Exam Wrappers, Reflection, and Student Performance in Engineering Mechanics – Part II

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Abstract

This paper presents the authors' continuing study in implementing a metacognitive exercise called exam wrappers. Although a previous study of a sophomore-level engineering mechanics (statics and dynamics) course found that exam wrappers did not have a significant impact on students' exam performance; overall, having students fill out quiz and exam wrappers did seem to foster reflection and adjustment in areas requiring improvement.

Currently, the authors continue their study in engineering mechanics to discern the different hindrances that need to be addressed for students to succeed. A coding system was implemented for tracking students in consecutive assessments to facilitate analysis of major factors affecting exam performance, namely: attitude, foundation, precision, knowledge, and reflection.

The authors surveyed students' attitude towards learning through questions on the exam wrappers addressing study activities, habits, and productivity, as well as preparation before class, participation during class, engagement after class, and seeking help outside of class. Information about students' performance in prerequisite courses, along with their level of confidence in utilizing these foundational subjects was collected. Through exam wrappers, students allocated their point loss into areas of foundation, precision, and knowledge. Foundation included issues with algebraic substitution, use of simultaneous equations, and geometry or trigonometry relationships. Precision included errors with significant figures, directions or units, unit conversions or orders of magnitude, careless computation error, calculator issues or miscopy, and incomplete or incorrect answer or format. Knowledge included confusion with terminology, issues with constructing a free body diagram, and uncertainty on how to approach the problem. Finally, students were prompted to reflect on what contributed to their exam performance and what they plan to do differently moving forward.

Statistical analyses and modeling were performed to elucidate relationships and factors affecting student performance. The results of this work will allow instructors to design targeted interventions to help students improve their performance and succeed in this course.

Introduction

For the last 5 years, the authors have been investigating ways to improve student performance in engineering mechanics (statics and dynamics), a required course for students majoring in bioengineering, civil engineering and environmental engineering at Florida Gulf Coast University (FGCU). Success in this course is critical to success in follow-up mechanics courses and upper-level engineering courses. Data has been collected on students' performance on homework, quizzes and exams, and also on the students' thoughts on learning and course delivery. Thus far, we have concluded that the use of traditional hand-written homework, frequent assessment via quizzes [1], or the Pearson Mastering Engineering [2] software for formative assessment did not have a significant impact on students' performance on exams. It was also observed that neither traditional nor online homework scores correlated well with exam scores; however, in-class quizzes did correlate with final exam scores. Most recently, using the Mastering Engineering Online system, specifically the inclusion of the Adaptive Follow-Up modules [3], it was observed that this also lacked any impact on overall student performance. In fact, Adaptive Follow-Up in the Mastering Engineering system was seen as punitive by some of the students rather than as a resource to encourage mastery of the material [4]. Finally, although Exam Wrappers did not seem to increase exam scores and performance; overall, having students fill out quiz and Exam Wrappers did seem to foster reflection and adjustment in most participants [5].

The course is a four-credit course taught in a combined lecture/lab environment with three meetings a week for a total of five contact hours. The course is typically taken by engineering students in their second year of study, either fall or spring. Although the course has been taught by seven different instructors over the past several years, it is essentially a team-taught course. The instructors use the same textbook and syllabus, they assign the same homework, they collaborate on writing quizzes and exams, and they use common grading rubrics. The course instruction closely follows the ExCEEd Teaching Model with the use of common board notes among the instructors. Since the course is taught in the combined lecture/lab format, there is ample time and opportunity for active, hands-on learning during the class period. Students spend a good portion of class time working in groups to solve problems under the supervision of the instructor. All instructors require attendance, take roll, and for students who have an excessive number of unexcused absences, there is a grade reduction outlined in the syllabus. Students are required to submit homework that is then graded by undergraduate teaching assistants who randomly select several problems in each assignment to grade. The prerequisites for the course are Calculus 1 and Physics 1, and students are expected to be proficient in these areas. Students must earn a minimum grade of C in the course and at least a 70% exam average in order to move on to follow-up courses that require Engineering Mechanics as a prerequisite. Over the past three years, the overall passing rate for this course is 70% but there is a positive trend. The average passing rate in 2016 was 61%, in 2017 it was 70% and in 2018 it was 78%.

In our previous study, we introduced the use of Exam Wrappers as a means for students to reflect on their attitude towards learning, developing greater awareness of areas in need of improvement that may lead to better performance on exams. Exam Wrappers encouraged students to engage in a metacognitive manner with their work even after it had been graded. The act of metacognition, or thinking about thinking, has been identified as a key approach to teaching and learning [6] and encourages students to adopt a growth mindset [7] by prompting them to identify personal actions that contribute to their performance on class assignments [8]. A formalized approach to this has been termed as a "test autopsy," "test postmortem," or (as the authors' prefer) an "exam wrapper" [9]. Developed by Lovett [10], an exam wrapper compels students to look more closely at their returned assignment by asking questions about how they prepared, where and why they earned or lost credit, and what they plan to do differently for future assignments.

An issue we faced in our previous study was that later wrappers could not be linked to previous wrappers, by student, and thus only aggregated data could be used which limited the analyses. For the present study, students developed and "signed" their wrappers with a unique identifier, which provided us with a paired design that allowed for superior statistical modeling and analyses. The overall theoretical framework for this work is illustrated in Figure 1. This paper describes our investigation into whether changes in study habits, degree of course involvement, and attitude towards learning lead to better exam performance by exploring the following questions:

Question 1: Do exam wrappers mitigate the decrease in score from Exam 1 to Exam 2?
Question 2: What are the major factors that influence student performance?

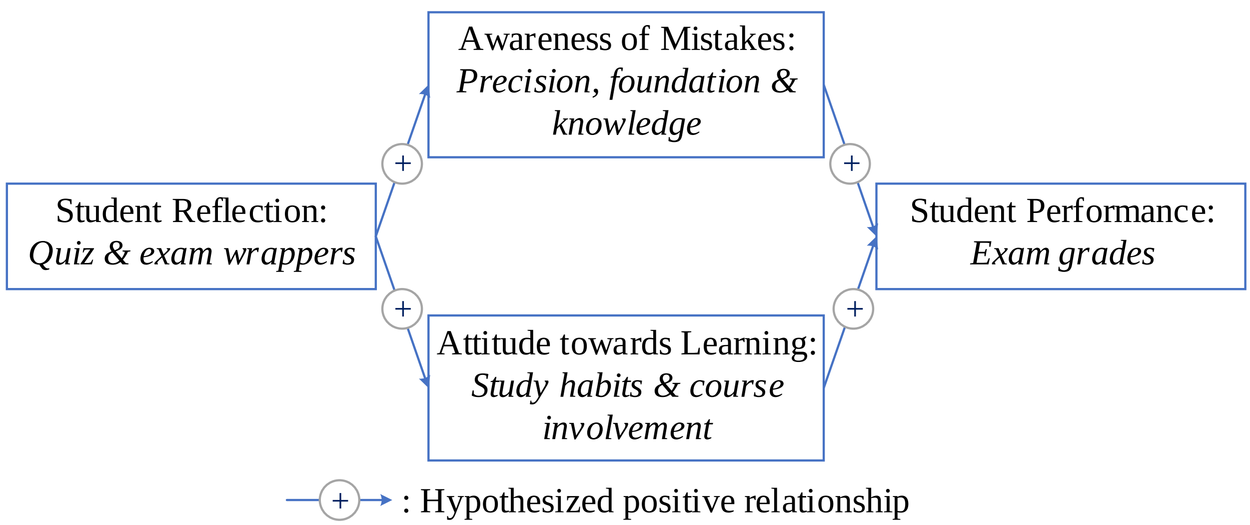

Figure 1. Theoretical framework for our continuing study. Student reflection increases awareness of mistakes and serves to highlight attitudes that may need improvement. Making adjustments in these areas should lead to better performance.

Methods

Exam Wrappers

Students in two sections of an Engineering Mechanics (Statics and Dynamics) course in Fall 2018 were given Exam Wrappers to fill out upon receiving their graded exams. Students were asked to label each Wrapper with a unique identification code that only they knew and could remember. This coding system enabled the tracking of Wrappers from Exam 1 to Exam 2 while preserving anonymity. Exam Wrapper questions are summarized in the Appendix (Table A1).

Exam Wrappers were designed to guide students in performing an "autopsy" of their graded exam by tallying their individual point losses in specific areas, which we pooled into principal factors of student performance for analysis, summarized in Table 1. Tallying point losses enabled students to witness quantitative patterns in their mistakes and target areas for improvement. Exam Wrappers also guided students in assessing their course involvement, study habits and activities, and overall productivity leading up to the assessment, examples in Table 2. Students were prompted to reflect on what contributed to their performance and what they plan to do differently moving forward.

In addition to encouraging student reflection, we sought the opportunity to survey students' prerequisite knowledge and confidence entering this course. Here, students were asked to enter their individual letter grades earned in each prerequisite course and rate their level of confidence on a 10-point scale in utilizing each foundational subject. This data, in conjunction with other factors mentioned above, were used to explore student performance.

Table 1. Description of Principal Reasons for Point Loss

Principal Reasons	**Specific Areas of Point Loss**
Precision	Significant figures, missing directions or units, unit conversions or orders of magnitude, careless computation error, calculator issues or miscopy, incomplete or incorrect answer or format
Foundation	Algebraic substitution, use of simultaneous equations, issues with geometry or trigonometry
Knowledge	Confusion with terminology, errors in constructing a free body diagram, uncertainty on how to approach the problem

Note: Students tallied their individual point losses in specific areas. Point losses were pooled into each principal reason of point loss for analyses.

Table 2. Description of Attitude towards Learning

Inventory Categories	**Components**
Study Habits	Hours spent studying for the exam, proportion of time within 24 hours of the exam, individual versus group, level of productivity
Study Activities	Reading the textbook, reviewing lesson notes, looking over solutions, reworking old problems, solving new problems, other online content
Course Involvement	Preparation before class, participation during class, engagement after class, seeking help outside of class.

Note: Students listed the percentage of time they spent on each study activity. Proportions were used to rank study activities from the most used to the least used (ranking from 7 to 1) for analysis. Students rated their course involvement from excellent to poor.

Statistical Analysis

Actual Engineering Mechanics exam scores for students that completed the course during the Fall 2016 through Fall 2018 time period were compiled to respond to Question 1 state in the Introduction. The file contained 451 students that took both Statics Exams 1 and 2. Two-hundred eighteen students did not have the opportunity to complete Exam Wrappers, whereas 233 did. The data are summarized in Table 3.

Table 3. Summary Information about Data Used to Investigate Question 1

Semester	**# of Sections**	**# of Students**	**Used Wrappers**
Fall 2016	2	64	N
Spring 2017	3	154	N
Fall 2017	2	74	Y
Spring 2017	3	82	Y
Fall 2018	2	77	Y

Survey data obtained from Wrappers used for the first two exams during the Fall 2018 semester were used to explore Question 2. Wrappers were received from 79 students after Exam 1 and 71 students after Exam 2, with 66 students completing both Wrappers. Some students may have dropped the course after Exam 1 or 2. These students are not identifiable and, as long as they completed both wrappers, their responses were included in the data set.

Inferential Methods

All data analyses stated in this section were performed in the R statistical system [11] at the 5% level of significance. A chi-square test for independence and the Wilcoxon Rank Sum test were performed to investigate Question 1.

An ordinal logistic regression model was generated to investigate Question 2, with the response variable being a measure of performance per Item 6 on the Statics Exam 2 Wrapper (see Table A1 in the Appendix). Wrappers with incomplete responses in variables that were pertinent to the model were excluded from the analysis.

Results

Principal Reasons of Point Loss

Individual student responses were analyzed from Exam Wrappers given after Statics Exam 1 and Statics Exam 2 in order to determine primary reasons for point loss. Students tallied their point loss in specific areas, which we categorized into Precision, Foundation, and Knowledge (see Table 1). Since exam scores vary, the proportion of points lost due to Precision, Foundation, and Knowledge were then computed and used to rank the principal reasons for point loss from the highest to lowest (ranking from 3 to 1) for each student.

Early in the semester on Statics Exam 1, students lost more points due to Precision than Foundation or Knowledge. Precision remained a major reason for point loss even later in the semester on Statics Exam 2. In contrast, there is a decrease in the proportion of point loss due to Foundation from Statics Exam 1 to 2, while there is an increase in the proportion due to Knowledge. Figure 2 provides a visual representation of these observations with error bars corresponding to 95% confidence intervals.

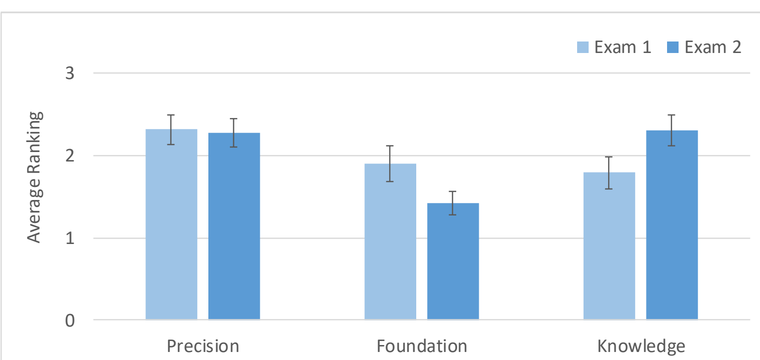

Figure 2. Average ranking of the principal reasons for point loss. The amount of points lost in each principal category was converted to a proportion of total points lost for standardization among students. Rankings of principal categories from least (1) to most (3) proportion of points lost.

We further investigated our observations by quantitatively comparing the proportion of point losses for each student by tracking individual exam scores from Statics Exam 1 to Statics Exam 2. Figure 3 shows the proportion of students who made less errors, same or no errors, or more errors in each principal category. Although some students are making less errors due to Precision (40%), others are making more errors in this area (47%), and thus the reason behind our initial observation that Precision remains a primary reason for point loss. Visualizing the data this way confirms that students are making less errors due to Foundation (49%), rather than increasing errors (16%), which indicates an improvement in this area. Also, most students are making more errors due to Knowledge (60%) rather than improving in this area (24%).

Figure 3. Change in errors rates from first to second assessment. Proportion of students who made less errors, same or no errors, and more errors in each principal category of point loss from Statics Exam 1 to Statics Exam 2.

Some insight is gained by looking at the average loss for those that did better, worse, or the same on Exam 2 compared to Exam 1, by loss category (see Figure 4). Interestingly, those that did better on Exam 2 lost most of their points due to precision, whereas those that did worse lost points primarily due to knowledge.

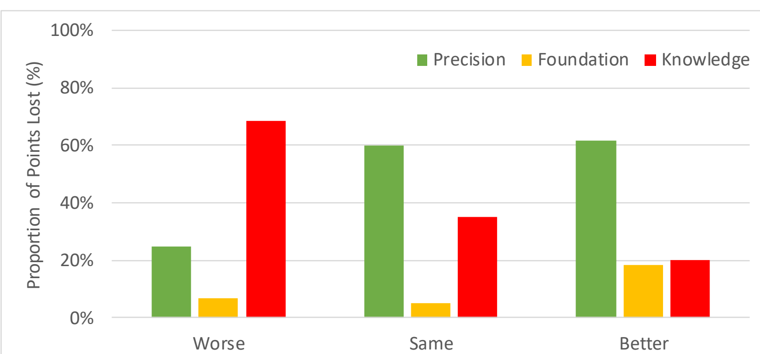

Figure 4. Mean percentage of point loss due to precision, foundation, and knowledge by performance on Exam 2 compared to Exam 1. Those that did worse on Exam 2 lost most of their points due to knowledge, whereas those that did better were weakest in precision.

Study Habits and Activities

After each assessment, Exam Wrappers asked students to list the percentage of time they spent on each study activity (Table A1). Proportions were used to rank study activities from the most utilized to the least utilized (ranking from 7 to 1). Figure 5 arranges study activities from most passive (i.e. reading the textbook) to most active (i.e. solving new problems and seeking other online content outside of the course). Rankings of each student activity are plotted with error bars corresponding to 95% confidence intervals. Students spend less time reading the textbook than reviewing lesson notes, looking over solutions, and reworking old problems. Solving new problems and seeking online content outside of the course ranked lower than reviewing lesson notes, looking over solutions, and reworking old problems.

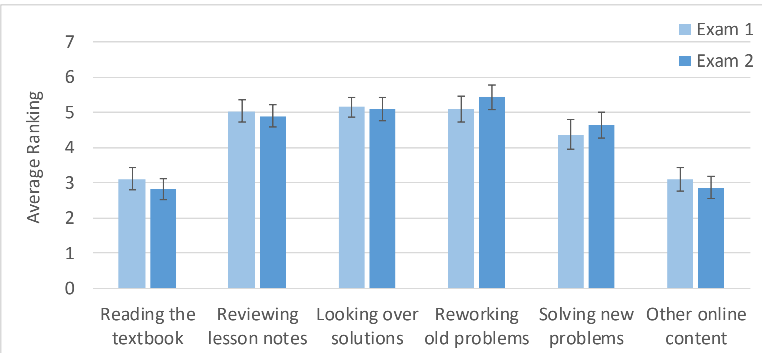

Figure 5. Average ranking of study activities. The proportion of time students spent on each study activity was used to rank study activities from the most (7) to least (1) utilized. Study activities are shown from most passive (left) to most active (right).

Another item on the Wrapper asked students to state the percentage of prep time they spent on highly productive, productive, and non-productive activities. Highly productive activities include studying lecture notes, reviewing the textbook, and solving problems. Students that spend more time on the highly productive activities should benefit from the effort. A new categorical variable was created in which a student was deemed to have increased their highly productive efforts if their reported percentage was at least 10 percentage points higher than what they reported on the Exam 1 Wrapper, decreased if more than 10 percentage points lower, otherwise their efforts were perceived as being the same for both exams. Figure 6 shows the percentage of students for each performance level based on the change in their highly productive efforts. Most students that did not change their percentage of time spent on highly productive prep activities performed as well on Exam 2 as they did on Exam 1. Surprisingly, an increase resulted in a similar proportion of students that did better on the exam compared to those that did worse. The same pattern is seen for those that decreased their level of high productivity.

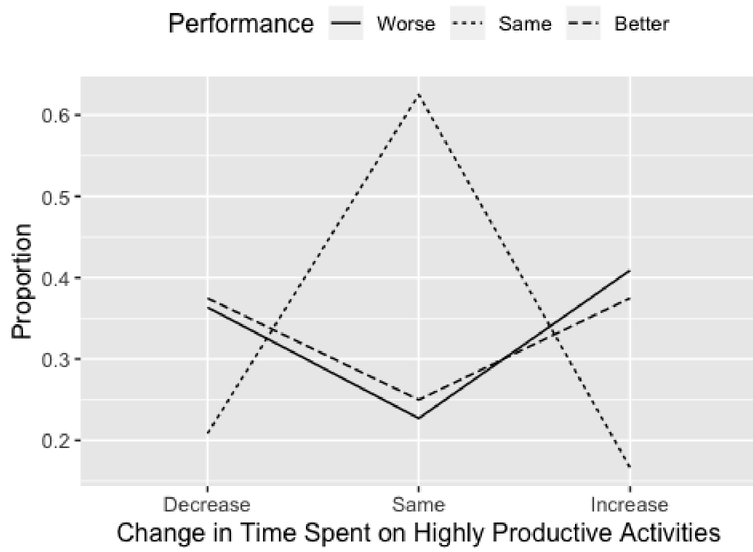

Figure 6. Percentage of students that performed better, worse, or the same on Exam 2 as Exam 1, based on the change in the percentage of their prep time spent on highly productive activities. Students that maintained the same level of high productivity as the first exam performed just as well on the second test. Any change in productivity appears to be a gamble, nearly resulting in the same percentage of students that did better as worse on Exam 2.

Course Involvement

Students were asked to rate their level of course involvement leading up to each assessment. The areas we investigated were preparation before class, participation during class, engagement after class, and seeking help outside of class (Table A1 in the Appendix). Figure 7 arranges course involvement in phases from before class (i.e. preparation before class) to after class (i.e. engagement after class and seeking help outside of class). Proportion of students who rated their level of involvement from poor to excellent are shown for each phase of course involvement. Most students (92%) reported good (62%) or excellent (30%) participation during class. In addition, level of involvement remains high with the majority of students reporting good (53%) to excellent (24%) engagement with reviewing lesson notes and problems after the class period. We note that nearly even proportions of students report poor or fair (44%) preparation for class compared to those with good to excellent (56%) preparation for class. In addition to preparation, another area of involvement that could improve student performance is seeking help outside of class. Most students (90.5%) report that they never (57.5%) or rarely seek help outside of class. This pattern is consistent with what we have observed. Students are not proactively seeking help outside of class even with extra resources such as access to dedicated Learning Assistants for the course and organized study sessions held by Teaching Assistants. However, steps should be taken to ensure that students who perform poorly on assessments receive the help they need to improve. It was observed that a positive change in preparation before class was associated with an improvement in performance from Exam 1 to Exam 2 (r=0.26). Similar relationships existed with respect to a positive change in engagement after class (r=0.33) and seeking extra help (r=0.24). However, no association was observed for a change in class participation, since participation during class was consistently high.

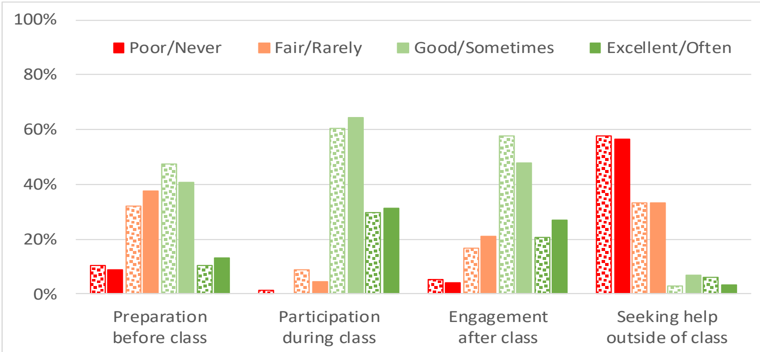

Figure 7. Student involvement in the course. Proportion of students who rated their level of involvement from poor/never to excellent/often are shown for each phase of involvement. Course involvement is shown in phases prior to class (left) to after class (right).

Prerequisite Courses

Grades in prerequisite courses as well as students' confidence in utilizing each foundational subject were examined for their relationship to one's change in exam performance as provided by Item 6 in Exam Wrapper 2 (Table A1 in the Appendix). Algebra and geometry/trigonometry were included since instructors were noticing that students had difficulty with solving simultaneous equations as well as identifying sine versus cosine of angles or triangle ratios when resolving forces into components. The prerequisite requirement to enter this course is a letter grade of C or above in Calculus 1 and Physics 1. However, College Algebra is a prerequisite for Pre-Calculus, which is a prerequisite for Calculus 1. Trigonometry is included in Pre-Calculus, whereas students may have taken Geometry in high school. Figure 8 shows the proportion of students who earned an A, B, or C in each foundational subject. Moderately positive correlations were observed between the letter grades earned in prerequisite courses and the difference in performance between Exams 1 and 2 with Physics 1, Calculus 1 and Geometry/Trigonometry all having a correlation coefficient of 0.50 and Algebra yielding an association value of 0.39. Students were asked to rate their level of confidence in utilizing each foundational subject on a scale of 1 to 10, with 1 being not confident and 10 being very confident. Most students performed very well in pre-college courses, earning A's and B's in algebra (95%) and geometry/trigonometry (92%) with high confidence in utilization. However, we see that many students are entering this course with B's and C's in Calculus 1 (57%) and Physics 1 (62%). Although Calculus 1 is not yet vital for student success in the Statics portion of this course, it is used in the Dynamics portion later on. However, Physics 1 is essential to Engineering Mechanics and, without a solid foundation and confidence in this subject, students may not perform to their potential in this course. Even though the average confidence level in the utilization of Physics 1 is moderate overall, more students reported low confidence in this subject (18%) as compared to any other prerequisite (3-4%).

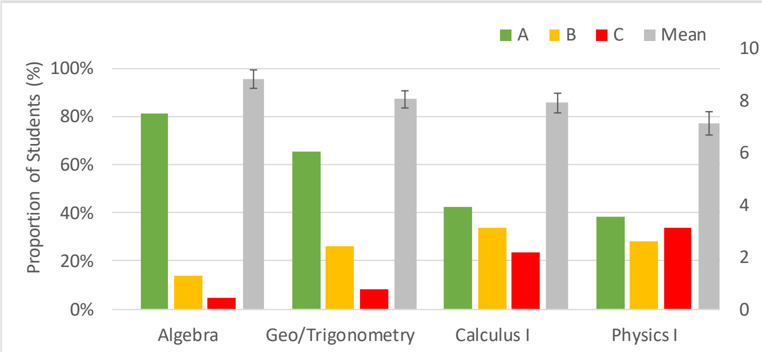

Figure 8. Prerequisite course grades and confidence in utilization. Proportion of students who earned a letter grade of A, B, or C in foundational courses. Average level of confidence in utilizing each foundational subject is on a scale of (1) not confident to (10) very confident.

Effect of Exam Wrappers (Question 1)

We discovered early in the analyses that wrappers themselves, were unlikely to diminish the decrease in scores from Exam 1 to Exam 2. While our hope was that they would have such an effect, Figure 9 shows that a larger proportion of students did worse on Exam 2 than Exam 1 in classes with Exam Wrappers compared to those without. A chi-square test for independence confirmed a significant relationship between performance and Wrapper usage (χ^2=6.41, df=2, p=0.04). This suggests that if the Wrappers are effective, then the evidence will depend on whether a student made any positive changes due to their reflection that resulted in an improved performance on Exam 2. Many students did make changes to their level of involvement, but often at a cost to another category. For example, a student may decide to increase their engagement after class, but also participate less during class. A Wilcoxon Rank Sum test revealed that students that made a net increase in their overall involvement did significantly better on Exam 2 than Exam 1 compared to those that did not (W=304.5, p=0.0054).

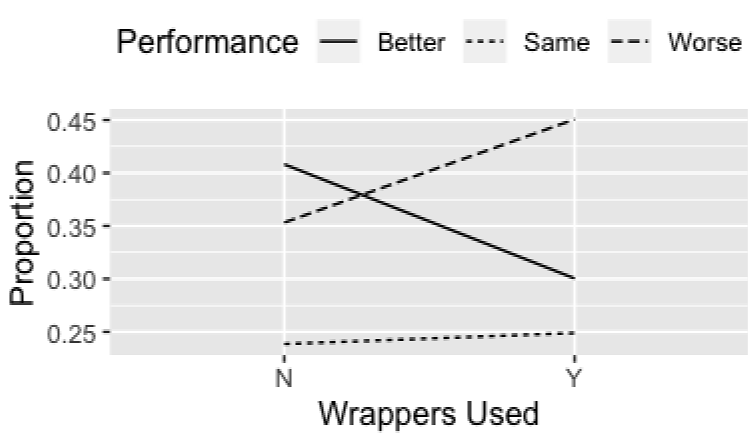

Figure 9. Line diagram showing the proportion of students in sections with and without Wrappers that performed worse, the same, or better on Exam 2 versus Exam 1.

Factors Influencing Student Performance (Question 2)

Engineering Mechanics requires a good foundation in Physics 1, which is a prerequisite for entering this course. Students take Physics 1 with multiple instructors and some have fulfilled this prerequisite outside of our University, and so may have experienced Physics 1 at varying levels of difficulty. Thus, we asked students to rate their level of confidence in applying concepts from this foundational course on a 10-point scale. These ratings were used to formulate confidence levels where students were considered to have “mastered” the subject if they chose a 9 or 10 in confidence, “deficient” if they chose 6 or lower, otherwise they are considered “proficient” in this foundational subject. Most students that feel very comfortable with the prerequisite material (i.e. they have mastered the concepts) studied about 8 to 10 hours for Exam 2, whereas proficient students studied between 5-8 hours. Most of those that studied at least 19 hours were also proficient. Deficient students demonstrated a similar pattern where one group studied a little (i.e. 0 to 5 hours) and another group studied between 10 to 18 hours for the exam (see Figure 10).

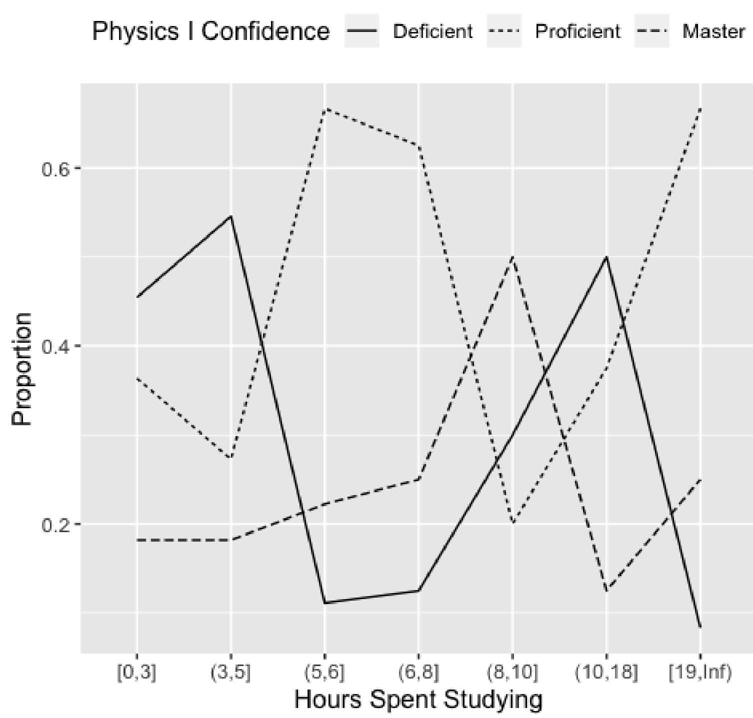

Figure 10. Hours spent studying for Exam 2 by level of confidence in Physics 1. Students that are very weak in the prerequisite material either study too little or too much.

While studying for a longer duration may represent effort, a different picture arises when looking at the ratio of hours spent studying for Exam 2 compared to the hours spent studying for Exam 1. Figure 11 shows that the group most likely to study less for this harder exam (i.e. ratio less than 1) are those that were deficient to begin with. So, the large number of hours we saw in the previous plot are often comparable to the hours that students spent studying for the previous, easier exam. Proficient students most often studied as much as they did prior. The curve corresponding to those that mastered Physics 1 concepts suggests that they studied less since the material came more easily to them, or they increased their studying, possibly to try to improve upon a disappointing Exam 1 score.

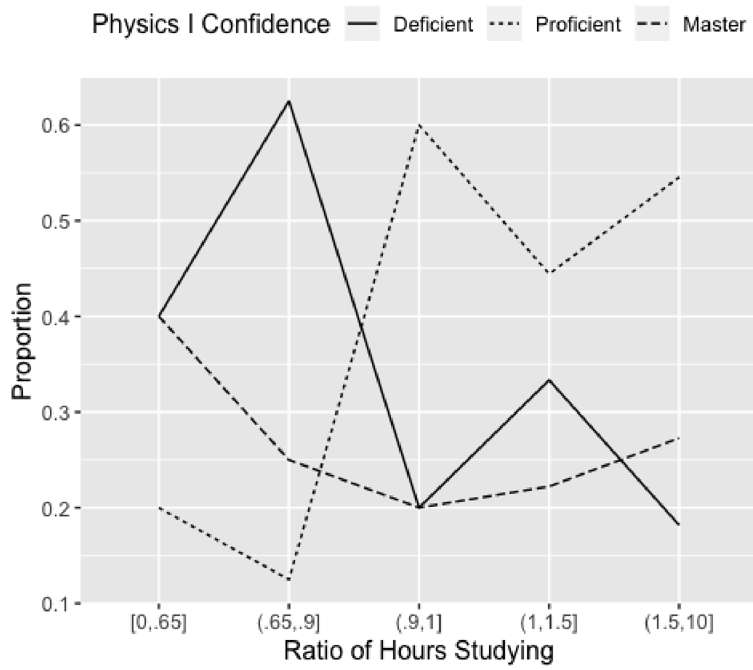

Figure 11. Students that studied less for Exam 2 than they did for Exam 1 tend to be deficient in Physics 1 concepts, whereas proficient students maintained a similar level to their Exam 1 efforts. Students that have mastered the prerequisite material are mostly at the extremes, either spending less time studying because they grasped the material more easily or studying longer in hopes of improving their overall grade.

Not surprisingly, most students in the bottom 33% of a class are deficient in Physics 1 concepts (see Figure 12 below). As confidence increases, so does the likelihood of a student performing in the top third of the class.

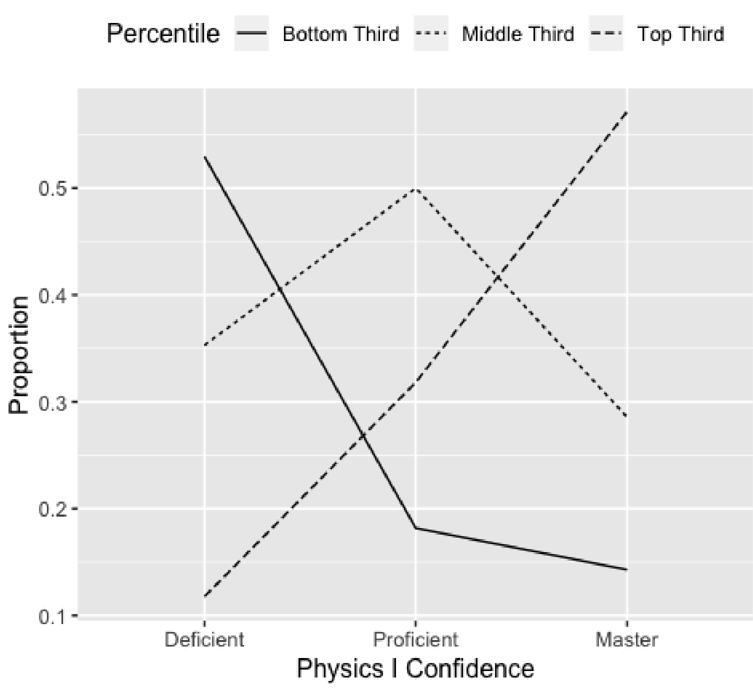

Figure 12: A closer look at the Physics 1 confidence of students, after splitting classes into thirds by performance. Most proficient students are in the middle third of the class. In general, as students improve on their confidence with respect to Physics 1 material, they are likely to move up in the class rankings.

An analysis of covariance was initially conducted to investigate the change in exam performance after accounting for grades in prerequisite courses; however, the homogeneity of regression slopes assumption could not be satisfied. Ordinal logistic regression was then used to model Exam 2 performance compared to Exam 1. Factors associated with involvement (i.e. preparation, participation, engagement), attitude (i.e. precision, foundation, knowledge), and productivity were initially included in the model, along with Physics 1 confidence and a categorical variable depicting whether a student is in the bottom, middle, or top third of the class. After including a continuous variable corresponding to the ratio of hours a student spent studying for Exam 2 compared to Exam 1, stepwise regression resulted in a model that considered one's change in point loss due to knowledge, confidence in applying Physics 1 concepts, and percentile category in the class. Brant's test verified that the model satisfies the parallel slopes assumption (χ^2=10.47, df=7, p=0.16). Some of the model's measures of quality are summarized in Table 4. A good model should have a small AIC, a pseudo-R^2 value close to one, and a low rate of predicting an observation as belonging to an incorrect group. The misclassification rate was determined for a training data set comprised of 60% of the observations and a testing data set containing the remaining 40%.

Table 4. Descriptive statistics depicting the quality of the ordinal logistic regression model.

Measure	**Value**
Akaike Information Criterion (AIC)	61.8
Maximum Likelihood Pseudo-R^2	0.59
Misclassification Rate	0.23 (training), 0.41 (testing)

Figure 13 shows the predicted probabilities for the ordinal logistic regression model. A lot of information is contained in the graph, but here are some interpretations that can be drawn:

- If a student is in the bottom third of the class and their confidence in applying Physics 1 concepts is at a *master* level, then if they can reduce the percentage of points lost due to knowledge as compared to the first exam, they will most likely perform as well on Exam 2. However, if there point loss is the same as before, then they need to study at least 2.5 times more than they studied for Exam 1 in order to be likely to achieve the same level of performance. They will have to study more than 3 times as much to perform equally well if they do worse on knowledge-based issues.

- A *proficient* student in the middle third of the class that may lose a greater percentage of points due to knowledge is likely to perform as well as the previous exam if they study at least twice as much. If they maintain the same point loss, then studying at least the same amount should result in a comparable grade. Proficient students that can improve upon their point loss and have studied about 4 times as long (or more) are likely to be rewarded with a better performance than on the first exam.

- *Deficient* students in the top third of the class have some leeway. If they improve upon their point loss, they are almost sure to perform better than on Exam 1. If they encounter the same level of point loss due to knowledge, then they need to study at least the same amount as before to receive a better grade, whereas a student that makes a larger percentage of knowledge-based mistakes will need to have studied at least twice as much to be likely to attain a better grade.

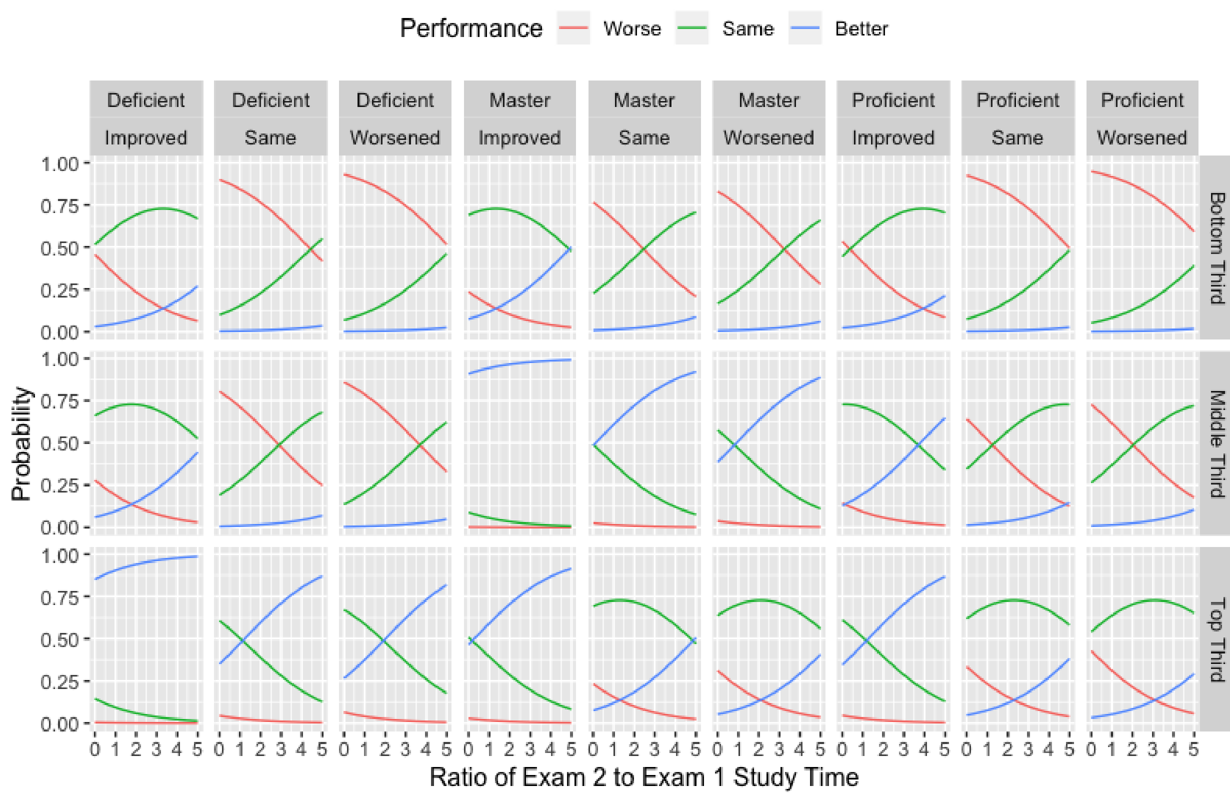

Figure 13. Predicted probabilities of performance based on Physics 1 confidence (Deficient, Proficient, Master), percentage of point loss due to knowledge (Improved, Same, Worsened), percentile category (Bottom, Middle, Top Third), and the ratio of hours spent studying for Exam 2 compared to Exam 1.

Student Perception

Students' perception about their performance in the course was assessed by a formal, anonymous survey as part of the Student Perception of Instruction (SPoI) questionnaire administered at the end of each semester for every course taught at Florida Gulf Coast University. Instructors have the option of adding supplemental questions to the SPoI, and four questions regarding student perception of factors impacting their performance, ranking of these factors, self-reflection, and adjustments were added as detailed in the Appendix, Table A2. Out of 77 students, 51 (66%) responded to these additional questions in the SPoI.

Sample of students' responses to the first question in the SPoI survey are reported here. Many factors were cited, the positive factors that were repeatedly mentioned by students were: in-class problems, working with peers on the board, one-on-one interactions during class at whiteboards, learning through the professor solving problems thoroughly. At a lower frequency, exam wrappers were also mentioned among the positive factors. Among the factors that students perceived to negatively impact their performance include: having two different teaching styles (one of the two sections were co-taught by two instructors), lack of complete understanding of physics, lack of calculus base, not remembering geometry, careless mistakes, procrastination, time management skills, stress and distraction, work and volunteer work.

The ranking of students' perception of the factors that may have negatively influenced/impacted their performance in the course (Question 2, Table A2) is shown in Figure 14. Students were instructed to select among foundation, attitude, precision, knowledge, and others as described in Table A3 in the Appendix.

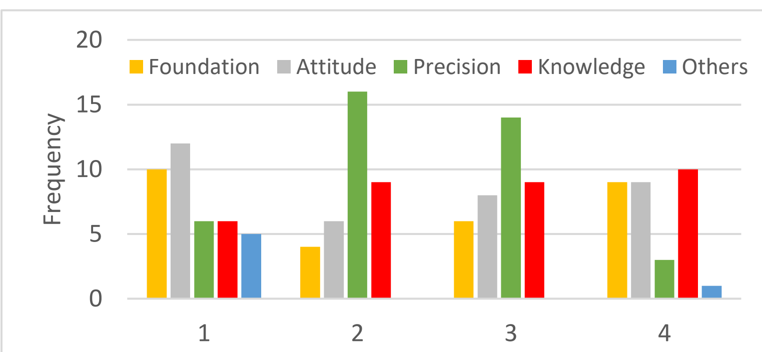

Figure 14. Students' perception of the factors that may have negatively influenced/impacted their performance in the course. Students ranked factors from primary (1) to minor (4).

By assigning a weight to each response, it was found that the students ranked precision as the overall primary factor negatively impacting their performance. The overall order of importance as perceived by the students are found to be (1) Precision, (2) Attitude, (3) Knowledge, (4) Foundation and (5) Others (see Figure 15).

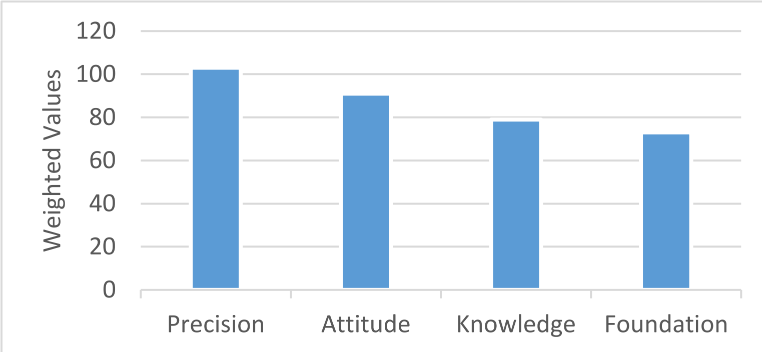

Figure 15. Students' perception of factors negatively impacting their performance in the course. Factors ordered by weighted values.

It is remarkable that students ranked knowledge and foundation as less of a weakness compared to precision and attitude. At FGCU, the faculty at the U.A. Whitaker College of Engineering have adopted a combined lecture/lab setup. The professor initiates a lesson by explaining the first part of a topic, solving a relevant problem, then letting the students work in groups to solve other problems on the whiteboards around the classroom. During this time, the instructor goes around to answer students' questions, giving them hints and/or correcting their mistakes as needed. Thereafter, the faculty reviews common errors as a class and continues with the next part of the lesson. Throughout the years, students have positively evaluated this setup, emphasizing that instantaneous depiction of errors by the instructor and their peers is of a tremendous benefit and helps them understand the professor's subsequent explanations within the same lesson. The success of the combined lecture/lab strategy adopted; which indeed strengthens the foundation and knowledge of the students by the continuous interaction between the instructor and the students during the group board sessions in each class, is believed to agree with the students' perception.

Students responded to the self-reflection question in Table A2. Overall, students' answers revealed the benefit of the wrapper, as one student states:

"My exam performance went really well because I studied really hard to get those good grades. The exam wrappers were really helpful as well because 1) It helped boost grades up and 2) It helped teachers understand what caused the reasons for poor exam grades or good exam grades."

Other students reported the recognition of weaknesses in the different factors as listed in Table A3 by stating:

"One realization I made after the exam wrappers would be my need to review trigonometric properties and improve on some free body diagrams. Additionally, I found that doing extra problems proved to be beneficial," and

"The first realization I made after reflecting on my exam performance is that I should focus on the concepts when I study. I feel like when I study for the problems, there are so many details to account for like units and direction. But then I realized the basic concepts we learned in class are important for me to know well and understand. For example, on the first exam I luckily understood the moment equation and remembered the distance was perpendicular to the force, when usually I just write down the equations and use them blindly. Similarly, on the 2nd exam I did not know the 2-force member concept enough to get one of the problems correct. Another realization I made was how important time is on the test. Sometimes when there are shortcuts in problems, I didn't bother to learn them because I was used to doing them the long way, but after the 2nd test, I plan on learning all the shortcuts I can to have time on the final."

For the last adjustment question of Table A2, two students reported the following:

"1. I increased my precision, since I made a few careless mistakes in the first exam. it worked because the second exam had no careless mistakes. 2. I reviewed exams and quizzes and learned where I was making mistakes." and

"One adjustment made is more studying for exams and quizzes and another is participating more on in class example problems. Both have helped me to improve."

Discussion

In effort to encourage students to reflect on their exam performance in a more holistic manner than simply the grade earned, this study continued using the metacognitive exercise called exam wrappers in a sophomore-level engineering mechanics (statics and dynamics) course. Exam 2 wrapper responses revealed that the number one area for point loss was precision. It may be that students become more confident in their foundational subjects when given the opportunity for application. As we build on course material and rigor, it is not surprising that students lose more points due to knowledge; however, with more practice, we expect students to improve on their precision, which does not seem to be the case here.

Comparing the percentage of point loss due to each principal area on Exam 1 versus Exam 2, we observed that more students lost a greater percentage of points due to knowledge on Exam 2 than on Exam 1, while the proportion of those that improved or worsened in the area of foundation were about equal, but high. These results indicate that students require more support to master new and challenging content knowledge as well as more rigorous training to avoid mistakes due to precision. We expect our future engineers to be precise in their work, so it is unfortunate to see that precision is ranking similarly as high as knowledge as the primary reasons for point loss.

Another issue is that students, in general, take a passive approach to studying. Most focus on lesson notes and problems they are already familiar with rather than seeking out new problems and approaches from other resources. However, students would benefit from solving new problems (such as other problems in the textbook) and reinforcing lesson content with other online resources (such as videos). These study activities should be encouraged and facilitated via the online course management system to reach students who need extra practice and enable their engagement with course content through interactive media outside of class.

Regarding course involvement, it is evident that the instructors of this course are actively engaging students in lesson content and class activities. Since this course is taught in a combined lecture/lab format there is ample time and opportunity for active, hands-on learning during the class period. Students work in groups to solve problems on whiteboards around the classroom as instructors provide feedback on problem solving approach and prompt students to correct errors as they occur. Thus, it was not surprising to see a large percentage reporting good or excellent levels of participation during and engagement after class; however, the results suggest that we would benefit from making changes that would engage the students more prior to class meetings. In its current format, the course does not have primers to get students thinking about the lesson topic before attending class, nor are there assignments to hold students accountable for being prepared for class. It would be beneficial to incorporate activities for students to complete online prior to each lesson or block of lessons. This interaction would introduce students to the lesson topic very broadly, in a way that demonstrates physical relationships or facilitates connections to experiences in their everyday lives. Coming to class prepared with prior exposure and questions in mind could serve to enhance students' learning experience in class by shifting their mindset from receiving information to constructing knowledge about the lesson topic.

Though wrappers encourage reflection, administering them in a course was not sufficient to warrant improvement. Students need to make the choice to act on their reflection and make changes that will hopefully yield a reward. In fact, we observed that students that made a net improvement across the various forms of involvement did significantly better on Exam 2 than Exam 1 compared to those that maintained the same level or had a net decrease.

Perhaps the biggest surprise was that most of the factors were not deemed to have a significant impact on student performance on Exam 1 versus Exam 2. This could be due to the relatively small sample size of 53 complete records. Despite this shortcoming, the results depicted in Figure 13 have value from an "economic" sense. It arms readers with information to encourage students to work towards particular changes. For example, if a student is proficient in Physics 1 and of the caliber to be in the bottom third of the class, then if they lose the same percentage of points due to knowledge, they are almost certain to perform worse on Exam 2 than they did on Exam 1; however, if they can be encouraged to work hard to reduce their percentage of points lost due to knowledge, then studying at least as much as they did on Exam 1 should result in a comparable performance on Exam 2. In contrast, a top third-quality student that is proficient in Physics 1 is likely to perform the same on the second exam as they did on the first. Pointing out that students should be rewarded with a better performance on Exam 2 if they (1) study at least as much as they did previously and (2) can improve upon their point loss due to knowledge, may be incentive enough to bring about positive changes.

Overall, Exam Wrappers appear to be useful. They encourage students to think about their study habits, the types of errors they tend to make, and the variety of ways that they are or could be engaged in the course. It is difficult to know who would have made changes without wrappers. However, the authors feel confident that wrappers promote more than common changes in study habits, but also potential shifts in attitude and involvement. These deeper, often unthought of paths to improved performance, may bring about a greater appreciation for a course, in addition to better grades. Future work should try to differentiate between those that would have made changes without a wrapper and those that need the guided reflection to bring about change. In addition to classification of point loss by the students as an activity to foster error analysis and reflection, it would be valuable to have graders participate in the classification process using augmented rubrics to investigate discrepancies between student perception and instructor assessment.

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APPENDIX

Table A1. Exam Wrapper Questions

1. What was your letter grade in each foundational subject? Rate your current level of confidence in utilizing each foundational subject on a scale from 1 to 10. (Algebra, Geometry/Trigonometry, Calculous 1, Physics 1)

2. What do you consider your typical level of preparation for class:
   - Excellent (read Canvas page; studied textbook; printed worksheets before class)
   - Good (skimmed Canvas page; looked over worksheets before class)
   - Fair (aware of lesson topic before class)
   - Poor (did not prepare before arriving in class)

   What do you consider your typical level of participation in class:
   - Excellent (copied board notes and added your own side notes, involved in class
   - discussions by asking and answering questions, took the lead in group work)
   - Good (copied board notes, listened to class discussions, helped with group work)
   - Fair (copied board notes, watched group work)
   - Poor (copied board notes)

   What do you consider your typical level of engagement after class:
   - Excellent (reviewed board notes and added your own side notes, studied textbook,
   - reworked in-class problems on your own)
   - Good (skimmed board notes, looked over in-class problems)
   - Fair (skimmed board notes)
   - Poor (did not review between classes)

   How many classes did you miss for lessons covered on this exam?

3. Approximately how many hours in total did you spend preparing for this exam?
   What percentage of this time was in the 24 hours prior to the exam?
   What percentage of your preparation time was individual rather than group?
   What percentage of your preparation time was spent on the following student activities: reading the textbook, reviewing lesson notes, looking over solutions, reworking old problems, solving new problems, other online content
   What percentage of your prep time would you attribute to each level of productivity?
   - Highly productive (studying lesson notes, reviewing the textbook, solving problems)
   - Productive (skimming lesson notes, looking over solutions, identifying problem approaches)
   - Non-productive (locating items, chatting with classmates, “spinning wheels” on problems)

   How often did you seek help from the instructor out of class? (often, sometimes, rarely, never)

4. How many points did you lose in total on this exam? Of those points, how many were due to the following sources of error?
    - Units, formatting equations and/or answers, numerical accuracy (e.g. missing or wrong units and/or direction, missing distance in sum of moments, inappropriate significant figures, etc.)
    - Careless computational error or calculator issues (e.g. correct work but used wrong value later on in the problem, punched in wrong value on calculator, etc.)
    - Other mathematical errors (e.g. unit conversions, orders of magnitude, etc.)
    - Substitution or the use of simultaneous equations (e.g. correct equations containing unknowns but error in solving equations or substituting variables etc.)
    - Geometry or trigonometry (e.g. sine versus cosine of angle, triangle ratios or slope, etc.)
    - Constructing a correct FBD (e.g. missing reactions at supports, identifying two-force members, tension of cable, etc.)
    - Uncertainty on how to approach the problem (e.g. drew a blank, got stuck, etc.)
    - Other (please describe)

5. What were two most valuable habits and/or activities that contributed to your performance on this exam?
    What are two things you plan to do differently to prepare for the next exam?
    What can we as instructors do to assist and support your mastery of the course material? (You may list things you find helpful that are already being done or things we should add.)

Follow-up questions on Statics Exam 2 Wrapper

6. For EXAM 2 (this exam), how many points did you earn in total?
    For EXAM 1 (previous exam), how many points did you earn in total?
    How was your performance on the 2nd exam (this exam) compared to on the 1st exam (previous exam)?
    - Significantly better (increased more than a 10% in score from 1st to 2nd exam)
    - A little better (increased 6-10% in score from 1st to 2nd exam)
    - About the same (within 5% increase or decrease in score from 1st to 2nd exam)
    - A little worse (decreased 6-10% in score from 1st to 2nd exam)
    - Significantly worse (decreased more than a 10% in score from 1st to 2nd exam)

7. Did you make any changes to your course involvement in general?
    - If YES – What primary changes did you make in your involvement in this course?
    - If NO – Why did you not make changes to your involvement in this course?

    Did you make any changes to your study habits from the 1st exam to the 2nd exam?
    - If YES – What primary changes did you make in your approach to studying for this exam?
    - If NO – Why did you not make changes to your approach to studying for this exam?

Table A2. Students Perception of Instruction (SPoI) Survey Questions

1. Proposed Factors: Think about the factors that influenced/impacted your performance in the course. In other words, possible reasons/causes that hindered or helped your performance. DESCRIBE/DISCUSS/EXPLAIN at least two (2) factors that negatively influenced/impacted your performance and at least two (2) factors that positively influenced/impacted your performance in the course.

2. Rank of Factors: Review the following list of factors that may have negatively influenced/impacted your performance in the course. These are possible issues that may have caused you to perform less than desired in the course. RANK the factors from the #1 (i.e. major or primary) reason/cause for poor performance to #4 (i.e. minor) reason/cause for poor performance. You may add one (1) additional factor called "OTHER" in your ranking and describe/discuss/explain this other factor. "FOUNDATION": poor performance (e.g. letter grade) in pre-requisite courses, lack of confidence in utilizing pre-requisite subjects; e.g. algebra, geometry, trigonometry, calculus, engineering statics, chemistry biology, physics, differential equations. "ATTITUDE": issues with study habits, sense of responsibility, level of preparation (before class), participation (in class), and involvement (after class). "PRECISION": issues with attention to detail and/or carelessness; e.g. reading/answering questions being asked, following instructions, units and conversions, calculation/computational errors, identifying similarities/differences. "KNOWLEDGE": issues with conceptual knowledge (e.g. remembering, describing/explaining, providing examples of concepts) and/or issues with problem-solving (e.g. determining approach, executing analysis methods, interpreting results). "OTHER": please describe/discuss/explain this other factor and incorporate it into your ranking

3. Self Reflection: Think about your exam performance and the analysis we've conducted through the use of exam wrappers in the course. DESCRIBE/DISCUSS/EXPLAIN at least two (2) trends you saw and/or realizations you've made after analyzing/reflecting on your exam performance/experience.

4. Adjustments: Think about the incremental adjustments you've made in effort to improve your exam performance throughout the course. DESCRIBE/DISCUSS/EXPLAIN at least two (2) adjustments you've made and comment on whether these adjustments resulted in an improvement of your exam performance. If no improvement, speculate on why these adjustments did not affect your exam performance.

Table A3. Description of Factors Impacting Student Performance (SPoI Survey Questions)

Factors	**Description**
Foundation	Poor performance (e.g. letter grade) in pre-requisite courses, lack of confidence in utilizing pre-requisite subjects; e.g. algebra, geometry, trigonometry, calculus, engineering statics, chemistry biology, physics, differential equations.
Attitude	Issues with study habits, sense of responsibility, level of preparation (before class), participation (in class), and involvement (after class).
Precision	Issues with attention to detail and/or carelessness; e.g. reading/answering questions being asked, following instructions, units and conversions, calculation/computational errors, identifying similarities/differences.
Knowledge	Issues with conceptual knowledge (e.g. remembering, describing/explaining, providing examples of concepts) and/or issues with problem-solving (e.g. determining approach, executing analysis methods, interpreting results).
Other	Describe/discuss/explain any other factor and incorporate it into your ranking