Student performance, engagement, and satisfaction in a flipped Statics and Mechanics of Materials classroom: A Case Study

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Abstract

This paper presents a case study of the evidence-based practice of flipping a classroom. The flipped (or inverted) classroom has long been promoted as a method of improving student engagement in the classroom as it creates opportunities for active learning experiences during lecture time that would otherwise be consumed by passive instruction. A flipped classroom relies on students to independently prepare for class prior to the scheduled lecture time, typically by watching pre-lecture videos or by reading material assigned by the instructor. Having been exposed to the lecture material, synchronous class time can be used to complete active learning exercises in small groups with direct oversight and immediate feedback offered by the instructor.

At Johns Hopkins University, Statics & Mechanics of Materials has been taught using a traditional lecture-style instructional mode to civil, environmental, and mechanical engineering majors for many years. Aware of the documented benefits of the flipped classroom model, in 2019 the author created a library of pre-lecture videos and accompanying in-class learning exercises to experiment with this instructional mode. In 2020, when universities shifted to virtual instruction as a result of the COVID-19 global pandemic, the author used these same materials to create an online version of the flipped classroom. Thus, over a three-year period, a single author teaching the same class with the same content and assessment methods collected data to evaluate the impacts of three different instructional modes on student performance, engagement, and satisfaction. In total, data from course evaluations, class attendance, and performance on final exams was collected from 213 students who took the course from 2018 to 2020. Consistent with the findings of previous studies, the data presented in this paper demonstrates that the flipped classroom results in greater student engagement and a higher level of student satisfaction with both the course and the instructor. The impact on student performance, however, is inconclusive, primarily due to the quasi-experimental nature of the study. Beyond presenting the results of the study, this paper will also describe the implementation of specific elements of the flipped and online flipped classrooms.

Keywords: flipped classroom; active learning; Statics; Mechanics of Materials

Introduction

Whether or not you have experience flipping a class, it’s likely that you are at least familiar with the concept. It goes like this: Instead of passively listening to their instructor and taking notes from a chalkboard in a lecture hall, and then doing homework assignments on their own using the material they took notes on in class, students in a flipped (or inverted) class watch pre-recorded video lectures before attending class, and during class they use the material they already learned about in the video lectures to complete active-learning exercises with their
classmates under the guidance of their instructor. According to Strelan and Osborn [1] “what distinguishes a flipped classroom from traditional teaching is not so much that information is pre-recorded, or that students engage with fundamental information using technology outside the lecture theatre but, rather, that students have an opportunity to engage in active learning and problem-solving with hands-on guidance provided by an expert.” While there is a large body of research providing evidence that active learning strategies in flipped classrooms produce at least modest improvements in student performance [2] [3], student engagement [4] [5], and satisfaction [6] [7], there is now a need to refine our understanding of best practices when it comes to implementing these techniques in specific learning communities [2, 8].

This paper represents the culmination of a three-year exploration of three different teaching modes for a large sophomore-level Statics and Mechanics of Materials course. The first year of the study (2018) was both the author’s fifth year teaching the course, and her last year teaching it using a traditional lecture-style instructional mode. In 2019, aware of the documented benefits of the flipped classroom model, the author restructured the course to implement a flipped instructional mode, creating a library of pre-lecture videos and accompanying in-class learning exercises in hopes of increasing student engagement and creating more opportunities to interact with the students. In fall 2020, like many other instructors, the author found herself moving classes online as a result of COVID-19 [9] [10] [11], though unlike her other classes that existed only on paper in three-ring binders, the existing pre-lecture videos and course structure for Statics and Mechanics of Materials allowed the author to adapt it to online learning with relative ease.

Thus, over a three-year period, a single author teaching the same class with the same content and assessment methods collected data to evaluate the impacts of three different instructional modes on student performance, engagement, and satisfaction. In total, data from course evaluations, class attendance, and performance on final exams was collected from 213 students who took the course from 2018 to 2020. This paper will not only discuss the results of the data, it will also detail the implementation of the flipped classroom model in a large, sophomore-level engineering course, and it will discuss how the materials and structure used in the course were adapted to online learning and an online flipped classroom as a result of COVID-19.

**Instructional Modes**

Statics & Mechanics of Materials is taught to sophomores in the Departments of Civil & Systems Engineering, Environmental Health and Engineering, and Mechanical Engineering at Johns Hopkins University. The author of this paper has been teaching the course since 2014 and was the sole instructor during the three years data was collected for this paper: 2018 (N=71 students), 2019 (N=82 students), and 2020 (N=60 students). During those three years, the instructional mode evolved from traditional (2018) to flipped (2019) to online flipped (2020) as a result of the COVID-19 pandemic. Aside from the instructional mode, the course remained relatively unchanged over those three years, including the lecture topics, homework format, assessment (two midterms and one final exam), and the use of iClickers to take attendance and
engage students during lecture. Table 1 presents the grading breakdown of these items recorded in the syllabi for each year in this case study. Descriptions of the three instructional modes follow.

Table 1. Grading breakdown for Statics & Mechanics of Materials in 2018-2020

<table>
<thead>
<tr>
<th>Graded Component</th>
<th>2018 (traditional)</th>
<th>2019 (flipped)</th>
<th>2020 (online flipped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>26.7%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Midterms</td>
<td>2@20%</td>
<td>2@20%</td>
<td>2@15%</td>
</tr>
<tr>
<td>Final</td>
<td>26.7%</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td>Preparation</td>
<td>0%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Participation</td>
<td>6.67%</td>
<td>5%</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Traditional Instructional Mode (2018)**

The instructional mode used in 2018 was traditional in the sense that it consisted of two 75-minute lectures each week, weekly homework assignments (completed outside of the lecture), two midterm exams, and one final exam. Lectures consisted of a mix of theory and example problems presented on a chalkboard, with 3-4 real-time polling questions peppered throughout each lecture using iClickers. The iClicker questions were introduced to the course in 2015 to improve student attendance and engagement, as well as to gauge students’ understanding of a particular topic [12] [13]. Student responses to clicker questions were not graded, but they had to answer all but one question each day to receive full participation credit (see Table 1).

Examining Table 1, an important detail to note is that in 2018, Statics & Mechanics of Materials was a 4-credit class, made up of a 3-credit lecture component and a 1-credit laboratory component. In 2019 and 2020, the lecture and laboratory components were separated. Since the original grading breakdown included a 25% lab grade and this paper is only examining the lecture component of the course, the grading breakdown in Table 1 has been adjusted for 2018 so that the lecture components of the class add up to 100% of the grade rather than 75% of the grade. For example, in 2018 the midterms were each counted as 15% of the final grade when the laboratory grade of 25% was considered, but without the 25% laboratory grade, the midterms would be worth 15% \( \cdot \frac{100\%}{100\% - 75\%} = 20\% \)

**Flipped Instructional Mode (2019)**

In 2019, the instructional mode was flipped, so that students watched pre-recorded video lectures prior to class, and spent a majority of class time working in small groups of 2 – 3 students to complete active-learning exercises with the help of the instructor and several teaching assistants. The video lectures were animated, voiced-over PowerPoint slides created specifically for the class by the instructor and based on the chalkboard lectures given from 2014 – 2018, but “chunked” into two to three 20-minute lectures that were easier for students to digest.

To ensure that students watched and retained some of the information from the video lectures, they were required to submit short electronic journal entries through the Learning Management
System (LMS) before each class. This form of reflection is called “write to learn” and can help students improve their ability to retrieve information, make connections between new and old material, and explain concepts in their own words. [14] These journal entries were used to assign the “preparation grade” (see Table 1), and the questions asked by students in their journal entries formed the basis of a short (10 – 15 minute) review of the lecture material at the beginning of each class.

Similar to what was done in the traditional classroom (2018), real-time polling continued with 3 – 4 iClicker questions each day, except that all iClicker questions were asked at the beginning of the lecture during the review of material and a small penalty was imposed for answering a question incorrectly, again to encourage students to arrive prepared. Students were allowed to work in their pre-assigned small groups to answer the questions.

To make up for the time students had to spend outside of class watching video lectures and writing journal entries, and because the in-class exercises offered an additional problem-solving opportunity, the number of homework problems was reduced from five to four each week, but otherwise the types of homework problems remained similar to those assigned in 2018. Prior to 2019, any work done outside of class was considered “homework” so with the addition of a class preparation grade, and the reduction in the number of homework problems, the grading breakdown was modified as shown in Table 1.

The act of flipping the class allowed the instructor to incorporate regular active learning exercises that students completed in small groups during synchronous lecture time. The exercises were created by the instructor and generally consisted of a problem similar to a homework problem but broken down into smaller steps to guide students towards a solution, while asking questions to get them thinking critically about the process. Examples of in-class exercises are provided in Figure A4 and Figure A5 in the Appendix. While students worked through the problems as a group, the instructor and the TAs moved around the room asking the students questions to make sure they were not skipping steps, and answering questions posed by students. The time spent on the active-learning exercises was approximately 45 minutes.

Generally, the last 10 minutes of class were spent reviewing the in-class exercise, sometimes showing a solution on the board, sometimes addressing common misconceptions observed during class. Typically there was not enough time to solve the full problem for the students, so the completed worksheet was posted to the LMS after class to provide students with the “solution”.

**Online Flipped Instructional Mode (2020)**

In Fall 2020, with the university continuing to operate in a fully virtual environment due to COVID-19, the flipped classroom of 2019 was modified to an online flipped classroom. Changes to the grading breakdown (Table 1) created a more uniform distribution across graded components, reducing the weight of the two midterms and the final exam, while increasing the weight of the homework, journal entries, and iClicker questions. This approach was encouraged by Johns Hopkins’ Center for Educational Resources as it was thought to reduce student stress and curb academic ethics violations in the online environment.
The structure of the class remained largely unchanged from 2019 to 2020, with the exception of the small groups, which met in private breakout rooms during online synchronous lecture time instead of inside the classroom. And rather than handing out paper copies of in-class exercises, these were posted to the LMS before class so students could download them in preparation for their small group meetings or print them if they had access to a printer. The instructor and her TAs moved through breakout rooms asking and answering questions just as they had in 2019.

Results and Discussion

Using data collected from 2018 to 2020, the impacts of instructional mode on student satisfaction, engagement, and performance were evaluated using end-of-term course evaluations, attendance records, and final exam questions, respectively.

Student Satisfaction

Student responses to end-of-term course evaluations – consisting of both numerical ratings and responses to open-ended questions – were used to assess the impact of each instruction modality on student satisfaction.

Figure 1 summarizes the numerical ratings data from the course evaluations collected between 2018 and 2020 wherein students were asked to rate the overall course quality, the instructor’s teaching effectiveness, the course’s intellectual challenge, feedback provided, and workload. In the first four categories, students rated the flipped (2019) and online flipped (2020) modalities higher than the traditional mode (2018). Surprisingly, students rated the online flipped modality (2020) even higher than the flipped modality (2019) in the first three areas: overall quality of the course, teaching effectiveness, and intellectual challenge.

Also surprising is that the last question regarding workload shows that students considered the level of work required to be lower in both the flipped and the online flipped modes than in the traditional mode, despite the additional time needed outside of class to watch video lectures and write journal entries. A score of “3” indicates that the workload was comparable to other classes the student took at Johns Hopkins; a score higher than 3 indicates that the workload was higher and a score lower than 3 indicates that the workload was lower. A possible explanation for students’ responses to this question is that as previously noted, the 2018 course included a laboratory portion which required lengthy laboratory reports, while in 2019 and 2020 the laboratory portion was separated from the lecture course. Thus the 2018 data used to evaluate satisfaction includes students’ feelings about the laboratory portion of the course which may skew the data as lab reports are time intensive. Still, the 2019 and 2020 workload was judged by the students to be reasonably similar to that of other courses at the university.

Another fact to be aware of is that in 2020, the university allowed students to see their course grades prior to completing course evaluations. Withholding course grades until evaluations are submitted, at least for a short amount of time, encourages students to fill out their course evaluations, so while in 2018 and 2019 the response rate was 97.18% and 97.56%, respectively, in 2020 the response rate was only 82.26%.
While the numerical data resulting from the course evaluations presents the clearest and most unbiased quantitative evidence of students’ perceptions of the different instructional modes, students’ responses to open-ended questions were analyzed with the objective of making more nuanced observations. For each of the three years under consideration, student responses to two open-ended course evaluation questions were reviewed:

- What were the best aspects of this course?
- What were the worst aspects of this course?

Reviewing each student comment from 2018 – 2020, the four most frequently-cited “best aspects” were: lectures / video lectures, homework / in-class exercises, class organization / structure, and instructor. The four most frequently cited “worst aspects” were: lectures / video lectures, homework / in-class exercises, class organization / structure, and workload. Each comment was carefully reviewed and mapped to one or more of these best or worst aspects, and the total number of times each of these aspects was identified was tallied. Table 2 and Table 3 summarize the number of times those aspects were mentioned in the course evaluations and provide samples of student responses that were mapped to each aspect.

![Figure 1. Course evaluation data from 2018 – 2020 for EN.560.201 Statics and Mechanics of Materials](image)

While the course was never designed to be offered online, it’s worth remarking on some of the observations made in 2020. Regarding student satisfaction which was high that semester (Figure 1), this was likely in large part because the course was so much more organized than the majority of the students’ other courses, which had very little time to prepare and organize their content for virtual delivery. By its nature, the flipped classroom is highly structured, and that structure was
Table 2. Sample student responses to the question “What are the best aspects of this course?”

<table>
<thead>
<tr>
<th>Best Aspects</th>
<th>Number of Student Responses</th>
<th>Student Response Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture / Video Lectures</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Homework / In-Class Ex</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Organization / Structure</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Instructor</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>
Table 3. Sample student responses to the question “What are the worst aspects of this course?”

<table>
<thead>
<tr>
<th>Worst Aspects</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>Number of Student Responses</th>
<th>Student Response Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture / Video Lectures</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>8 10 1</td>
<td>The worst part about this class is the variation of pre-class video lengths. I'm fine with watching a 30 min video lecture twice a week, but it's hard when the time commitment isn't predictable and what I'd expect to be a 20 min lecture ends up being 50 min long. Prelectures were sometimes deriving a lot of equations that seemed very difficult and sometimes not necessary. Lectures can be dry and repetitive. Prelectures were sometimes deriving a lot of equations that seemed very difficult and sometimes not necessary.</td>
</tr>
<tr>
<td>Homework / In-Class Ex</td>
<td>7</td>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I didn't like the style of the class at all. I thought [sic] the video lectures and in class clicker questions were helpful, but I didn't like the style of the in class exercises. one of my partners didn't show up and my other partner and I didn't know how to solve the problem, so we just sat in class waiting for TA's to be able to help wasting a lot of in class time. I would have preferred the professor just doing examples with the whole class so that more examples were covered since there weren't that many given for homework. Homework is sometimes long and difficult, though not unreasonable and there are lots of opportunities to get help on it. The active learning exercises completely missed the mark for me. I barely talk with my group and sometimes we don't even do the problems because everyone in my group woke up at 6:30 for this class so they just fall asleep sometimes.</td>
</tr>
<tr>
<td>Organization / Structure</td>
<td>0</td>
<td>21</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Because of the flipped classroom, I had to struggle more than the average class where I learned as the professor taught so questions could be immediately asked. This definitely does not mean that the flipped classroom is invalid though, I just need to attend more office hours and my questions just need to wait for a few days before they get answered in class or during office hours. This class is really meant to be taught in person in an active learning environment. The reverse classroom style learning would have been much more effective in person because breakout rooms made it difficult to get help.</td>
</tr>
<tr>
<td>Workload</td>
<td>11</td>
<td>6</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The reverse-classroom approach did not work well for me. I found it challenging to learn outside of the classroom at the desired pace and still complete the problem sets. Oftentimes learning the material would take several hours and the homework would also take several hours, resulting in an extremely heavy workload. Although the flipped-classroom helped reinforce information, it definitely increased the workload of the course as well. I found it harder to spend as much time with the pre-lectures as I would have liked in the busier periods of the semester. I felt as I was only really skimming through the textbook and watching the videos once before moving on, whether I truly understood the material or not. Consequentially, I relied on the problem sets to better understand the material. But, this could just be a personal experience since I took a somewhat heavier course load this semester. The homeworks take a very long time to complete and so do the exams.</td>
</tr>
</tbody>
</table>
in place in the LMS months before COVID-19 reached the United States. While the quantitative
data suggested high student satisfaction, the open responses identified a weakness of the course in
the fully online delivery: the in-class exercises. Students in small groups did not all have
access to the technology that would have made working collaboratively possible. On the first
day of class in their breakout rooms, students were asked to brainstorm how they might solve a
problem collaboratively with the technology they had available to them. While many ideas were
generated, by the end of the semester the instructor observed that most groups gravitated towards
one of following:

1. One person shared their screen and wrote the solutions on the screen with a tablet while
   the others annotated the shared document using Zoom’s annotation feature.
2. Students worked on their own papers and discussed the work with their partners at certain
   points in the exercise.
3. Students turned off their cameras and did not work together, or they simply left the Zoom
   meeting after answering the iClicker questions, never joining their breakout room.

**Student Engagement**

Attendance records were collected and analyzed using iClicker data. While the weight of
attendance in the overall grade calculation changed over the three-year period as the weighting of
class participation changed (see Table 1), the importance of class attendance was communicated
to students on the first day during each of the study years and quantified in the grading
breakdown posted in the syllabus.

Quizzes were also administered using iClickers, but student performance on those quizzes is not
considered in this paper due to inconsistencies in how those quizzes were administered over the
course of the three years in the study. For example, in 2018 and 2019 students were allowed to
consult with their neighbors or group members when answering iClicker questions. In 2020,
while there may have been some consultation through private texting, it is believed that the
students answered iClicker questions independently as they were isolated in their dorm rooms or
at home.

Weekly attendance (by percentage of students enrolled in the course) for the three years of the
study is shown in Figure 2. The data demonstrates higher attendance was consistently achieved in
2019 (flipped) than in 2018 (traditional). While attendance decreased again in 2020 from
what it had been in 2019, during most weeks, online class attendance was still higher in 2020
than it was in 2018 when the class was taught in the traditional lecture mode. Performing a
linear regression on each of the data sets is even more telling, as the results in Table 4
demonstrate. While the change in the number of students attending class each week was
approximately -1 in 2018, the change in the number of students attending class each week in
2019 and 2020 (flipped and online flipped modes, respectively) was approximately -0.5. Thus,
by the end of the 13-week semester in 2018, there were approximately 13 fewer students
attending class, at the end of the semesters in 2019 and 2020, there were only approximately 6
fewer students attending class.
Student engagement appeared relatively high (Figure 2) in 2020, but two facts may skew that data:

1. Students were not in one location, so they accessed the iClicker app on their phones, instead of using a remote and a classroom receiver as was done in 2019. This allowed students to log in to the iClicker app, answer the questions, and log off without ever joining the Zoom room.

2. Students sometimes attended class via Zoom for the first 20 minutes to hear the lecture and get credit for answering the iClicker questions, but then left the Zoom room without moving into breakout rooms with their partners.
Student Performance

The final exam in Statics and Mechanics of Materials was used to assess students on several of the course learning objectives (CLOs), including each student’s ability to:

- draw Free Body Diagrams (FBDs), substituting appropriate reaction forces for physical constraints
- apply the equations of equilibrium to determine unknown reaction forces in a statically determinate system
- calculate the internal forces (axial and shear) and bending moments in an axial force member, a member in pure torsion, or a beam in bending
- calculate the elastic stresses and strains that develop within an axial force member, a member in pure torsion, or a beam in bending when that member is subject to a system of external forces

The final exams administered in 2018, 2019, and 2020 each included a statically determinate truss problem and a statically determinate frame problem that required students to demonstrate their ability to meet the CLOs above. To assess students’ performance, four parts of the final exam corresponding to the four CLOs were assessed on a scale of 1 – 4, where “1” represented student work at the novice level and “4” represented student work at the mastery level. The results of that assessment are shown in Figure 3.

While the exam questions used across the three years were similar to the description above, they were not identical, and in some cases the questions were more difficult than others. Thus, this evaluation of the CLOs required a great deal of care to attempt to use problems of a similar nature and degree of difficulty for comparison. When there were not problems of a similar nature, the CLOs were evaluated using parts of different problems, e.g. drawing the FBD and calculating the reaction forces in a frame, while analyzing a truss and determining the internal axial stresses in one of its members.

While three out of four CLOs demonstrate an increase in performance from 2018 to 2019, knowing just how different the problems were makes the author unwilling to assert that there was a clear improvement in student performance. For example, while students’ abilities to draw free body diagrams appeared to improve from 2018 to 2019, and again from 2019 to 2020, in the author’s view that improvement may have been a function of the decreasing complexity of problems over the course of those three years. And while it is not surprising that students’ abilities to calculate internal forces in a truss dipped from 2019 to 2020 when the flipped class had to be taught online, the increase in their ability to calculate stress and strain in 2019 may simply be due to the fact that of the three years studied, 2019 was the only one that asked for normal stress in a tension member, while in 2018 and 2019 students were asked to calculate normal stress in a compression member. One of the primary reasons for taking points off in those two years was for failing to indicate that the stress was negative or compressive. Had the answer been a negative normal stress in 2019, the author feels it is possible that the trends could have looked much different.
Figure 3. Student performance on final exam questions in EN.560.201 Statics and Mechanics of Materials used to assess four course learning objectives: (1) draw Free Body Diagrams (FBDs), substituting appropriate reaction forces for physical constraints; (2) apply the equations of equilibrium to determine unknown external (typically reaction) forces in a statically determinate system; (3) calculate the internal forces (axial and shear) and bending moments in an axial force member, a member in pure torsion, or a beam in bending; and (4) calculate the elastic stresses and strains that develop within an axial force member, a member in pure torsion, or a beam in bending when that member is subject to a system of external forces related to truss analysis and stress calculations within straight, two-force members.

Conclusions

The most encouraging finding to result from flipping the Statics and Mechanics of Materials classroom using the techniques described herein was the increased level of engagement among the students (see Figure 2). The reason for the higher attendance is unknown; students may have felt that the in-class exercises (2019, 2020) were more useful to them than sitting through a traditional lecture (2018), or they may have felt some sense of accountability to the other members in their small groups. Quantitative data from course evaluations also suggest that students were more satisfied with the flipped class (2019, 2020) than with the traditional lecture (2018), though open responses demonstrated that a significant cohort of students were not satisfied with the flipped classroom organization (see Figure 1 and Table 3).

If the flipped modality gets students into the classroom and keeps them there through the whole semester, and their level of satisfaction is at least as high as it was in the traditional lecture mode, why do we not see indisputable improvements in student performance? It may be that there is room for improvement in the active-learning exercises, either by experimenting with more
engaging activities or by making small modifications to address the errors observed in the final exams. However, the author feels that the data is simply inconclusive as a result of the quasi-experimental method used here – where students were not randomly assigned to learn via alternative instructional modes and whose performance was not evaluated using identical assessment tools (i.e. final exam questions), but rather different groups of students were evaluated using different assessment tools in subsequent years as the instructional mode evolved. This method ultimately led to too much uncertainty in the data.

In conclusion, the author suggests that flipping a large, sophomore-level engineering class to create more opportunities during synchronous face-to-face lecture time for active-learning in small groups holds promise in terms of student engagement and satisfaction, but to truly understand the impact on student performance, a more intentional and experimental study needs to be undertaken. And while the online flipped class was a good solution in a pinch, engaging undergraduate students in a fully online environment without sufficient technology to work collaboratively is not recommended.

**Acknowledgements**

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**References**


Appendix

Figure A4. Example of an in-class learning exercise from the truss analysis module

Figure A5. Example of an in-class learning exercise from the flexural stresses module