending."

The problem-solving questions emphasized basic skills critical to success in the course. Typically, two short problems were included, which could be completed in less than 20 minutes per problem. In the earlier assignments, students were required to recall prerequisite math and physics knowledge. In later assignments, knowledge from earlier lesson topics were reassessed [4]. The concepts assessed were necessary for completion of comprehensive problems sets and examinations. This allowed students to practice applying the material throughout the semester. Example problem-solving questions are shown below:

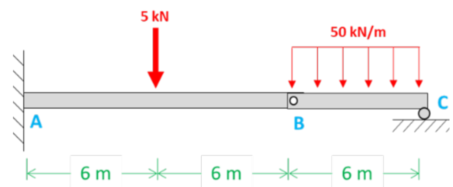
1) *Equilibrium*: Draw a free-body diagram and calculate the support reactions for the structures shown below.



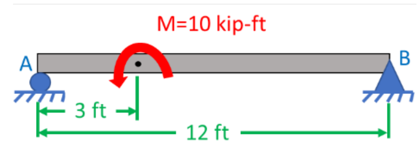
2) *Trusses*: Solve for the internal force in members GH, GC, and BC. Draw a complete free-body diagram of any cuts. Indicate any zero-force members on the structure with a Ø.



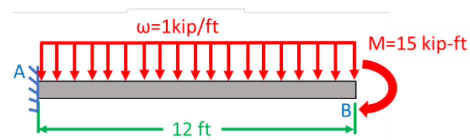
3) *Frames*: Draw a free-body diagram for each member (AB and BC). Solve for the reactions at C.



4) *Shear and Moment Diagrams*: Draw a complete free-body diagram, and complete shear and moment diagrams for the beam. Identify the maximum shear and moment.



5) *Deflection*: Calculate the maximum deflection for the beam using superposition. The W12x26 beam is made of ASTM A36 structural steel bent about its strong axis. Check if the beam is elastic.



Select homework assignments placed emphasis on either conceptual questions, problem-solving questions, or interconnected questions. For example, the first homework assignment on axial members focused on the equations, terminology, and variables necessary to identify and calculate axial stress, strain, and deformation. The homework assignments on shear and moment diagrams included only problem-solving questions of both basic and intermediate difficulty. The homework assignments on beam analysis and design connected students' knowledge for creating free-body diagrams and shear and moment diagrams, calculating section properties, and solving for flexural normal stress, shear stress, and beam deflection.

After completion of a major topic or subtopic, students would complete a comprehensive problem set, which included multi-part, real-world application questions. The problem sets were designed to take approximately 180 minutes to complete. The problem sets built off the knowledge assessed in previous homework assignments. On average, the students completed four to five homework assignments before submitting a comprehensive problem set. Topics were interleaved into the homework assignments and problems sets, so critical concepts could be assessed multiple times throughout the semester. This provided spaced practice, which is critical for retention of knowledge. Engineering design projects and laboratory report evaluated students' ability to solve ill-defined problems [22]. In order to increase the significance of homework assignments and incentivize out-of-class participation, the scopes and graded weights of the comprehensive problem sets and the engineering design projects were slightly reduced.

Evaluation Criteria

The impact of providing homework assignments in lieu of reading quizzes was measured and compared based on four factors:

1) student preparation time spent outside of class.
2) student grades on major graded events.
3) student feedback.
4) instructor feedback.

For each graded event, students provided an estimated time spent completing the assignment. This data evaluated if students were consistently engaged with the lesson material. At the United States Military Academy, students are required to track time spent on each academic course. The midterm and final examinations for the course have been used for six previous semesters to directly compare student performance on major graded events. The authors acknowledge student grades may be variable for each sample set. Instructors used a similar process for assessing historical examinations for consistent grading. Student feedback surveys were administered twice during the semester. Both quantitative and qualitative feedback was collected on the students' perceptions of the course and assessments. Nine instructors were responsible for delivering the new version of the course across 18 sections. All instructors provided the same assessments. All examinations were team graded. Five instructors taught the course in the previous version. Surveys of the instructors' perspectives on student outcomes and administrative overhead were collected as well.

Results

Time Spent Out of Class

One of the goals of this study was to increase the consistency at which students engaged with course material outside of the classroom. The homework assignments allowed students to apply the course concepts multiple times throughout the semester. Self-reported student time data was collected and compared to historical data. The time reported included time spent completing assignments, readings, studying course concepts, practicing problems, watching video content, and discussing the course with their peers or instructor. Over the six previous semesters, the average student spent approximately 98 minutes per lesson. The averages ranged from a high of 110 minutes to a low of 76 minutes. During this study, the average student spent 120 minutes per lesson preparing for class, a significant increase of 22%. Figure 1 shows the student time spent on course material per lesson in 2019 and 2020. In 2019, on lessons when no graded assignments were due, the average student spent approximately 45 minutes engaged with the course material. In 2020, with the introduction of homework assignments, preparation for a standard lesson increased to 76 minutes. However, the time spent preparing for midterm and final examinations decreased significantly, by 44% and 5%, respectively.

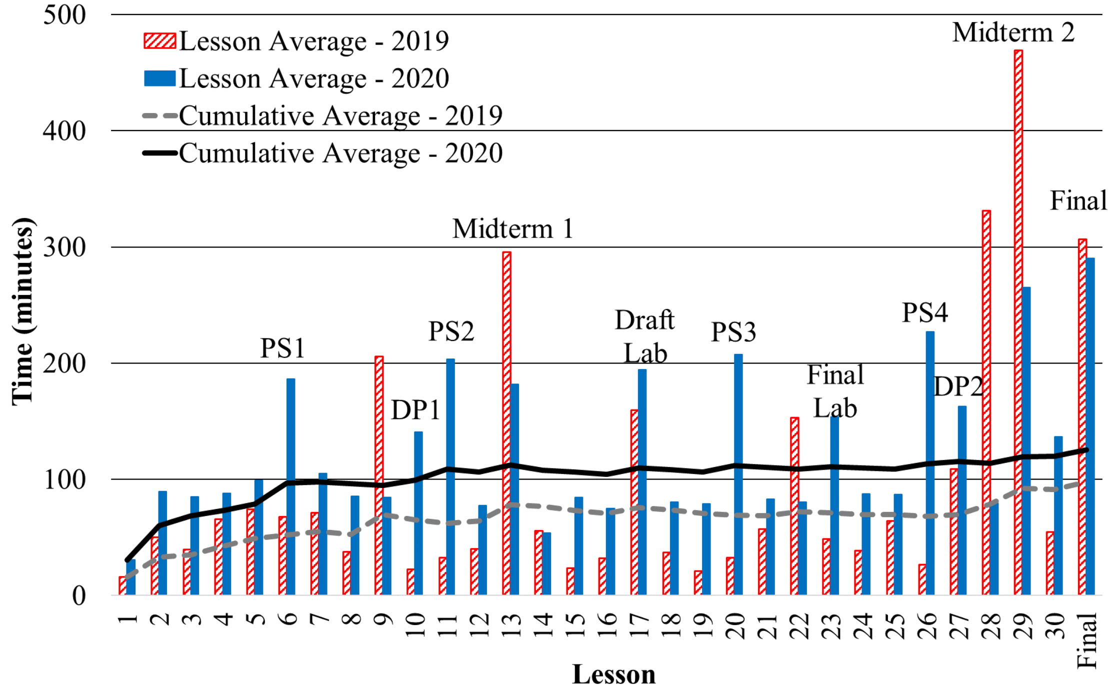


*Figure 1: Student time spent out of class per lesson. Major graded events are identified on the graph: PS=Problem Set, DP=Engineering Design Project, Lab=Laboratory Report. **Note: Major graded events were not necessarily due on the same lesson in both studies, the lesson identified correspond to 2020.***

Student Performance on Historical Graded Events

Student outcomes were assessed by three major graded events: two midterm evaluations and a comprehensive final exam. The two midterm assignments have been consistent for the previous six semesters and the comprehensive final has been the same since 2005. The results for the three major graded events are shown in Table 3. Table 4 shows the results for each topic assessed on the final examination. On the first midterm, student scores on the statics topics of truss and frame analysis decreased by 5% and 10%, respectively. However, these topics were reassessed on the final exam and student scores increased by 5% and 7.8% on truss and frame analysis, respectively. On the second midterm, the analysis and design of axial and flexural members was covered. The student performance improved by 4.5% on the axial design questions but decreased significantly by 12% on flexural member topics. The trends were opposite when comparing the performance on the final exam. Student scores decreased slightly by 2% on axial member design and increased by 3.7% for flexural member design. The student results showed incorporating consistent practice and reflection may have contributed to the students' retention of statics material as indicated by improved performance on the final exam.

Table 3: Historical grades on major graded events

	Academic Year			
Questions	**2017**	**2018**	**2019**	**2020**
Midterm Exam 1	85%	81%	81%	80%
Midterm Exam 2	86%	81%	76%	77%
Final Exam	80%	83%	82%	84%

Table 4: Historical grades by topic on the final exam

Questions	Academic Year 2017	2018	2019	2020
Frames	74%	79%	82%	82%
Trusses	77%	80%	75%	83%
Axial Member Analysis	91%	94%	92%	90%
Shear & Moment Diagrams	84%	75%	80%	79%
Flexural Design	84%	79%	81%	84%

Anonymous Student Feedback

Student feedback was collected twice during the term studied; once before the first midterm exam and again before the final exam. 152 responses were gathered during the first evaluation, representing approximately 50% of all students. Students were asked to rank the effectiveness of out-of-class activities are shown in Figure 2. 32% of students selected homework as the most effective out-of-class activity with another 37% selecting it as their second choice, well above any other resources available.

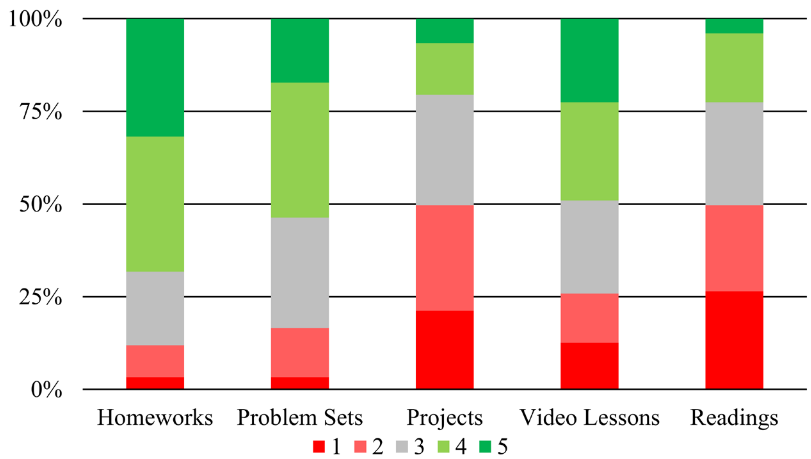


Figure 2: Student ratings of effectiveness of out-of-class activities. ("5" = top choice)

Students were asked to rate five statements regarding the homework assignments on a Likert scale from "Strongly Agree" to "Strongly Disagree." The results from the student responses are shown in Figure 3. The statements were "the homework assignments ___________":

1) *Helped me prepare for class*
2) *Allowed me to practice applying course concepts*
3) *Were too challenging*
4) *Prepared me for the problem sets*
5) *Prepared me for the Midterm*

79% of students agreed the homework assignments prepared them for class with only 7% of students disagreeing with the statement. 87% of students agreed the homework assignments helped them apply the course concepts with only 3% disagreeing. Approximately 33% of students stated the homework problems were too challenging, indicating that in the future, some assignments should be shortened or clarified to improve student perceptions of the assignments.

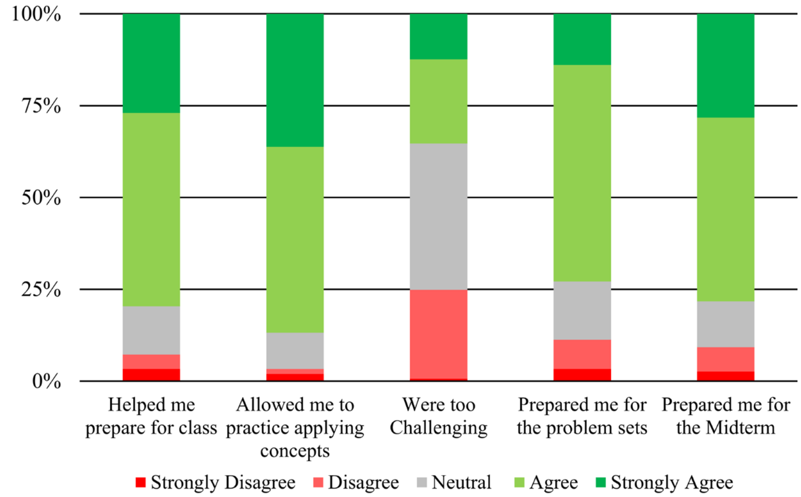


Figure 3: Student Likert responses to statements above regarding the homework assignments

The students were also asked about their preferred method of receiving feedback on homework assignments. The results are shown in Figure 4. Most students, 60%, preferred to see a correct solution of the problem and correct their own errors with an additional 24% selecting that they preferred their instructor reviewed the solution with them in class. Only 13% preferred written feedback from their instructor.

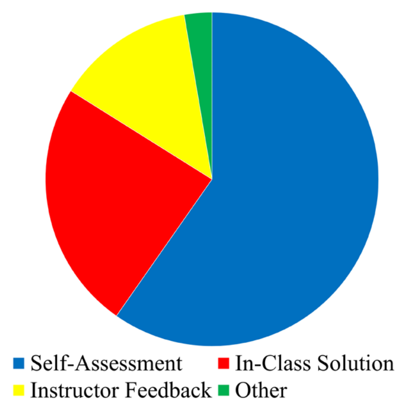


Figure 4: Student preferred methods of receiving feedback

Prior to the final examination, feedback was collected from 290 students, representing 96% of the course. The primary feedback received was from the following five free-response questions:

1) How did self-correcting your homework in class improve your understanding of the course material? If it did not, explain how you would prefer to receive feedback.
2) Explain how the reading reflection questions on homework helped focus your class preparation and improve your understanding. If they did not, explain how you would prefer to focus your preparation for each lesson.
3) Describe what contributed the most to your learning about statics and mechanics of materials. Explain why it was the most effective for you.
4) Did solving problems on homework improve your ability to understand and apply the course material? If not, describe what methods you would rather see implemented.
5) Explain how you would change out-of-class assignments to improve your understanding of the course material.

Many students expressed the need for more timely feedback. Instructors who consistently allowed students to correct their homework assignments at the beginning of in-person lessons, received favorable feedback with the experience of self-correcting. Sections that did not consistently allow the students to review the homework solutions in class received requests for more prompt feedback. Due to social distancing restrictions during the COVID-19 pandemic, the two cohorts had assignments due on different days, which made timing for grading difficult for instructors. This study was conceived for an in-person environment, but additional restrictions contributed to delays in feedback by up to three days. Further refinement is needed to implement self-correction for virtual and hybrid learning environments. However, overall feedback implies positive opinion to self-assessing assignments. A few students also provided constructive comments referencing the use of web-based textbook publisher systems which offer immediate feedback upon submission; similar methods were described by Hedtrich and Graulich [14].

Approximately 68% of students agreed the conceptual questions on the homework assignments helped focus their attention on key course topics. The most common response was that reading reflections allowed students to process important topics and make connections between new and previous material. Students appreciated the assistance in focusing their class preparation.

The student responses provided mixed feedback on their preferred learning activity. 11% cited homework assignments, 35% in-class example problems, 14% video lectures, 18% peer interactions, 5% office hours, 7% hands-on projects, 7% problem sets, and 3% other sources. It would have been valuable to know what percentage of students' time was spent completing each of these activities within their total time reported. This may be studied during future research.

86% of students indicated the homework assignments improved their understanding of the material. Less than 5% of students expressed that conceptual material should not be included in the homework prior to explicitly being covered during class. The conceptual questions were designed to require synthesis of the reading, which some students struggled with. An additional 5% of students indicated the homework assignments were too challenging or too long. Since homework assignments were due each lesson, the students did have the perception that they were spending more time on the course material than the targeted 2:1 out-of-class to in-class time spent on the course (140 minutes:70 minutes).

The student feedback regarding improvements for the homework assignments have been assessed and are currently being incorporated. To provide more prompt feedback, students recommended the final numerical answer to each problem be included to aid in self-correction. Students requested only topics covered in class be included on assignments. Students also wanted more questions similar to those on major graded events. Some students requested shorter, multiple choice FE exam style questions be included, as a self-correcting option. A web-based textbook publisher system could be incorporated with a prebuilt bank of questions.

Instructor Feedback

Instructor feedback was largely neutral, given the significantly increased grading burden and marginal impacts on student performance. The previous reading quizzes anecdotally took approximately 30 minutes to grade per section, while the longer, more detailed homework assignments took one to two hours per section. Instructors appreciated the lead-in to each lesson by discussing the homework assignments through the self-correcting process. The engagement from students was higher compared to starting the class with a quiz. The numerical averages on quizzes and homework assignments were identical, approximately 85%. Negligible influence was observed on all student assessments compared with previous semesters. When comparing the performance between the 18 sections, no significant trends were observed. Each of the sections taught by different instructors had similar results.

One metric commonly used to assess course difficulty is the change in incoming and outgoing grade-point average, based on a 4.33 grading scale, accounting for an A+ [24]. For the previous six semesters, the change in grade-point averages was +0.03 with a low of -0.05 and a high of +0.07. In the term studied, grade-point averages increased by +0.02. This change is similar to the performance seen in previous semesters indicating the overall difficulty of the course did not increase. Further analysis of impact of the course delivery on student performance in follow-on courses must be observed.

Conclusions

The new course structure centered on regular homework assignments to allow students to practice both new and previous knowledge, engage with the course material outside of class, and self-assess their own work. Targeted assessments ensured students did not just engage with the course material but achieved the lesson and course objectives. Students spent a consistent amount of time preparing for each of the 30 lessons in the course, as opposed spending significant time concentrated before examinations. Student time spent engaged with course material increased by approximately 22%. The new format introduced self-assessment of homework assignments, which allowed students to identify errors in their own work and make corrections. The impact on student performance due to these changes was negligible. The final course grade and out-going grade point average were nearly identical to previous semesters. However, many students spent significantly less time preparing for examinations but achieved similar grades. This reduction in time spent studying may be attributed to retention of key course concepts through competition of regular homework assignments. The daily, interleaved practice increased the comprehension of the basic engineering fundamentals covered in the course.

The COVID-19 pandemic did not have a significant effect on the outcome of this study. Nevertheless, personal factors such as stress, travel restrictions, and family concerns may have placed a heavier burden on students than a normal semester. The course was delivered in a hybrid approach where only half of the lessons were in-person and half of the lessons were remote. Based on the student feedback, there is no substitute for in-person instruction, but including homework assignments provided the students with regular engagement with the material and assessment of their learning. Completion of the homework assignments ensured that students were achieving the course objectives, even during remote learning.

Recommendations & Future Research

The new version of the course with homework assignments will continue to be administered in future semesters. Slight modifications will be made to improve course delivery and address recommendations from students for improving the course. One of the main changes is to provide more prompt feedback on student performance. This was a major concern when evaluating the effectiveness of the homework assignments. The authors will investigate the potential to use a web-based textbook publisher system to administer homework assignments. These systems may be used to efficiently monitor student time, scores, understanding, and difficulty of problems. It will also provide immediate feedback to the students. The student feedback also showed a desire for in-person learning. During the COVID-19 pandemic, students and teachers alike have adjusted to the “new normal” of higher education. The shift to more remote classes has been unpopular for most students, but educators continue to investigate more effective techniques for remote course delivery and students are developing more helpful strategies for completing remote classes. Future studies should continue to research the effects of frequent assignments and interactions with students on the performance of remote and hybrid course delivery.

A longitudinal study will be conducted to investigate the effect of the new version of the course on student performance in advanced engineering courses such as structural analysis and machine component design. MC300 is the first engineering course taken by civil and mechanical engineering majors. It is expected that instilling stronger fundamentals early will provide a stronger foundation on which to build greater future knowledge. The long-term positive impact of early incremental advantages results from a reinforcing feedback loop, like a snowball rolling downhill, as author Malcolm Gladwell notes in his chapter on “The Matthew Effect” [25]. Student performance on the FE exam will also be observed. Historical data shows engineering students from the institution conducting this study have performed below the national average in the statics and mechanics of materials sections. The retention of fundamental engineering concepts should improve success on the FE exam.

References

[1] H. Cooper, J. Robinson, and E. Patall, “Does homework improve academic achievement? A synthesis of research 1987-2003,” *Rev. Educ. Res.*, vol. 76, no. 1, pp. 1–62, 2006.

[2] N. Podoll, K. Tarhini, H. Jackson, U. States, C. Guard, and N. London, “Model activities For coordinating core engineering courses,” in *American Society of Engineering Education. Zone 1 Professional Paper Proceedings*, 2010, pp. 1–7.

[3] A. Chickering and Z. Gamson, “Seven principles for good practice in undergraduate education,” *Am. Assoc. High. Educ.*, no. AAHE Bulletin, pp. 3–7, 1987.

[4] P. C. Brown, H. L. Roediger, and M. A. McDaniel, “To Learn , Retrieve,” in *Make It Stick*, 2014.

[5] J. P. Hanus, M. D. Evans, and M. Orwat, “Daily fundamentals - Your daily dose of mechanics exercises,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2002, pp. 2201–2221, doi: 10.18260/1-2--10984.

[6] D. Koban, M. Fukuzawa, R. Slocum, M. Fletcher, and J. Pleuss, “Differential effects of incentivized homework on student achievement in undergraduate mathematics,” *Primus*, vol. 0, no. 0, pp. 1–19, 2019, doi: 10.1080/10511970.2018.1530703.

[7] R. Wieman and F. Arbaugh, “Making homework more meaningful,” *Math. Teach. Middle Sch.*, vol. 20, no. 3, pp. 160–165, 2014.

[8] J. R. Grohs, T. Kinoshita, B. J. Novoselich, and D. B. Knight, “Exploring learner engagement and achievement in large undergraduate engineering mechanics courses,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2015, doi:

10.18260/p.24066.
[9] E. T. Mullen, “Teaching an engaged analysis class through active learning,” *Primus*, vol. 22, no. 3, pp. 186–200, 2012, doi: 10.1080/10511970.2010.497957.
[10] A. J. Kalkstein, “Passing the test : Is self-grading a viable option at west point ?,” 2011.
[11] P. Linford, J. Bluman, G. Freisinger, J. Rogers, and B. Novoselich, “The self-evaluation and revision method for homework : a homework method for metacognition improves post-secondary engineering students ’ attitudes towards homework The self-evaluation and revision method for homework : a homework method for metacognition,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2020.
[12] M. G. Simkin, “Should you allow your students to grade their own homework?,” *J. Inf. Syst. Educ.*, vol. 26, no. 2, pp. 147–153, 2015.
[13] W. Y. Hwang, N. S. Chen, R. Shadiev, and J. S. Li, “Effects of reviewing annotations and homework solutions on math learning achievement,” *Br. J. Educ. Technol.*, vol. 42, no. 6, pp. 1016–1028, 2011, doi: 10.1111/j.1467-8535.2010.01126.x.
[14] S. Hedtrich and N. Graulich, “Using software tools to provide students in large classes with individualized formative feedback,” *J. Chem. Educ.*, vol. 95, no. 12, pp. 2263–2267, 2018, doi: 10.1021/acs.jchemed.8b00173.
[15] J. Lang, *Small Teaching: Everyday lessons from the science of learning*. San Francisco, CA: Jossey-Bass & Pfeiffer, 2016.
[16] M. Boelkins and T. Ratliff, “How we get our students to read the text before class,” *Math. Assoc. Am.*, pp. 1–6, 2017.
[17] C. J. Coulter and S. Smith, “The impact of preclass reading assignments on class performance,” *Curr. Pharm. Teach. Learn.*, vol. 4, no. 2, pp. 109–112, 2012, doi: 10.1016/j.cptl.2012.01.008.
[18] S. Lynch, S. Morse, and M. Steward, “Motivating class preparation with oral quizzes,” *Math. Mil.*, vol. 24, no. 1, 2019.
[19] N. F. McGinn and E. Schiefelbein, “Getting students to read before class: Innovation in a university in Chile,” *Prospects*, vol. 45, no. 4, pp. 447–464, 2015, doi: 10.1007/s11125-015-9369-7.
[20] H. M. Walker, “Classroom vignettes: Encouraging student preparation for class,” *ACM Inroads*, vol. 5, no. 1, pp. 24–25, 2014, doi: 10.1145/2568195.2568202.
[21] P. C. Brown, H. L. Roediger, and M. A. McDaniel, “Mix Up Your Practice,” in *Make It Stick*, 2014.
[22] B. Morra, “The chemistry connections challenge: Encouraging students to connect course concepts with real-world applications,” *J. Chem. Educ.*, vol. 95, no. 12, pp. 2212–2215, 2018, doi: 10.1021/acs.jchemed.8b00137.
[23] C. Ryan and N. Hemmes, “Effects of the contingency for homework submission on homework submission and quiz performance in a college course,” *J. Appl. Behav. Anal.*, vol. 38, no. 1, pp. 79–88, 2005.
[24] J. Bruhl, E. Bristow, and J. Klosky, “Assessing the impact of new teaching methods by predicting student performance,” in *American Society of Engineering Education (ASEE) Zone 1 Conference*, 2008, no. 2000, pp. 326–330.
[25] M. Gladwell, *Outliers: The Story of Success*. Little Brown and Company, 2008.

Appendix: *Example Homework Assignment*

UNITED STATES MILITARY ACADEMY
MC300: FUNDAMENTALS OF ENGINEERING MECHANICS AND DESIGN
HOMEWORK 12

INSTRUCTOR: ______________________________

CADET ____ SECTION ___

DATE: ____________________________

Presentation of Problem Solution Standards	YES	NO
Problem solutions are organized logically, and explanations of the problem-solving process (i.e. "footprints") are provided as appropriate.		
Handwriting is legible and appropriately spaced (not crammed).		
A *Statement of the Solution* is highlighted for each problem.		
All final answers reported to three (3) significant figures with MUD-P.		
A straightedge is used for all drawings, diagrams, and double underlining answers. In simplest form: Straight line = Straight edge.		

Homework Grade

Problem	Points Earned	Points Possible
LSN 18 Reading Reflection		10
Axial Member Design Problem		10
TOTAL POINTS EARNED		**/ 20**

I spent a total of __________ minutes since the last class period completing MC300 related work including class preparation, problem sets, and studying. (Do not include time watching lesson videos.)

_______ My documentation identifies all sources used and assistance received in completing both the written and online portions of this assignment.

_______ No sources were used or assistance received in completing the written or online portions of this assignment.

Signature:____

This is an individual assignment worth 20 points and due at 1600 the day of your LSN 18. Complete these problems in the space provided. Use the Cover Page provided with this handout and document IAW the current DAW. Presentation counts – you will be deducted up to 10% for failure to meet the problem submission standards as listed on the Cover Page.

1.

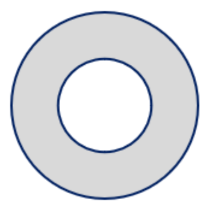
a. (5 points) **Describe** how shear stress (τ) and normal stress (σ) are similar. **Explain** how they are different.

b. (5 points) **Describe** what a failure plane is in a connection and how to identify them.

2. The Piper PA-18 *Super Cub* is a popular vintage "taildragger" aircraft. The wings are partially supported by 3-m long hollow lift struts made of 6061-T6 aluminum. Each strut is tested to a maximum force of 70,000 pounds. The struts are fixed to the fuselage and are joined to the wings by pins.

(image retrieved from https://www.airplane-pictures.net/photo/319469/g-aypm-private-piper-pa-18-super-cub/)

strut cross-section



a. (5 points) **Determine** the minimum area required using a factor of safety with respect to yielding of 1.8. (ANS: 3.15 in^2)

b. (5 points) **Determine** the maximum axial compressive load that may be supported by a single strut if a factor of safety of 2.5 with respect to buckling is specified. (ANS: 28.4 kN)