ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #38029

Improvement in Student Learning Objectives from Group Discussions Between Exam Sittings

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ASEE 2022 Paper

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Abstract

Students learn well by correcting their mistakes. Some engineering classes have offered students an opportunity to earn credit for redoing incorrect answers on exams. Professors may allow students to revise their responses to the same set of questions with or without additional support; for example, feedback may point students to specific references to revisit. This paper will describe one approach to this practice which leverages the power of peer learning.

An Introduction to Statics course with 96 students was taught by the first author in Fall 2021. The class ran for seven weeks, which is the typical quarter term for the university. In-class work included lectures four times per week, hands-on activities approximately once per week, and two in-class exams, which each had two sittings 2-3 days apart.

Students were allowed to bring one sheet of notes to exams, with no interaction permitted between students. Students turned in this sheet along with exam solutions. The instructor encouraged students to then take the exam questions to group study sessions before the second exam sitting. At the second sitting, they received a fresh sheet of exam questions with minor clarification updates, their notes sheet, and their graded first sitting exams, and could write new solutions to problem sub-parts which they previously answered incorrectly. The class grade used the mean of the first and second sitting scores.

This paper uses non-experimental methods to address the research question: To what extent does peer learning between exam sittings impact gains in student learning and self-efficacy? A sample of 85 students (representing an 89% response rate) participated in the study. Data were collected using the Student Assessment of their Learning Gains (SALG) tool, which is a validated retrospective survey developed with support from the NSF (DUE 0920801) as a less-biased alternative to course evaluations. The survey asks students to assess their growth toward each student learning objective, as well as the contribution of each learning activity to their learning gains.

A series of correlations reveal small to moderate positive relationships between group discussions between test sittings and several student learning outcomes (e.g., identifying what type of problem you are asked to solve; working effectively with others). A series of hierarchical regression models were constructed to assess whether group discussions between test sittings was still a significant predictor of student learning gains after controlling for their gains in self-efficacy and learning from attending lectures. Five outcomes are significantly predicted by peer learning between exam sittings even after controlling for self-efficacy gains and the learning from attending lecture: identifying what type of problem you are asked to solve, working

effectively with others, how studying this subject area helps address real world issues, planning to take additional engineering classes, and willingness to seek help from others on academic problems.

Introduction

Radical changes to the use of assessments in courses have recently been promoted, such as ungrading (Kohn & Blum, 2020; Stommel, 2020), standards-based grading (Lewis, 2020), and unlimited resubmissions (Posner, 2011). In engineering, some instructors have offered students an opportunity to earn credit for redoing incorrect answers on exams (Felder *et al.*, 2000; Fengler & Ostafichuk 2015; Nease *et al.*, 2021). Professors may allow students to revise their responses to the same set of questions with or without additional support. For example, feedback may point students to specific references to revisit.

This paper will describe one approach to this practice which specifically leverages the power of peer learning. This study focuses first on how peer learning and exam retaking and resubmission were combined in an Introduction to Statics course to promote student learning through assessment. Peer collaboration can be a powerful tool for promoting learning in several ways: This can support life-long learning by helping students to develop the practice, and encouraging habits, of learning on their own. Analyses then explore the extent to which an adaptation of these practices in a colleague's Stress Analysis course. The study therefore illustrates the process and impact of sharing this teaching innovation within an informal community of practice.

Literature Review

The value proposition behind the innovative teaching practices examined in this study is predicated on three premises: the utility of self-correcting in learning, the positive influence of peer learning, and the need for innovative teaching practices to be sufficiently pragmatic.

The Utility of Self-Correcting in Learning

Students learn well by correcting their mistakes. The mistake and its correction form a memorable narrative, a story of what was wrong but was made right. This is anecdotally reported in tutoring sessions, where concepts mastered quickly often fade, but those which required correction persist in a student's memory. To scale this concept beyond 1:1 tutoring sessions, multiple authors have reported on assigning students to retake tests, often in teams or as a take-home exam (Felder et al., 2000; Fengler & Ostafichuk, 2015; Nease et al., 2021). Each of these investigators describe potential benefits of such practices, but they do not rigorously examine their effects on learning outcomes.

The Positive Influence of Peer Learning

Peer learning can take many forms. "Flipping" the classroom, in which students learn subject material on their own or in groups, facilitates developing the habit of individual or team learning, rather than passive receipt of knowledge conveyed by the lecturer. Peer learning in groups encourages students to think about how to explain concepts in ways which meet each other's learning styles, rather than simply reproducing explanations on a test or homework assignment.

Those who choose to structure classroom activities to encourage or require peer learning often do so because of its positive influence on student outcomes. Academically, peer learning can encourage students to think about problems and concepts in multiple ways, from multiple angles, which can lead to longer-lasting learning. And the practice of learning from peers can promote life-long learning, and can work well with project-based learning, in which students learn to find background information and concepts on their own before using it to solve problems. These show positive influence on several affective outcomes, which in turn play critical roles in academic outcomes as well as STEM identity development.

Self-efficacy in STEM has also been tied to STEM identity development. For marginalized students, including women and BIPOC students, providing classroom experiences that build self-efficacy is particularly meaningful (Marra, Rodgers, Shen, & Bogue, 2009). Women students tend to rate themselves as having lower confidence in their ability to identify and solve engineering problems (Moreno, et al., 2000; Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Morozov, Kilgore, Yasuhara, & Atman, 2008). Those with lower self-efficacy may be more likely to under-report their skills and, therefore, self-efficacy should be controlled in analyses using student self-reported data.

Pragmatism in Innovative Teaching Adoption

There is great empirical persuasion to embrace several innovative teaching practices in STEM undergraduate courses. Project-based learning (Cohen, 1977; Schachterle, 1998; Guo, Saab, Post, & Admiraal, 2020) and active learning (Hartikainen, Rintala, Pylväs, & Nokelainen, 2019; Chi & Wylie, 2014), ungrading (Ferns et al., n.d.; Sharp, 1997) and authentic assessment (Ashford-Rowe, Herrington, & Brown, 2014) - the empirical support for the value of such practices outweighs their adoption.

Peer Learning-Based Exams in This Study

An *Introduction to Statics* course with 96 students was taught by the first author in Fall 2021. The class ran for seven weeks, which is the typical quarter term for the university. In-class work included lectures four times per week, 110-minute hands-on activities approximately once per week, and two in-class exams, which each had two sittings 2-3 days apart. The first exam had three engineering problems with three sub-parts each, the second had four questions with a total of eight sub-parts. Questions included a mixture of multi-part engineering problem-solving and short conceptual explanations. 96 students completed the class.

The first sitting of each exam was strictly timed at 50 minutes, and students were allowed to bring one sheet of notes to exams, with no interaction permitted between students. Each student turned in his/her notes sheet along with exam answers. The instructor encouraged students to then take the exam questions to group study sessions before the second exam sitting. At the second sitting, each student received a new set of exam questions, his/her graded first sitting answers and the notes sheet. Each could write new solutions to problem sub-parts which they previously answered incorrectly in the first sitting, again with no interaction. Absence of a new answer in the second sitting resulted in the same credit as they received in the first setting. Students were given as much time as needed to complete the second sitting. The class grade used the mean of the first and second sitting scores. First exam mean scores were 63.7% and 94.6% for the first and second sittings respectively, and second exam mean scores were 67.6% and 94.6%. Three students earned 100% scores on the first exam first sitting and one earned 100% on the second exam first sitting.

The instructor repeatedly emphasized to students, in lectures and other communications, the importance of scheduling group study sessions with other students in the class between exam sittings. Beyond correcting their mistakes, a second benefit of the practice of two exam sittings was to encourage peer learning. This has some of the benefits of a team second sitting (Fengler & Ostafichuk, 2015).

While encouraging students to learn in groups, the practice here required students to at least memorize, if not learn, new ways to approach problems done incorrectly. Students were each required to complete the second sitting on his/her own, rather than copying or rewriting others' answers. Nor could "cheat-sheets" with student notes be used to bring answers copied from peers to the second sitting, as they are collected at the end of the first sitting and redistributed to students for the second one. This is different from team-retake or home-retake practices, in both of which students could potentially copy new answers without understanding or even remembering them. The grading practices used here may increase grading pressure on students during the second sitting, but giving students as much time as needed to complete the second sitting alleviates this pressure to some extent.

After hearing about the practices and initial findings from assessments, Author C decided to adapt the practice for their course, *Stress Analysis*.

Methods

This paper uses non-experimental methods to address the research question: To what extent does peer learning between exam sittings impact gains in student learning and self-efficacy? The multi-phase sequential design first examines this question in the context of the first author's course, followed by an analysis of data from an adaptation of these practices in a second course. This approach allows these analyses to provide exploratory evidence of the transferability of findings from the initial implementation to other contexts.

Sample

A total of 141 students in two courses participated in this study. All students enrolled in one section of Introduction to Statics in Fall 2021 and all students enrolled in one section of Stress Analysis in Fall 2021 were invited to participate in the study. The sample includes 85 students (representing an 89% response rate) in *Introduction to Statics* and 56 students (representing a 97% response rate) in *Stress Analysis*.

Measures and Data Collection

Data were collected using the Student Assessment of their Learning Gains (SALG) tool, which is a validated retrospective survey developed with support from the NSF (DUE 0920801) as a less-biased alternative to course evaluations. The survey asks students to assess their growth toward each student learning objective, as well as the contribution of each learning activity to their learning gains.

Independent Variables. The instructor of each student's course was indicated for each student response as an independent variable.

The influence of learning activities on student learning was captured in slightly different variables across the two courses. In the initial *Introduction to Statics* course, students were asked, "How much did each of the following aspects of this class help your learning?" for a series of learning activities and course design elements. The three used in this study were "Attending lectures," "The feedback on my work received after tests or assignments," and "Group discussions between test sittings." Response options were along a five-point Likert scale from "No help" to "Great help."

The students in *Stress Analysis* were asked the same question stem, "How much did each of the following aspects of this class help your learning?" The items completing that stem included in these analyses for that course also included "Attending lectures" and "The feedback on my work received after tests or assignments." However, because the exam practices were modified, two additional items asked "The opportunity to resubmit midterm corrections after receiving my grade" and "The opportunity to retake the final exam with access to notes, the book, and collaboration with classmates." Because the mid-term corrections were optional, students were also asked to indicate whether they opted to submit them.

In both courses, a score for gains in self-efficacy was calculated for each student by taking the mean response to five items with a common stem, "As a result of your work in this Statics class, what gains did you make in the following?" The five items related to self-efficacy are: "Enthusiasm for engineering," "Interest in taking or planning to take additional engineering classes," "Confidence that you understand the material," "Confidence that you can do statics work," and "Your comfort level in working with complex ideas." Response options were a five-point Likert scale from "no gains" to "great gains." These five items are moderately to highly positively correlated with each other (see Table 1) and have high internal reliability, with a Cronbach's alpha of .91; together these suggest the items can be combined to constitute a single measure that is a stronger signal of self-efficacy than each individual item.

Table 1. Correlations of Items in Self-Efficacy Measure

Item	**M**	**SD**	**1**	**2**	**3**	**4**	**5**
1. Enthusiasm for engineering	2.82	1.31	--				
2. Interest in taking or planning to take additional engineering classes	2.82	1.31	.87*	--			
3. Confidence that you understand the material	2.88	1.22	.58*	.54*	--		
4. Confidence that you can do statics work	2.90	1.18	.58*	.44*	.90*	--	
5. Your comfort level in working with complex ideas	2.82	1.24	.64*	.52*	.81*	.81*	--

Note: $n = 85$; * $p < .01$

Student Outcomes. This study explored gains in student outcomes related to conceptual knowledge, student learning objectives for the course, as well as collaboration skills. Four items asked students "As a result of your work in this class, what gains did you make in your understanding of each of the following?" These items describe general competencies in conceptual knowledge and included "The main concepts explored in this class," "The relationships between the main concepts," "How ideas from this class relate to ideas you encounter in other classes," and "How studying this subject area helps people address real world issues." These items were asked of students in both courses included in this study. Response options involved a five-point Likert scale from "no gains" to "great gains."

Another set of items asked the same question stem for items specific to the student learning objectives shared with students on the course syllabus, which were different across the two courses. In *Introduction to Statics*, these items included "Identifying what type of problem you are asked to solve (e.g., particle vs. rigid body, 2D vs. 3D)," "Drawing appropriate free body diagrams (FBDs) for given systems," "Developing a logic argument to defend a proposed solution," and "Working effectively with others." In *Stress Analysis*, these items included "Applying the fundamentals required for 2D and 3D stress analysis problem solving," "Demonstrating the effects of stress distributions over cross sectional areas," "Synthesizing effects of different types of loading into combined loading scenarios," and "Examining the ways in which the physics you analyze on paper is manifested in the physical world." Response options followed the same five-point Likert scale from "no gains" to "great gains."

Finally, students in both courses were asked the same question stem with two items to assess gains in collaboration skills. These items were "Working effectively with others" and "Willingness to seek help from others on academic problems." Response options followed the same five-point Likert scale from "no gains" to "great gains."

Analysis Procedures

Analyses were organized into two studies. The first examines the impact of this approach encouraging students to rework their exam responses between test sittings in the first author's *Introduction to Statics* course. Survey data were assessed for univariate characteristics and to ensure the data meet assumptions for statistical tests. Pearson correlations were calculated to assess the relationships between the items describing the influence of grading practices and items describing student outcomes to justify more complex analyses.

A series of hierarchical regression models were constructed to fit data from the initial course, *Introduction to Statics*. Each student outcome was modeled using a series of four regression models. The first model included students' self-efficacy score to control for any potential effect of self-efficacy on student learning gains. The second model added the helpfulness of attending lecture; this allows us to establish the extent to which learning during lecture contributed to learning outcomes after controlling for variability in students' self-efficacy. The third model added the helpfulness of feedback received after tests to the second model; the fourth model removed that variable and added the helpfulness of group discussions between test sittings. By adding these variables in separate models after controlling for the effects of attending lecture, we are able to distinguish the unique influence of each element of this innovative assessment practice. These models were constructed for each student learning outcome to examine any patterns across them.

In the second study, we examined whether the patterns found in the initial course are sustained when the first author shared the practice and the third author adapted them for her *Stress Analysis* course. Because the assessment practice was adapted to the course context by the instructor and the due to student learning objectives being difference across courses, the individual items in the SALG survey varied. Consequently, in this study, mean scores were computed as measures of conceptual knowledge, student learning objectives, and resubmission opportunities for both course's datasets. While the individual items varied, each serves the same function and were used to construct a series of hierarchical regression models that could assess the contribution of those functions to students' learning gains.

The first model controls for the potential influence of instructor/course with a single dummy variable, followed by a second control model with students' self-efficacy scores and the helpfulness of attending lecture added. Separating these control variables into two models allowed us to assess whether there were significant differences across the two courses while taking any differences into account in analyses. The third model then adds the helpfulness of resubmission practices as scale scores.

Findings

A series of correlations revealed moderate positive relationships between group discussions between test sittings and several student learning outcomes (see Table 2). Therefore, analyses proceeded to examine the influence of these practices on student outcomes in the original course and as adapted in a second course.

Table 2. Correlations of Student Outcome Items with Resubmission Practices

Item	M	SD	1	2	3	4	5
1. Resubmission practices	3.87	1.08	--				
2. Conceptual Knowledge	3.68	0.92	.56*	--			
3. Student Learning Outcomes	3.48	0.83	.55*	.82*	--		
4. Working effectively with others	3.42	1.19	.44*	.41*	.61*	--	
5. Willingness to seek help from others on academic problems	3.51	1.18	.52*	.36*	.46*	.51*	--

Note: n = 139; * p < .01

Study 1: Outcomes of Initial Practice

Students reported modest gains in conceptual knowledge, with 30% to 57% of students reporting good to great gains across the surveyed learning outcomes and another 19% to 31% reporting moderate gains (see Table 3).

Table 3. Distribution of Learning Gains in *Introduction to Statics*

		Frequency				
Survey Item	**N**	**No gains**	**A little gain**	**Moderate gain**	**Good gain**	**Great gain**
Understanding main concepts	85	4%	19%	31%	38%	9%
Understanding the relationships between main concepts	85	4%	18%	31%	41%	7%
Relating statics ideas to other classes	85	6%	24%	19%	41%	11%
Addressing real world issues	84	6%	17%	20%	37%	20%
Identifying the type of problem	84	2%	16%	31%	38%	13%

Drawing appropriate free body diagrams	84	4%	21%	30%	31%	14%
Defending a proposed solution	84	11%	30%	30%	24%	6%
Working effectively with others	84	13%	14%	32%	24%	17%
Willingness to seek help	84	8%	16%	26%	33%	17%

A series of hierarchical regression models were constructed to assess whether the feedback provided after tests and group discussions between test sittings were still significant predictors of student learning gains after controlling for students' gains in self-efficacy and learning from attending lectures. In the first control model, a significant portion of the variance in every student outcome was explained by student gains in self-efficacy (see Table 4). In other words, students' increased self-efficacy explains, in part, their learning gains.

In the second control model, a significant portion of the variance in many student outcomes was explained by the helpfulness of attending lecture (see Table 4). The only outcomes that attending lecture did not explain, in any significant portion, were how ideas from this class relate to ideas in other classes and working effectively with others. Together, the widespread significant findings in the first two models confirms the need to control for these influences before assessing the impact of grading practices.

In the third model, a significant portion of the variance was explained by the helpfulness of feedback received after tests for three outcomes: understanding the relationships between main concepts, understanding how studying this subject area helps people address real world issues, and willingness to seek help from others on academic problems (see Table 4).

The exam practices that the first author put in place do not stop at providing feedback on tests, however. The fourth model shows that two of the outcomes significantly influenced by feedback received after tests - how studying this subject area helps people address real world issues and willingness to seek help from others on academic problems - are also significantly influenced by the helpfulness of group discussions between test sittings (see Table 4). Furthermore, the helpfulness of group discussions between test sittings also explained a significant portion of the variance in student gains in identifying what type of problem students are asked to solve and their skill working effectively with others (see Table 4).

Table 4. Summary of Explanatory Power for Modeling Student Outcomes in *Introduction to Statics*

	Model 1: Self-Efficacy Gains		Model 2: Attending Lectures		Model 3: Feedback after Exams		Model 4: Peer Learning in Exams	
Learning Outcome Predicted	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
The main concepts explored in this class	.46	.46*	.53	.07*	.55	.02	.55	.02
The relationships between main concepts	.53	.53*	.56	.04*	.60	.03*	.58	.02
How ideas from this class relate to ideas in other classes	.40	.40*	.41	.01	.41	<.01	.42	.02
How studying this subject area helps people address real world issues	.40	.40*	.45	.05*	.50	.05*	.48	.04*
Identifying what type of problem you are asked to solve	.30	.30*	.39	.09*	.39	.01	.43	.04*
Drawing appropriate free body diagrams for given systems	.31	.31*	.35	.04*	.35	<.01	.35	<.01
Developing a logical argument to defend a proposed solution	.38	.38*	.42	.04*	.43	.01	.42	<.01
Working effectively with others	.16	.16*	.17	.02	.18	.01	.28	.11*
Willingness to seek help from others on academic problems	.10	.10*	.19	.09*	.29	.10*	.34	.15*

Note: n = 85; * $p \geq .05$

Study 2: Adapting Practices across Courses

By combining conceptual knowledge variables, student learning objectives, and items describing the helpfulness of resubmission practices into scale scores, the second study allows us to further explore the value of these assessment practices across courses. Students reported significantly higher learning gains in *Stress Analysis* than they did in *Introduction to Statics* (see Table 5). This may be due to a number of factors, including differences in instructor experience and expertise: *Stress Analysis* was taught by a faculty member who regularly teaches the course and has won several awards for effective active learning pedagogy, whereas the faculty teaching *Introduction to Statics* was new to the course.

Table 5. Significant Differences in Student Outcomes in *Introduction to Statics* and *Stress Analysis*

	Introduction to Statics			Stress Analysis				
	n	**M**	**SD**	**n**	**M**	**SD**	***t***	***p***
Conceptual Knowledge	85	3.34	.92	56	4.20	.64	-6.53	<.001
Student Learning Outcomes	84	3.18	.80	56	3.93	.66	-5.79	<.001
Working effectively with others	84	3.17	1.25	56	3.80	.98	-3.21	<.001
Willingness to seek help from others on academic problems	84	3.35	1.18	56	3.77	1.16	-2.09	.02
Resubmission Practices	85	3.46	1.03	56	4.47	.84	-6.08	<.001

Regardless of the reason, these significant differences suggest that modeling must control for the influence of instructor/course on student outcomes. The first model therefore includes a dummy variable for enrollment in *Stress Analysis*, which accounts for a significant portion of the variance for each of the student outcomes (see Table 6).

Table 6. Summary of Explanatory Power for Modeling Student Outcomes in Combined Courses

	Model 1: Instructor/ Course		Model 2: Self-Efficacy & Attending Lectures		Model 3: Exam Resubmission	
Learning Outcome Predicted	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
Conceptual Knowledge	.21	.21*	.66	.45*	.68	.02*
Student Learning Outcomes	.20	.20*	.65	.45*	.67	.02*
Working effectively with others	.07	.07*	.22	.15*	.28	.06*
Willingness to seek help from others on academic problems	.03	.03*	.22	.19*	.36	.14*

Note: n = 141; * $p \geq .05$

As we might expect based on the results of the first study, adding self-efficacy and the helpfulness of attending lecture in the second model also explains a significant portion of the variance for each of the student outcomes (see Table 6). For gains in conceptual knowledge and in student learning objectives, students' self-efficacy and the value of attending lectures has a large influence, explaining 45% of the variance. Their influence on learning how to work effectively with others and on students' willingness to seek help from others on academic problems is more modest at 15% and 19%, respectively; however, these are still significant.

In the third model, the addition of resubmission practice scores accounts for a small, but significant portion of variance in student gains in conceptual knowledge (2%), student learning objectives (2%), and working effectively with others (6%). Resubmission practice scores have a relatively moderate impact on gains in students' willingness to seek help from others on academic problems. Accounting for 14% of the variance, this influence is almost comparable in explanatory power to that of attending lecture and students' self-efficacy.

As the hierarchical modeling has already accounted for the influence of different faculty and courses, this suggests that the power of resubmission practices remains while spreading the practice to colleagues and additional courses; even with the changes made while adapting the practice to a new course context and faculty preferences, allowing students to process feedback on their exam and resubmit their work contributed meaningfully to their learning.

Implications for Practice and Policy

The pandemic and the ensuing mental health crisis on college campuses has sparked increased interest in pedagogical practices that reduce student stress and promote collaboration while supporting learning. Ungrading has been promoted as one means of removing students' constant fixation on competing for grades. However, some faculty have noted that ungrading causes student stress as they try to make sense of expectations that are entirely outside the system of communicating expectations and whether they have met them. The grading practices examined in this paper pose a means of escaping a binary conceptualization of grading versus ungrading.

Much of the debate on grading practices is steeped in teaching philosophies and professional ethics. Personal beliefs always will - and arguably should - shape teaching practices. However, the question of whether assessment practices that allow students to work together and resubmit revised work are effective is an empirical one, not one of opinion.

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