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Evaluating the Effectiveness of a Statics Recitation Course

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Evaluating the Effectiveness of a Statics Recitation Course (Work In Progress)

Abstract:

This work in progress paper describes the development and implementation of a Statics Recitation Course designed to improve both the passing rate in a fundamental class and student retention in the engineering program. The recitation's effectiveness will be measured by comparing the passing rate of Statics students who participated with those who did not participate in the recitation. This will be achieved by collecting data through a baseline period when the course is not yet offered (fall 2020) and implementation period (spring 2021) when the recitation is first offered. Learning data such as midterm grades and short surveys were analyzed to evaluate trends in student progress throughout the traditional Statics course. Paired t-tests showed no statistical difference between midterm and final grades, and the correlation coefficients suggested a correlation between student performance on the midterm and overall course grade. If this trend persists as data collection continues over the coming semesters, it will be used as a tool to predict student success in the course and invite at-risk students to participate in the recitation course. Data from recitation students will be analyzed to evaluate the impact on student success in the Statics course and identify areas of improvement. This paper discusses the motivation for intervening with Statics, the data collection procedure, and the recitation course pedagogy.

Intro:

Statics is an introductory engineering course where sophomore-level students first synthesize the technical skills gained in math and physics courses. As such, it can be a challenging introduction to engineering concepts and routinely has a high attrition rate. Most engineering majors in the Penn State system require a Statics grade of C or better before graduation. As a result, poor grades require students to repeat the course and failing Statics has a large impact on retention of engineering students. The Mechanical Engineering (ME) Department at Penn State Behrend has identified the Statics course as one of the major factors for delayed graduation in that major. As a prerequisite for other required courses, a setback in that class can severely limit the amount of schedulable engineering courses. A student must be able to pass Statics by the end of their fourth semester in order to graduate from the ME program within four years.

In addition to retention issues caused by current students, the Behrend School of Engineering has seen a drop in enrollment over the past few years. Although some may be attributed to more students opting to complete their degree at the University Park campus, the overall forecast for Pennsylvania is a steep enrollment decline through 2026 due to declining birthrates [1]. In 2019 Hoover [1] reported that there was a 20% enrollment drop since 2010 at state-owned universities in PA and forecasts another 15% drop to come. With a declining number of high school graduates entering the system, the School of Engineering has made student retention a priority.

Justification for Recitation

In order to effectively engage engineering students, improve passing rates, and increase retention in their programs, universities have looked to innovative teaching pedagogies. Active learning [2], increased class time [3], recitation [4], project-based learning [5], and peer tutoring [6] are just a few of the methods chosen to enhance traditional lecture-based courses. However, studies for some of these methods point to mixed results when integrated into the main Statics course [3], [5]. Some show that the results are statistically insignificant when compared to previous lecture-based approaches, and that any improvement can be attributed to factors such as student attendance, participation, and course satisfaction [5], [7], [8].

Additionally, active learning and other innovative pedagogies have barriers which prevent instructors from embracing instructional change. Bonwell and Eison [9] list issues such as maintaining faculty-student interaction in large classrooms, increased pre-class preparation, and a difficulty in covering all required course content within limited class time as a few of these major obstacles preventing active-learning from achieving widespread use. Faculty egos and limited incentives to change also discourage new practices, especially when the course is shared among multiple instructors. For these reasons, an optional recitation course offered outside of the traditional class structure would be the best choice for ease of implementation that does not affect other professors and their unique teaching styles. A single instructor could create a supplemental course with innovative teaching methods that does not force other faculty members to practice new methods, spend more time prepping, or revising course outcomes. Recitation is also easily testable to determine efficacy without potentially harming students who learn best through traditional methods. A recent study by Gannon University has shown that although a similar supplemental instruction program gave ambiguous results for grade improvement, it did prove that the additional help was not harmful to students [6]. Thus, a recitation course provides a low-risk method to increase student performance without negatively affecting the other faculty or students.

The Statics course is often taught over multiple sections divided between instructors; a recitation could also provide additional continuity between sections. This is especially true in semesters where students may have hybrid or completely online classes. The recitation allows students another point of view on class material, especially if they have trouble learning from their specific instructor's teaching method. Recitation can provide an opportunity for a single instructor to unify course goals across the sections and bring students together to collaborate with peers outside of their normal class. Students may feel more inclined to participate when surrounded by peers who struggle with the same topics. Results from a North Carolina A&T State University study found "a strong direct relation between grades and recitation attendance." It went on to praise recitation's effectiveness at encouraging feedback loops between students and instructors, allowing faculty to tailor lecture material to student needs which resulted in a deeper understanding of the material [4].

Online supplemental instructional material can also be a no-risk, high-reward tool for improving student performance when integrated with the recitation course. Open Educational Resource (OER) learning modules provide instruction and video tutorials which can provide a flexible

learning environment. Online course material allows students to learn at their own pace and review specific topics when stuck. Douglas [10] found that online students spent more time with course material than face-to-face or hybrid learning modes. Higher student interaction generally correlated to higher grades. Therefore, online OER tutorials will be combined with a recitation course to increase the likelihood of student success in Statics.

Course Background:

Statics is taught as a lecture-based, intro-level engineering course with 50-minute classes held three times a week. Although teaching styles can differ slightly based on the instructor, most class sessions consist of a short, note-taking introduction to the engineering concept and then solving example problems together as a class. Class size is limited to 30 or less students per section and typically six sections are taught in the fall with three additional sections in the spring.

Due to the number of sections offered per year, multiple faculty teach the course. This can lead to students perceiving a difference in learning between sections as the instructors vary in experience, teaching style, and confidence in their teaching ability. To ensure consistency across all sections and minimize the perceived differences, common grading criteria as shown below in Table 1 are used. Assignment weights are the same in each class for the exams, but each instructor has the freedom to change the weighting on the in-class work or homework to best match their teaching pedagogy. For example, some instructors may prefer a flipped classroom with daily knowledge quizzes instead of traditional lecture-based class with homework assignments. Common exams are taken throughout the semester and grading is shared between the instructors to provide consistent grading.

Table 1: Common grading criteria

In-Class Work	5%
Online Homework	10%
Midterm Exams	4×15% = 60%
Final Exam (comprehensive)	25%
Total	100%

Baseline Semester:

In order to explore the efficacy of the recitation course, the plan is to examine the passing rate of students with similar exam scores both with and without the course. In the fall of 2020, the recitation course was not offered to students and thus will serve as a baseline for student grade comparison. Within the first 3 weeks of class an invitation was sent to all students throughout the 6 sections of Statics asking for participation in the upcoming study. If they consented, they were asked to complete a short survey and their learning data was used for the study. At the end of the semester, gradebooks were compiled and anonymized so that no personally identifiable student information remained. The data from the grades and survey were analyzed for trends in passing rate based on midterm 1 scores.

Student Performance

In the baseline semester of Fall 2020, 45 out of the 139 total Statics students consented to data being collected. Of those, 41 students completed the course and have data for midterm grades while 4 students dropped Statics. Statistical tests were performed comparing students' exam 1 grade and their final grade in the course. The results of a two-sample paired t-test can be seen below in Table 2. Data shows that the mean score between the first midterm and final grade is not statistically different.

Table 2: Paired t-test two sample for means

	Midterm 1 Grade	*Final Course Grade*
Mean	81.5	80.6
Variance	230.0	138.8
Pearson Correlation	0.7	
P(T<=t) two-tail	0.6	

The correlation coefficient between the exam score and final grade is 0.7. With a value of 1 showing a strong positive relationship and a value of zero implying no relationship, the correlation between midterm exam score and final course grade is minor but not significant. A visual representation of this trend is shown in Figure 1.

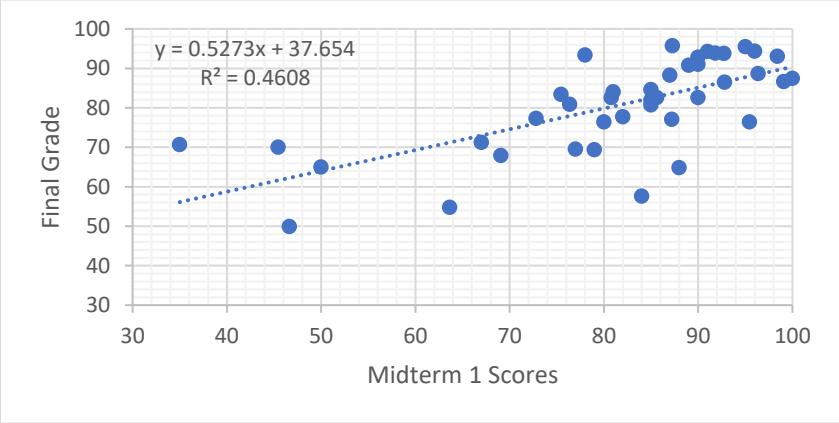

Figure 1: Comparison of midterm 1 scores with final course grade

Of the 41 participants with grades, the passing rate was 80.5% for the course. The data for these students is shown below in Figure 2. By including the four students who withdrew, the passing rate drops to 73.3%. This is similar to the overall course pass rate and highlights the importance of improving student performance.

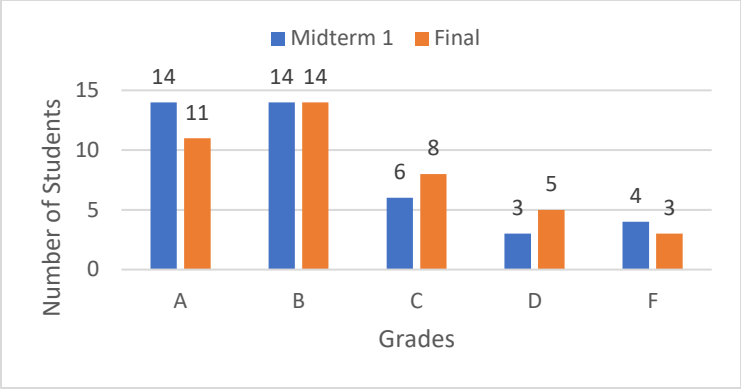

Figure 2: Grade distribution

As data from the recitation course is gathered, it will be compared to the baseline. Students with similar midterm 1 exam scores will be compared to measure the correlation between passing rates of those with and without the recitation course.

Student Survey

A survey was developed to assess student attitudes towards their personal course progress. The first portion was given in the week preceding the first midterm. Students who consented to participation in the study received a short survey which asked them to rate their ability to understand and complete Statics problems. The Likert Scale was used for the prompts shown in Table 3. Student responses were converted to a numerical value by assigning 1 for Unsatisfactory to 5 for Excellent. In addition, they were asked to rate their level of confidence in understanding what a question is asking on homework and exam problems on a scale of 0-100. The self-evaluation responses showed that on average, students were 73.4% confident in their understanding, with a standard deviation of 18.5%.

Table 3: Likert-scale survey prompts (1 indicates unsatisfactory and 5 indicated excellent)

	Statement	Avg. Score
1	Your ability to understand the problem statement and decide what information is important and which information is irrelevant (i.e. “fill”)	3.7
2	Your ability to understand the type of problem (i.e. dot product problem vs vector addition vs 3D equilibrium)	3.5
3	Your ability to remember the equations that are associated with each type of problem	3.5
4	Your ability to correctly draw the associated FBD	4.0
5	Your ability to work through the math correctly (writing equilibrium equations, solving system of linear equations, performing trigonometry)	3.7

This data will serve as a baseline for comparison to future courses. A follow-up survey offered at the end of the semester will track student progress in the recitation course and ask for qualitative feedback to gauge student perception of the intervention and suggest changes. It could also be used to explore the potential correlation between grades and students’ perceived confidence in

their abilities. If a correlation exists, it could be another tool to help identify students who are at-risk of failing the course and allow instructors to recommend intervention.

Discussion:

For future semesters, a better action plan will be implemented to ensure all instructors are aware of the importance of collecting grades directly after the first midterm is complete to prevent the data loss that occurs when students drop out. The fall 2020 semester was unique with COVID precautions forcing instructors to vary their teaching modes and course schedules. These extra changes led to some confusion in data collection and the loss of student grades of late drops. Without the midterm scores of the four students who dropped the course, the data may be biased towards the students who were able to bring up their scores near the end of the semester.

There were no statistically significant patterns found between student confidence and student success using the 45 student participants and a confidence level of 95%. With no statistical difference between midterm and final grades, the data may suggest a weak correlation between midterm scores and final grades as shown with the correlation coefficient of 0.7. Additional data collection will need to confirm a high correlation before midterm 1 may be ruled a good indicator for student performance. That indicator could then be used as a tool to help instructors target students who are at risk of failing the course.

If additional data only displays a weak correlation between midterm score and final grade, more tracking data may also be implemented to predict student performance and recommend corrective action in the recitation course. A similar study found that college GPA, Calculus, and Chemistry grades were found to be most significant predictors for student placement into at-risk courses [11]. Those may be tracked in addition to expanding the amount of graded material in Statics that is analyzed.

Recitation Design:

Pedagogy:

John Burkhardt published a study in 2015 which showed that an extra hour of weekly lecture, delivering the same material at the same pace, provided little to no significant improvements over the traditional course for at-risk students. It is suggested that student learning and engagement may be more dependent upon the implementation rather than the pedagogy [5], [3]. Therefore, a recitation course for Statics was developed to not simply increase instructional time but to deliver foundational principles and a supportive learning environment as stated by [5]. The recitation class developed in this paper focuses on creating a student-centered learning environment aimed at improving performance in Statics by reinforcing guiding principles and better identifying and addressing individual weaknesses in a personal classroom environment. There are 6 individual steps being implemented in the course to improve student learning. The course intends to 1) deliver flexible online course material 2) practice effective problem-solving methods 3) bolster problem recognition 4) establish Statics theory 5) reinforce guiding principles and 6) identify individual weaknesses.

It has been observed by the authors that students need flexible resources to supplement the course material. Students have regularly supplemented classroom material with free online resources and videos such as Khan Academy [12]. Without guidance, however, some students would watch the wrong video topics or try to apply incorrect methods to Statics problems. This would result in more confusion. To supply more accurate information and topics, a series of OER video tutorials were created and organized by major topic to be available to students taking the recitation in Spring 2021. For example, the Frames and Machines webpage has a short description of a frame system, the assumptions that allow simplification of the problem, the steps for solving, and an example problem with the video tutorials to follow as shown in the Appendix. The video tutorials are further broken down into short learning modules for the problem setup, free body diagram, solving, and common errors. A screenshot of a tutorial on common errors can be seen below in Figure 3. Videos are usually between 4-8 minutes long to keep students' attention and allow them to easily determine where they are getting stuck in the problem-solving process. The bottom of each topic's webpage contains additional resources such as handwritten solutions and a problem handout for students to write their notes as they follow along with the videos. Overall, there are 10 modules containing a total of 27 videos for 180 minutes of supplemental tutorial content made specifically for the recitation course. Another 32 videos provide 497 minutes of classroom lecture that they should have experienced in the original Statics course. Available 24/7, these resources provide a flexible learning environment where students can learn and review material at their own pace throughout the semester.

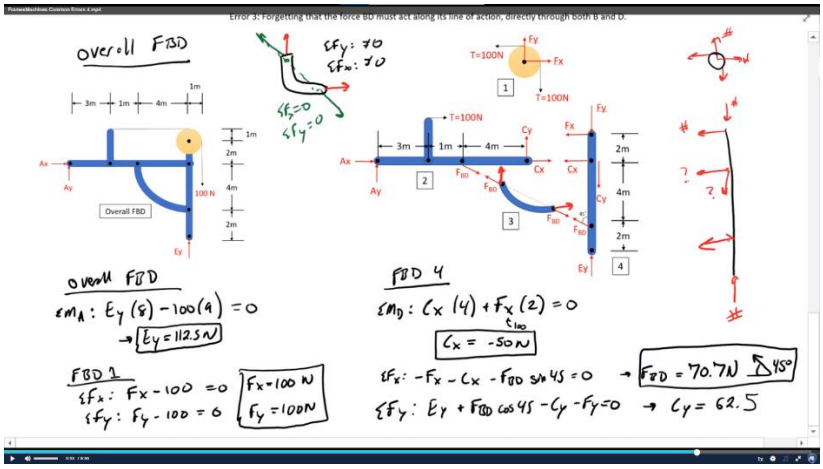

Figure 3: Screenshot of video tutorial on common errors with frames and machines

Class time is devoted to creating effective problem-solving methods. A standard step-by-step approach is taught and used on in-class work and homework assignments. Before solving, students must identify the type of problem, the steps required to solve, the associated equations, and the assumptions. The focus is on improving problem recognition and setup rather than the actual math where most students already succeed. To strengthen problem recognition, the students take turns identifying the major Statics topic as they solve a cumulative list of problems. The hope is to develop the ability to recognize topics and identify major formulae relevant to the problem. Statics theory is examined as students are quizzed on the assumptions behind each topic, and how those assumptions simplify and change the way each problem is approached.

This provides a deeper understanding of how topics differ from one another and how that changes the way forces are applied on the free body diagram, for example in 2-force members in a truss instead of a multi-force member in a frame system. These guiding principles are reinforced through homework and collaborative classwork designed to give students the fundamentals with which they need to succeed in Statics. Assignments are designed to complement and reinforce principles learned in Statics and help them understand the major topics at the rudimentary level. The small course size allows the instructor to implement feedback loops and work closely with students to develop an understanding of weaknesses and develop a strategy to fix them.

As a standalone course, students receive a grade for recitation independent of the Statics class. The purpose is to encourage attendance and participation rather than simply adding to the students' hefty workload. A study at the University of Texas San Antonio which tried to prove that an optional recitation course would improve grades in their associated core classes, instead found that the attendance and participation in the recitation course tracked with the grades. Student motivation, attendance, and completion of recitation assignments played a larger role in success than simply enrollment in the recitation course [7]. Essentially, a student that does not show up will not get the opportunity to benefit from the recitation. Therefore, the structure of a new recitation course should encourage attendance, participation, and assignment completion in order to stress these goals. The grading rubric developed for this course is shown in Table 4. With homework grades based on completion instead of correctness, effectively 90% of the grade comes from student effort.

Table 4. Recitation grading rubric

Category	**Weight**
Attendance	40%
Participation	10%
In-class Quizzes	10%
Homework	40%

Recitation Implementation:

EMCH 297 is the optional, 1-credit class that was developed based on the aforementioned pedagogy. It is not used to fulfill any degree requirements, but is taken concurrently with EMCH 211, the traditional Statics course. It is being offered for the first time in SP21 to all students, although an attempt was made to identify at-risk students and specifically invite them to add the course.

The small recitation class, limited to 15 people, meets once per week for a 75-minute session to supplement coursework in Statics. The 10-week course starts on the 6^{th} week of the semester, which is one week after students complete their first exam and offers a chance for students to improve their grade in the course. Recitation material trails the Statics course by one week, allowing students to first learn the material in the main course and then practice those concepts in a personal recitation environment where instructors can more easily identify sticking points.

Each week 2 homework problems are assigned, and relevant online video tutorials and lessons are released for students to review. A typical recitation day starts by answering questions about the previously assigned homework and solving the problems either together as a class or in groups on the board. Together the class completes an exercise developed to enforce new problem-solving methods by first identifying the type of problem, determining methods to solve, listing key equations, and citing assumptions that could simplify the problem, all without taking the time to solve the problem. A quick review lecture to reinforce Statics principles and discuss the difference between topics will follow. Finally, the class puts the lesson into action by practicing the new principles by solving 2-3 problems in small groups to encourage cooperative learning. The instructor visits each group to check on progress, answer questions, and identify class weaknesses. Every other week, the students will have a 5–10-minute quiz which focuses on problem recognition and identifying relevant equations rather than mathematically solving.

Recitation Data

The recitation course was first offered during the Spring 2021 semester. During that time, 36 students registered for the Statics course, seven of which enrolled in recitation after receiving the results of the midterm 1 exam. The course grade distribution was similar to the baseline semester as shown in Figure 4. Of the 14 students who consented to data collection, the overall passing rate was 64.3%. Separating the two groups, the passing rate for recitation students was 80% while the non-recitation rate was 55.6%.

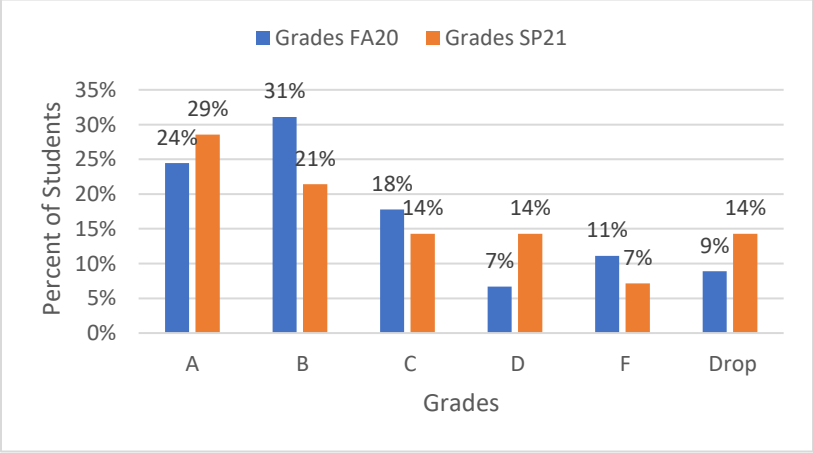

Figure 4: Statics grade distribution for Fall 2020 and Spring 2021

As performed with the baseline data, paired t-tests were conducted to determine if midterm 1 scores were valid indicators for overall student performance in the course. As shown in Table 5, there was no statistical difference between means and a strong correlation coefficient which suggests that midterm scores may help predict final course grades.

Table 5: Paired t-test sample for means between midterm 1 grades and overall course grades

	Midterm 1 Grade	*Final Course Grade*
Mean	77.8	77.8
Variance	664.2	334.3
Pearson Correlation	0.95	
P(T<=t) two-tail	1	

Of the six students who scored less than 70% on the midterm 1 exam, only one student went on to pass the course and that was a recitation student. In the baseline semester, three of seven students passed. By classifying students who score less than 70% as "at-risk", the plan is to compare their performance with and without the recitation course to determine the effectiveness of the intervention by using two-sample t-tests assuming unequal variances. In spring 2021 there were only six at-risk students: two in recitation, two without recitation, and two more without recitation who dropped and therefore have no final course grade with which to compare. With only four data points, t-tests would not produce any significant results. More data must be collected throughout the upcoming semesters before we can test if recitation had any statistically significant impact on at-risk student performance.

Student surveys were conducted before the first midterm and repeated in the last week of class to determine student attitudes towards personal course progress. The same Likert-scale survey prompts as shown previously in Table 3 were used and the results are shown below in Figure 5. In general, the scores of the FA20 were slightly higher in most categories than the SP21 results. As the SP21 semester progressed, scores went up on all questions except "ability to draw FBD."

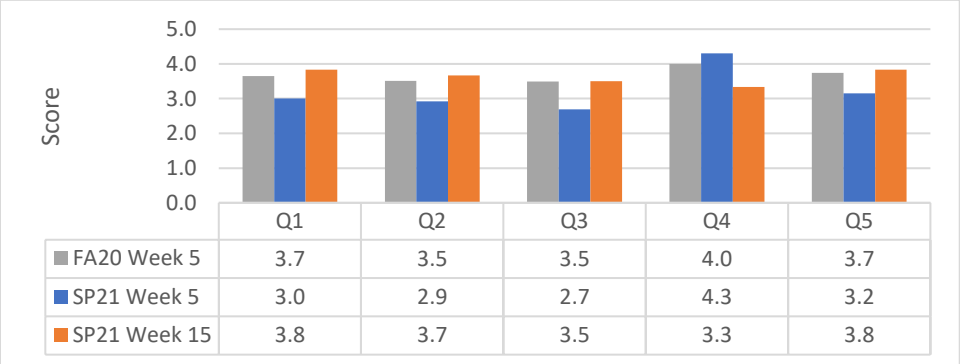

Figure 5: Likert-scale survey responses

Students were also asked to rank their confidence in understanding problem statements. On average, students were 64.0% confident in their understanding and revised that number to 82.5% by the end of the semester. Recitation students specifically went from 58.6% to 83.8%. This increase in confidence and Likert-scale scores on the survey indicates that all students believe

they have a deeper understanding of the problems by the end of the semester. The correlation between this confidence and overall course grade is poor for the first survey (0.2) and significant for the second survey (0.9), again showing that the students know themselves better by the end of the course.

Recitation students rated the effectiveness of EMCH 297 in multiple categories as shown in Table 6 through Likert-scale questions. Overall, they found it helpful, easy to navigate the online portions, and would recommend recitation to a friend. Qualitative feedback was also provided and is summarized in the Appendix.

Table 6: Likert-scale survey prompts for recitation students

	Statement	Avg. Score
6	Rate the helpfulness of the recitation class to assist your learning in Statics	4.0
7	Rate the helpfulness of the online review modules and video tutorials	4.3
8	Rate the ease of navigation through the online recitation review modules	4.0
9	What is the likelihood that you would recommend the recitation class to a friend in Statics?	4.5

In summary, the midterm 1 grades from SP21 seem to trend with overall course grade, which helps identify at-risk students. However, more data must be collected in order to verify this point as there was only a minor correlation shown in the baseline semester. Student confidence in the beginning weeks does not correlate with student success and therefore cannot be used as an additional indicator. At-risk students had a higher average final course grade when enrolled in recitation, but there were too few data points to statistically prove that the recitation had any impact on student performance. Overall, feedback shows students viewed the recitation as helpful and would recommend to their peers.

Future Plans

Over the next few semesters, the ME department plans to offer the recitation course and evaluate its effectiveness with increased data. Tracking data such as midterm grades and other progress indicators will be analyzed to try and predict at-risk students. Passing rates between the students with and without the recitation course will be compared to determine the usefulness of intervention. Surveys offered before the course starts and again when it ends, will further track students' perception of their abilities to meet course goals. Improvements to the course will be made based on feedback from the follow-up survey.

Additionally, OER material will continue to be compiled and added to the tutorial modules. These will later be shared with other courses, providing Statics tutorials as a review for students in Dynamics or Strengths of Materials. The goal is for other core classes to create similar material for their course and add to the collection. As the library of material continues to grow, there is the potential for an Engineering Mechanics library which houses common lessons and tutorials for students at all stages of their academic career.

Finally, improvements will continue to be made to increase accessibility to students. One of the goals of this study is to determine if the recitation course is effective and a proper use of department resources. One problem with this approach to improving passing rate and retention, is that it can be hard to make recitation effective on a large scale if only a few students sign up for the course and only a percentage of those really participate. As shown in the University of Texas study, the improvements in student grades based on recitation may be statistically insignificant because of a larger influence from student participation and attendance [7]. In the spring of 2021 at Penn State Behrend, one recitation section was offered and had 7 participants. More sections will need to be opened to increase availability to students with conflicting schedules because students cite scheduling conflicts as the main factor for skipping or not registering for recitation courses [13], [14]. It is hoped that with proper tracking of the success of the recitation, the data can be used to convince future students to participate in the recitation course.

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Appendix

Frames and Machines

Description

A frame or machine has a structure composed of multiple members, possibly connected to additional ropes, pulleys, or springs. The difference between a truss and a frame/machine is that trusses are composed of 2-force members while **a frame/machine must have at least 1 multi-force member.** This can be a force that acts on the middle of a member instead of just at the joint, or a moment couple that is applied to the object. On multi-force members, the pinned reactions must have both an x- and y-component.

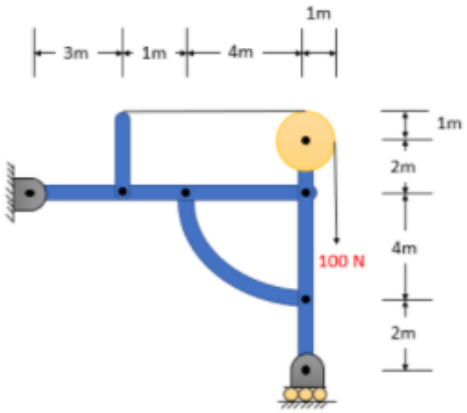
General Steps

Step 1: Draw FBD (overall and exploded view)

- Identify 2 force members (equal and opposite collinear forces acting at point of application)
- Draw forces common to any two contacting members with equal magnitude and opposite direction. (If drawing the overall system, most of the forces are internal and should not be shown.)
- Draw FBD for pins with multiple forces
- Do not reverse support reactions between overall and exploded view

Step 2: Apply equilibrium equations $\sum F_x = 0$ $\sum F_y = 0$ $\sum M = 0$

Example



Determine the forces in member FCDE.

	Recitation Feedback	
10	What helped you learn the most in recitation?	• Just the extra practice problems and going through them at a slower pace, • The individual homework problems that were focused on what we were doing during the 211 course, • The students doing the homework problems on the board and the Professor showing me exactly where I went wrong on my specific work and explaining why. • The quizzes at the end of class

11	What aspect of the recitation class was the least helpful?	• When the Professor would make up a problem. It was sometimes hard to understand without an exact picture. • The examples would be more helpful if we had the time to go through and solve them instead of just going over the concept on the board
12	What changes would make the recitation more valuable to learning?	• Do more problems that allow the student to do all the work instead of just writing them on the board. • Doing more of a mix of problems based on what we've previously learned in the semester. • I feel like it should have started before the first exam. I think I would have been more prepared if it started at the beginning of the semester.