Does Timeliness of Feedback Affect Student Learning?

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Abstract:

Despite the overwhelming evidence supporting the efficacy of assessment feedback, current feedback mechanisms are not meeting the demands of students. Surveys indicate that students routinely are not satisfied with the quality of the feedback that they receive on assignments. For this study, we leveraged the use of technology to help us provide feedback to students immediately after graded events, and measured the differences, both real and perceived, in student learning when feedback is delayed compared to when it is provided immediately after graded events. Our results show no statistical significance in the difference between the average student performance of students that received immediate feedback and students that received delayed feedback. Student perceptions of their own learning were also similar between the two experimental groups. However, students that took technology based assessments demonstrated a strong preference for this method of assessment over traditional paper based assessments compared to the control group.

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1. Introduction and Problem Statement

Long gone are the days when graded events had to be returned weeks after the exam to students who quickly became apathetic about their results. Technology has become more and more ubiquitous in each rising generation of college students. Teachers now have the ability to leverage this technology through interactive web-based learning platforms (WebAssign, Nearpod, Kahoot, and Socrative) that provide immediate feedback to students on their learning and performance. These interactive platforms have immense value in providing feedback to the student within the few crucial hours following graded events, where feedback may be most valuable to the student.

This study explores this topic by comparing the impact of delayed graded event feedback versus immediate graded event feedback on student learning. We believed that we could illustrate with quiz scores and open-ended survey results that immediate feedback, provided through technology, does indeed positively impact student learning and perception thereof. To accomplish this, a sample size of $n = 181$ collegiate-level mathematics students were subjected to a series of eight quizzes to gauge their comprehension of course topics. The experimental group of students were tested using tablets (iPads) that provided immediate feedback on their quiz performance, while the control group of students were tested with the more traditional written test and received feedback on their performance during the next lesson. Quiz scores were gathered and compared as quantitative data, while periodic surveys were given to solicit self-assessment of the testing method and impact on student learning. Although our data is inconclusive on the contribution of immediate feedback to learning, survey responses suggest that student's desire and value immediate feedback.

2. Literature Review

a. Importance of feedback

Research into student achievement has shown the importance of student assessment and feedback. Professor Graham Gibbs, who has published numerous works on student assessment, states that "summaries of what makes most difference to student achievement, involving reviews of many thousands of studies spanning decades of research, show clearly that the most powerful single influence is feedback." (Gibbs 2010) Within higher education literature it is widely acknowledged that feedback is critical to student achievement because it guides student learning (e.g. Hattie 1987, Sadler 1989; Black & Wiliam 1998; Yorke 2001; Higgins et al. 2002; Hattie & Timperley 2007).

b. Problems with feedback

Despite the overwhelming evidence supporting the efficacy of assessment feedback, current feedback mechanisms are not meeting the demands of students. Surveys indicate that students routinely are not satisfied with the quality of the feedback that they receive on assignments (Higgins et al. 2001, Sinclair & Cleland 2007, Hounsell et al. 2008, Ferguson 2009). Students report that they often do not understand the feedback they receive and that feedback is provided too late to assist them in the course. Ironically, studies also show that students overwhelmingly desire to receive feedback on their work (Higgins et al. 2002). In many cases students view feedback through the lens of "fairness" instead of as an opportunity to improve their learning. They feel that since they invested a large amount of time in completing the assignment it is only fair that their teacher also invest time in grading the assignment (Higgins et al. 2001, 2002).

Teachers generally appreciate the importance of student feedback but also have frustrations with student use of feedback. Teacher surveys indicate that students frequently do not engage with feedback. Studies show that even when provided with detailed and constructive comments on their assignments, most students fail to act upon them to improve their learning (Higgins et al. 2002, Orsmond et al. 2004, Smith & Gorard 2005, Crisp 2007). In many cases students do not read instructor comments at all and simply look at their final grade. Another reason that many teachers have a negative perception of assignment feedback is that providing quality feedback is time consuming, especially in large classes (Crisp 2007, Halliday 2015). When most students don't read or use the feedback they are provided, many teachers are left wondering if it is worth their time to provide any feedback at all.

c. What is quality feedback?

If both students and teachers are disillusioned about whether feedback is useful or not, how can one explain the vast amount of literature that states that student feedback is vital to student learning? Research on this question indicates that assessment feedback is most useful when it meets certain criteria. Gibbs & Simpson (2004), for example, propose six principles of quality feedback:

1. Sufficient feedback needs to be provided, both often enough and in enough detail.
2. Feedback should focus on students' performance, on their learning and on actions under the students' control, rather than on the students themselves and on their characteristics.
3. Feedback should be timely: received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance.
4. Feedback should be appropriate in relation to students' understanding of what they are supposed to be doing.
5. Feedback needs to be received and attended to.
6. Feedback should be provided in such a way that students act on it and change their future studying.

Other researchers have proposed principles along these same lines (Hattie & Timperley 2007, Wiggins 2012).

d. Feedback timing research

A subset of assessment feedback research has focused on Gibbs' third principle, the timing of feedback. Research in this area was spearheaded by educational psychologist Sidney Pressey in the 1920s (Pressey 1926, 1927, 1932, 1950). Pressey conducted a number of experiments on the impact of immediate assessment feedback and delayed assessment feedback. Most of his research dealt with in-class multiple choice quizzes. He designed a mechanical punchboard system that would immediately inform students if their answer selection was correct. He compared test performance of students using this system to students that received quiz feedback the day following their quiz. He found that students generally performed better when they received immediate quiz feedback.

Later, Kulik & Kulik (1988) conducted a meta-analysis of 53 studies on the impact of immediate feedback versus delayed feedback. This analysis categorized feedback timing studies into three groups; studies focusing on classroom quizzes, experiments on test content acquisition, and studies on list learning. Kulik & Kulik reported that immediate feedback seems to be most beneficial when engaging in classroom activities, quizzes, and list learning. The opposite is true for test content acquisition, where it appears that some delay in feedback allows students time to process the test content before receiving feedback. These are general findings as a number of studies included in this analysis found little or no difference in student achievement between immediate and delayed feedback groups.

3. Methodology

What follows are the steps taken by the authors to examine the differences in learning caused by the timeliness of feedback. For this study, a total of $n = 181$ collegiate-level core mathematics students from a total of nine MA205: Integral Calculus and Introduction to Differential Equations sections and MA100: Pre-Calculus sections. As an illustration, we broke down the MA205 schedule below.

	Hour			
	A	B	C	D
Section	A38 n = 17		C38 n = 17	D38 n = 17
	A27 n = 17	B27 n = 17		D30 n = 17
	A53 n = 17	B53 n=16		D53 n = 17
	Experimental Group		Control Group	

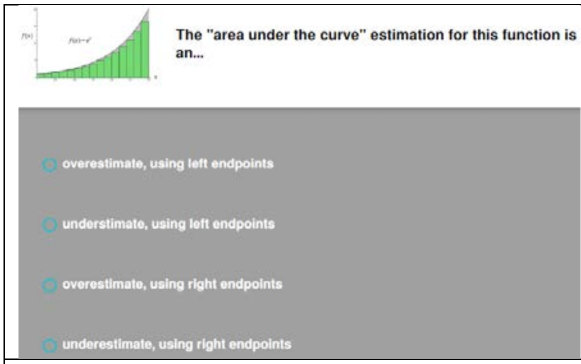
Section and Hour Breakdown

Quiz #	MA205 Lesson	Issue Date
1	4	21-Aug-15
2	12	3-Sep-15
3	19	18-Sep-15
4	27	2-Oct-15
5	39	23-Oct-15
6	47	5-Nov-15
7	58	1-Dec-15
8	61	7-Dec-15

Quiz Schedule

Figure 1: MA205 Hour breakdown and quiz schedule

A total of eight multiple-choice quizzes were issued throughout the fall AY15-16 semester on the days depicted in Figure 1 above. Each quiz consisted of ten multiple-choice questions with one of four correct responses selectable for each question. The experimental group was issued these quizzes via the web-based program NearPod, which offered immediate feedback on correct/incorrect responses at the conclusion of the quiz. (A sample of the NearPod quizzing interface appears below in Figure 2). The control group was issued these quizzes via 8½in x 11in paper, with feedback available the next lesson (usually 24 hours after completion of the quiz). A sample of the paper quizzing interface appears below in Figure 2.

<table>
<tr>
<td>
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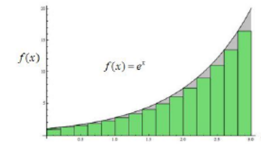
<td>1. The ”area under the curve” estimation for this function is an...


(a) overestimate, using left endpoints.
(b) underestimate, using left endpoints.
(c) overestimate, using right endpoints.
(d) overestimate, using right endpoints.</td>
</tr>
<tr>
<td>Sample of NearPod Quiz Question for Experimental Group</td>
<td>Sample of Written Quiz Question for Control Group</td>
</tr>
</table>

Figure 2: MA205 Sample Quiz Question

The intent was for students in the experimental group to walk away from their quiz knowing their quiz score, knowing which questions they had answered correctly/incorrectly, and (most important) knowing the correct answers for all incorrectly-answered questions. By contrast, the intent for the control group was for students to ruminate for at least 24 hours before they saw the results of their quiz or the answer key posted with it. Our group hypothesized that students would prefer immediate feedback over delayed feedback.

The Student Assessment of Learning Gains (SALG) website was used to gather these perceptions via a variety of multiple choice and open-ended responses. This survey is free for use and available at www.salgsite.org. Students in both the experimental and control groups were offered the opportunity to provide feedback on the current method of testing, their preferred method of feedback, and their perception of their own learning and performance in the course as a result of the feedback method being employed. Student MA205 and MA100 grades from the Academy Management System (AMS) were gathered along with this survey data to assess the impacts of both feedback methods to reject or fail to reject our hypothesis.

The SALG instrument (survey) was developed in 1997 by Elaine Seymore (http://www.salgsite.org/about), while she was co-evaluator for two National Science Foundation-funded chemistry consortia that developed and tested modular curricula and pedagogy for undergraduate chemistry courses (http://www.salgsite.org/about).

The SALG instrument is focused on the degree to which students have experienced gains in their learning. By focusing on student perception of gains, the survey precludes a *decrease* in learning over the course of the semester. In other words, after establishing a baseline of knowledge with the survey, the students are asked questions that target *how much they have learned*.

The instrument has since been revised to include five overarching questions, each of which an instructor can customize to a course through sub-items. These questions are:

- How much did the following aspects of the course help you in your learning? (Examples might include class and lab activities, assessments, particular learning methods, and resources.)

- As a result of your work in this class, what gains did you make in your understanding of each of the following? (Instructors insert those concepts that they consider most important.)
- As a result of your work in this class, what gains did you make in the following skills? (A sample of skills includes the ability to make quantitative estimates, finding trends in data, or writing technical texts.)
- As a result of your work in this class, what gains did you make in the following? (The sub-items address attitudinal issues such as enthusiasm for the course or subject area.)
- As a result of your work in this class, what gains did you make in integrating the following? (The sub-items address how the students integrated information.)

In addition to quantifying learning, the surveys also allow the students to provide free-response answers to certain questions. The complete survey and results can be found in Appendix 1.

Great effort was taken to reduce quiz variability to the maximum extent possible. All 152 students in MA205 were given similar quality level of mathematics instruction by three unique, highly-capable instructors prior to the quizzes. Thayer Hall classrooms 327, 338, and 353 served as the quizzing environments, which were, for the purposes of our study, identical and ideal. All 29 students in the MA100 sections were taught by the same instructor in Thayer Hall classroom 325, it can be considered identical to the other classrooms.

Student results were weighted equally without regard to gender, race, ethnicity, or socioeconomic status. All four instructors (proctors for this study) weighted the quizzes with a similar magnitude of points so no sections were incentivized to perform better than others. Students were assigned at random to their control/experiment groups in an effort to minimize the variability of student performance known to occur across A/B/C/D hours (i.e. not all D-hour sections were control group). All instructors participated in the quiz creation, review, and issuing process to reduce bias which might favor one section's performance over others (i.e. matching quizzes with teaching style).

A total of 152 students were sampled from the total 714-member MA205 student body, which suggests that the 21.3% of the total MA205 population sampled for this study are indeed representative of the total population we wish to generalize with the findings of our study. A total of 29 students were sampled from the 59 students enrolled in the MA100 course, or 49.2% of that population. Combining the two populations, 23.4% of all MA100 and MA205 students were included in our sample.

4. Study Results

a. Differences in Grades

In order to examine whether there is a difference between immediate feedback sections (treatment group) and delayed-feedback sections (control group), we chose to look at anonymous grade data between the two groups as a metric to measure student learning.

In order to reduce variance caused by individual instructor grading techniques, we chose only to include course-wide graded events in an adjusted average. This is because our course-wide events are graded by multiple instructors, so grading differences between sections are likely to be reduced.

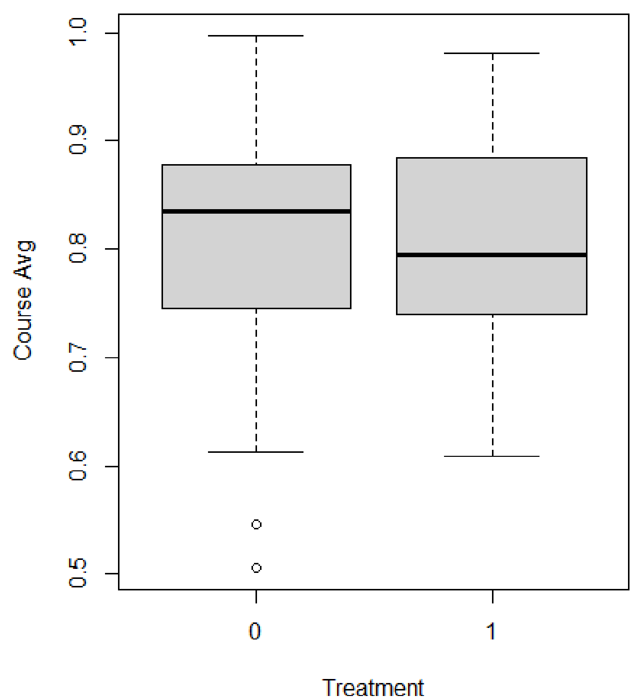


Figure 3: Course average of control (left) and treatment (right) groups

Using a two-sample t-test we found that there was no statistical difference (p-value > 0.05) between the average grades of the control group and the treatment group, which means we do not have sufficient evidence to suggest that the timeliness of feedback plays an important role in student learning.

We then attempted to standardize our data to account for *past* student performance. After all, a student who performed well in the past may be more likely to continue to perform well in the future due to acquired knowledge or habits. For each student, we compared their performance in the class and adjusted for their GPA from the previous year.

The results are shown in Figures 4 and 5, where we did an Academic Program Score Cumulative (APSC) quantile regression (Brundage, 2016). APSC is the equivalent of the student's GPA compiled for all previous semesters.

The charts show how the regression coefficient (slope) changes based on the different quantiles of APSC. These graphs help provide insight into how students performed relative to their established GPS. For both figures 4 and 5, the horizontal axis represents the quantile of student, and the vertical axis represents how much their grade changed as a result of our class. A higher y value indicates a higher regression coefficient (better performance relative to APSC).

The grey area represents one standard deviation of the regression coefficient. The red line indicates the overall average coefficient if we performed the regression on the entire sample of students, with statistically significant values (>95% confidence interval) lying outside the red dotted lines.

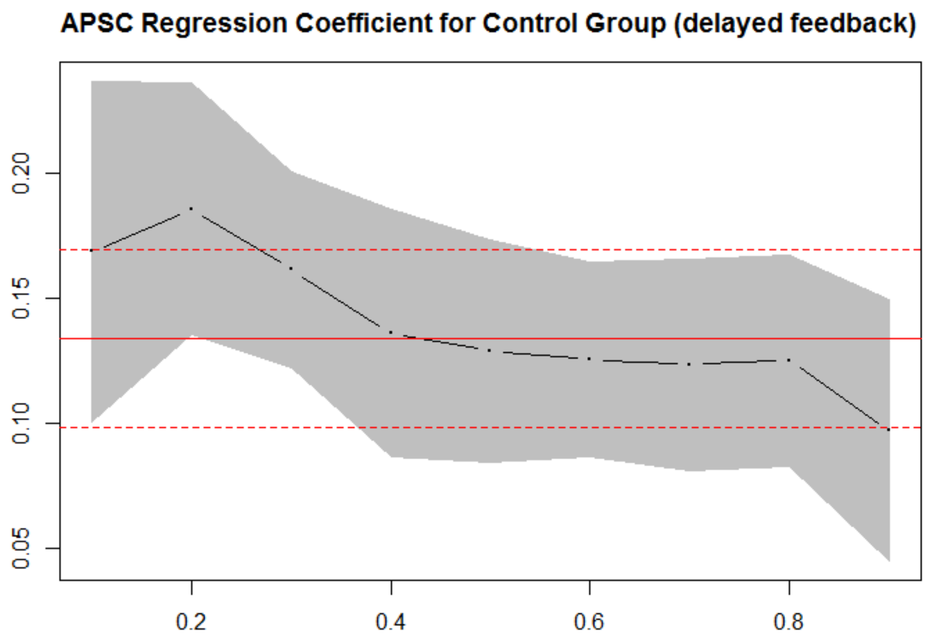


Figure 4: APSC Regression Coefficient for Control Group

In Figure 4 we see how the lower achievers see more of a change in their grade for every increase in APSC, compared to a smaller slope for the higher achievers. Think of it as, we see larger jumps in the course grade for every small increase in APSC at the lower tail, while those who are already high achievers see less change (e.g. a person with an APSC of 3.8 (A) will likely receive an A or B in the class, while a student with an APSC of 1.8 (D) was more likely to achieve a B or C in the class). We can also interpret this result as lower achieving students in the control group performed above expectation while higher achieving students performed in line with their expectations.

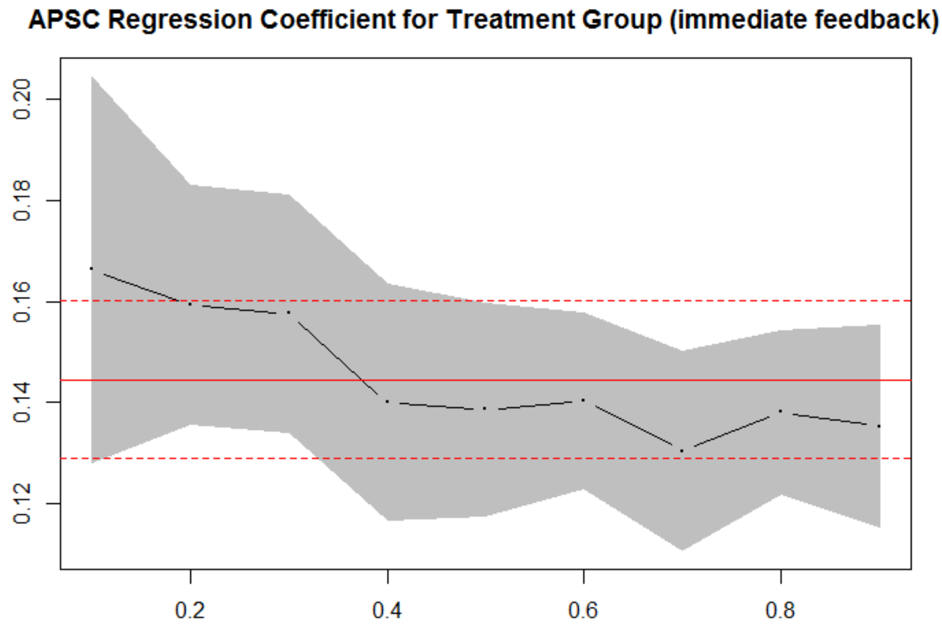


Figure 5: APSC Regression Coefficient for Treatment Group

The results from the treatment group (Figure 5) also show that lower achieving students saw a more significant improvement in their grade compared to their APSC score than higher achieving students. However, this effect is much less pronounced than in the control group. It is reasonable to conclude that students that received immediate feedback on their in-class assessments performed to their expectation across all APSCs.

These results provide an indication that delayed feedback may provide a slight benefit to lower achieving students. However, before conclusions are drawn it should be noted that there is no statistically significant difference between the overall regression coefficients of the control group (0.14) and the treatment group (0.15).

b. Differences in Perceived Learning

We found that there was no statistical difference in the students' own perception of themselves at the beginning of the semester (Figure 6). Moreover, we found that there was no statistical difference in student perceptions of knowledge gains between the control and treatment groups at the end of the semester. We examined skills, attitudes, and integration of their learning into other areas using the topics in Table 1. Students rated each topic on a scale of 0 (lowest level or gain) to 6 (highest level, or highest gain). In other words, a score on the beginning of the semester survey would indicate how well a student rated their current ability in that area or topic. A score on the end of semester survey would indicate how much ability a student thought he or she *gained* in that area or topic.

	Understanding of Class Content and Skill
1	Finding articles relevant to a particular problem in professional journals or elsewhere
1	Critically reading articles about issues raised in class
3	Identifying patterns in data
4	Recognizing a sound argument and appropriate use of evidence
5	Developing a logical argument
6	Writing documents in discipline-appropriate style and format (e.g. executive summary, appendices, ...)
7	Preparing and giving oral presentations
8	Using technology (e.g. Mathematica, Excel...) to help me solve problems
	Class impact on your Attitudes
9	Enthusiasm for the subject
10	Confidence that you understand the material
11	Your comfort level in working with complex ideas
12	Your willingness to seek help from others (teacher, peers, tutor) when working on academic problems
	Integration of your Learning
13	Connecting key class ideas with other knowledge
14	Using systematic reasoning in my approach to problems
15	Applying what I learned in this class in other situations
16	Using a critical approach to information and arguments I encounter in daily life

Table 1: SALG questions in three areas

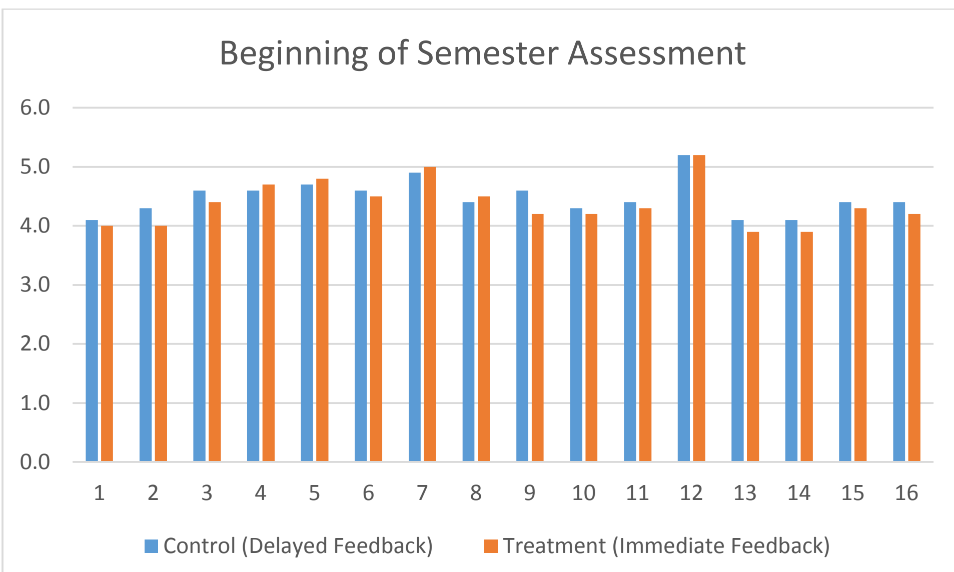


Figure 6: Beginning of Semester Assessment

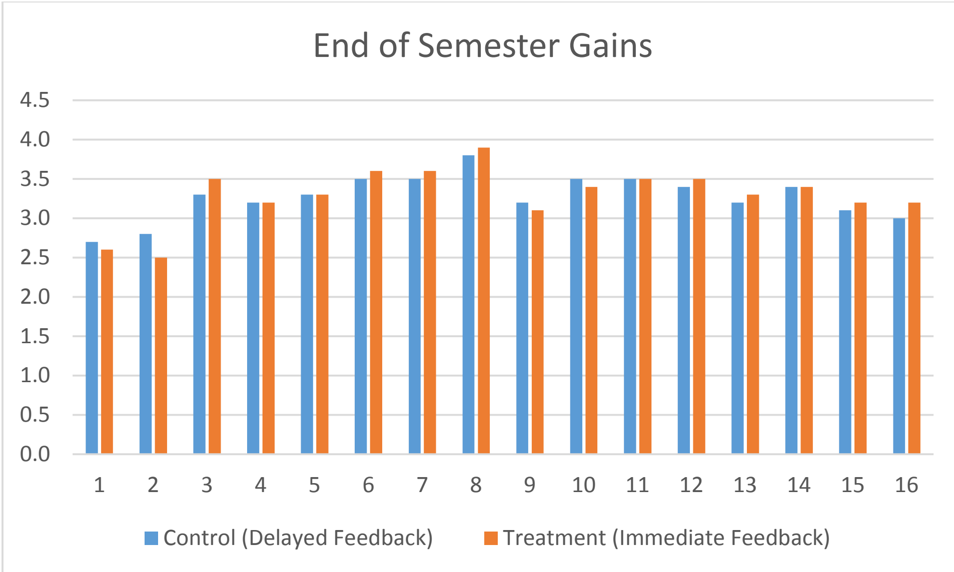


Figure 7: End of Semester Gains

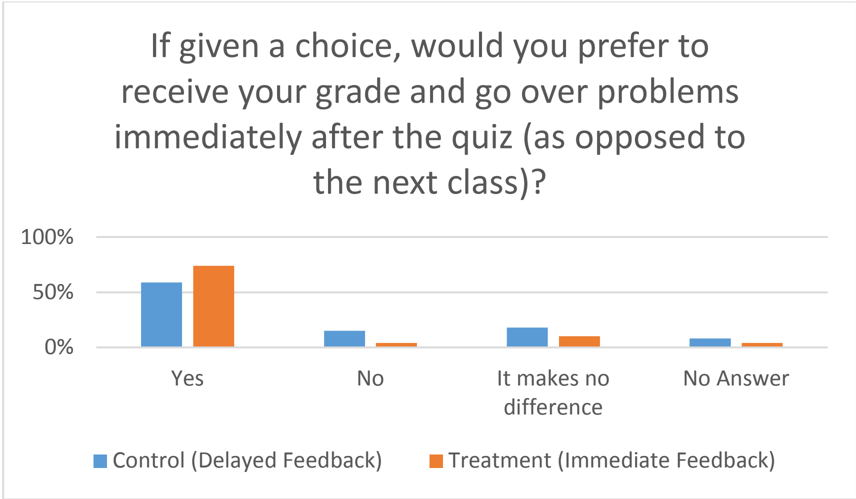
As shown in Figures 6 and 7, student self-perception as well as perceived gains in these areas are very similar between the control and treatment groups showing no real difference in perceived learning on the part of the student.

c. Instructor Directed Questions and Free-Response answers

To better understand the relationship between timeliness of feedback and student learning, we asked students a series of directed questions on the SALG survey at the end of the semester. We address three of these questions (Figure 8) whose results are significant for our research in this section. We polled students on their preference for immediate feedback, on the assessment instrument (iPad based or paper based), as well as on their attitude towards asking questions about the problems they got wrong.

There are a few significant observations we can glean from these results: Students who experienced immediate feedback were more inclined to prefer immediate feedback. While 16% of the control group said they would not prefer immediate feedback, only 3% of the treatment group who experienced immediate feedback said they would not prefer it.

Once students took a quiz on the iPad or computer, most would prefer it. 75% of the control group would not prefer to take a quiz on their iPad or computer, but among the treatment group that number dropped to 17%.



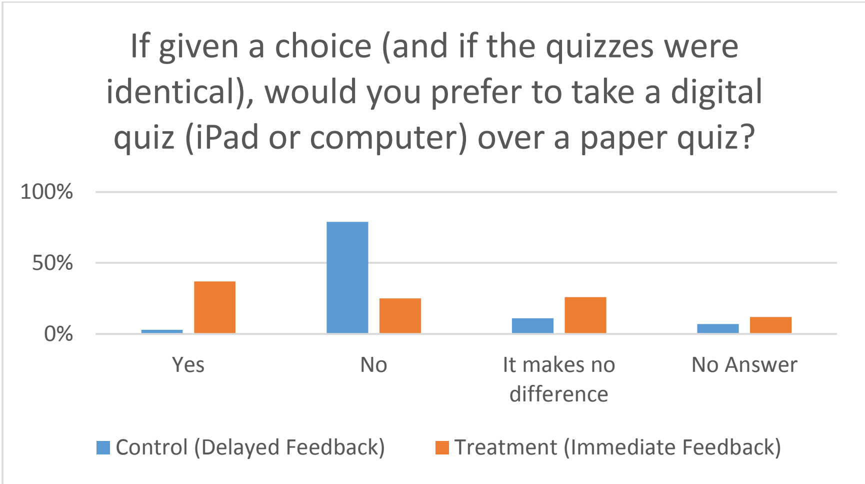


Figure 8: Other questions tailored to our research

5. Impacts on Teaching

Although we did not find a statistically significant difference in student learning between our control and treatment groups, we can still use our results and our experience using technology in the classroom to improve our teaching methodology. In particular we recommend that instructors leverage technology to provide frequent and focused feedback to students. By doing so instructors can minimize the amount of time students hold incorrect perceptions of course material while also making their classroom instruction more efficient by focusing on widely held misperceptions.

Gibbs & Simpson (2004) state that “sufficient feedback needs to be provided, both often enough and in enough detail” and that “feedback should be timely: received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance. The intent is to correct student misperceptions of course material as quickly as possible before these misperceptions become firmly held beliefs and before the course moves on to a new topic and student's loose interest in the material that was just assessed. The technology we used to conduct our assessments, iPads using the NearPod application, is an ideal platform to provide frequent "checks on learning" for students. After presenting material, the instructor could require a quick one or two question quiz to determine if the students understand the material before moving on. This feedback to the instructor allows them to immediately correct misperceptions of the course material while it is still relevant to the students.

Gibbs & Simpson (2004) also assert that "feedback must be received and attended to" and that "feedback should be provided in such a way that students act on it and change their future studying." The idea is to provide feedback in such a way that students want to engage with the material and learn from their mistakes. The results of our surveys suggest that the technology based immediate feedback methodology we used for our quizzes encourages student engagement with the material. Students generally enjoyed taking assessments using technology and felt less resistance to asking questions about their incorrect answers. These results indicate students in our treatment sections engaged with their assessment results and sought to learn from their mistakes more than in the control sections.

Based on our results and our experience conducting this research, we hope to increase the use of short, technology based, immediate feedback "checks on learning" in our classrooms. By doing so, we hope to minimize long term student misperceptions of course material and increase student engagement with the feedback that they are provided.

6. Summary and Recommendation for Future Work

In this project we explored the impact of the timeliness of assessment feedback on student learning. We hypothesized that by providing students with immediate feedback on course quizzes we would increase student knowledge gains compared to students that received delayed feedback on their quiz performance. To test this hypothesis we used a control group that took paper quizzes and received their grades the following lesson and compared their performance on course-wide graded events to students in the treatment group that took identical iPad based quizzes that provided immediate feedback on their quiz performance. An analysis of our results shows no statistically significant difference in student learning between the control and treatment groups. However, there was a small indication that lower performing students benefited from delayed feedback. Student perceptions of their own learning were also similar between the two experimental groups. Our most significant results were in student preference of assessment instrument. Once students had experience taking assessments using technology, most preferred this method over paper assessments. This contrasts with an almost universal preference for paper based assessments in the control group.

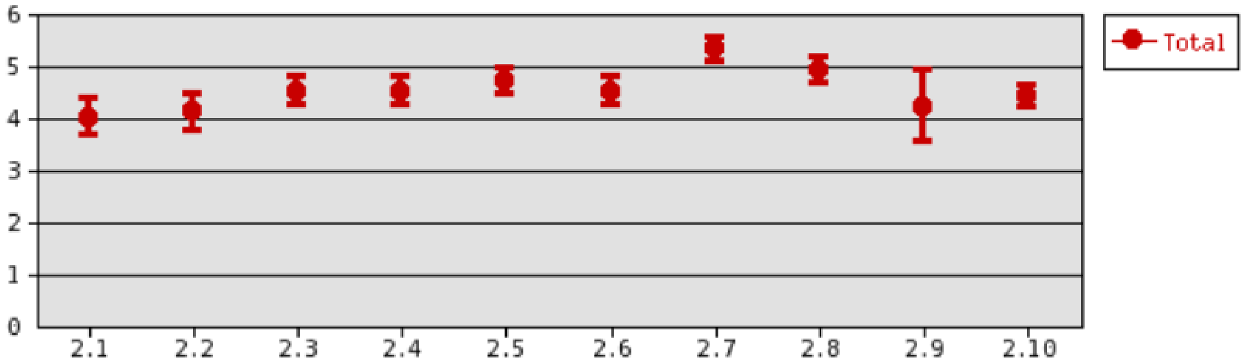
For future research we recommend an examination of the possible benefits of frequent, focused, immediate feedback "checks on learning" on student performance. We suspect that daily, technology based, non-graded assessments immediately following the presentation of new course material may reduce the time students hold misperceptions of course material and increase student engagement with feedback. Further research could also be conducted in different feedback platforms. In our study we used the application NearPod to conduct our assessments. There are a number of other applications available to assess student performance and provide feedback. A comparison of these applications may provide insight methods to increase student engagement with the course material and assessment feedback.

APPENDIX – SALG SURVEY AND RESULTS

Beginning of Semester Skills evaluated by the SALG Survey in the Control Group

Skills

2. Presently, I can...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
2.1 Find articles relevant to a particular problem in professional journals or elsewhere	7%	13%	13%	24%	21%	19%	4.0	66
2.2 Critically read articles about issues raised in class	7%	9%	10%	25%	28%	18%	4.1	66
2.3 Identify patterns in data	3%	0%	13%	25%	37%	19%	4.5	66
2.4 Recognize a sound argument and appropriate use of evidence	6%	0%	7%	21%	49%	15%	4.5	66
2.5 Develop a logical argument	3%	0%	9%	19%	51%	16%	4.7	66
2.6 Write documents in discipline-appropriate style and format	3%	0%	10%	27%	43%	15%	4.5	66
2.7 Work effectively with others	1%	0%	3%	6%	42%	46%	5.3	66
2.8 Prepare and give oral presentations	3%	0%	3%	21%	45%	27%	4.9	66
2.9 Use Technology (e.g. Mathematica, Excel...) to help me solve problems	7%	0%	20%	13%	47%	7%	4.2	14
2.10 Use Technology (e.g. Mathematica, Excel...) to help me solve problems	0%	0%	10%	50%	29%	12%	4.4	52

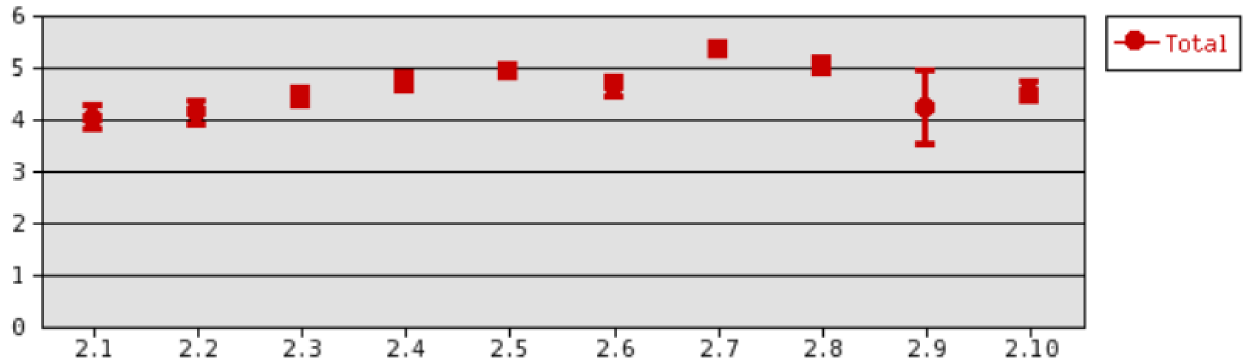


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

Beginning of Semester Skills evaluated by the SALG Survey in the Treatment Group

Skills

2. Presently, I can...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
2.1 Find articles relevant to a particular problem in professional journals or elsewhere	2%	12%	20%	29%	27%	9%	4.0	115
2.2 Critically read articles about issues raised in class	4%	6%	22%	23%	34%	10%	4.1	115
2.3 Identify patterns in data	0%	1%	11%	41%	35%	10%	4.4	115
2.4 Recognize a sound argument and appropriate use of evidence	2%	0%	6%	22%	54%	16%	4.7	115
2.5 Develop a logical argument	0%	0%	2%	28%	50%	20%	4.9	115
2.6 Write documents in discipline-appropriate style and format	2%	3%	4%	33%	42%	15%	4.6	115
2.7 Work effectively with others	0%	0%	1%	9%	48%	41%	5.3	115
2.8 Prepare and give oral presentations	0%	1%	2%	17%	59%	20%	5.0	115
2.9 Use Technology (e.g. Mathematica, Excel...) to help me solve problems	0%	8%	23%	31%	15%	23%	4.2	13
2.10 Use Technology (e.g. Mathematica, Excel...) to help me solve problems	0%	2%	12%	36%	34%	16%	4.5	102

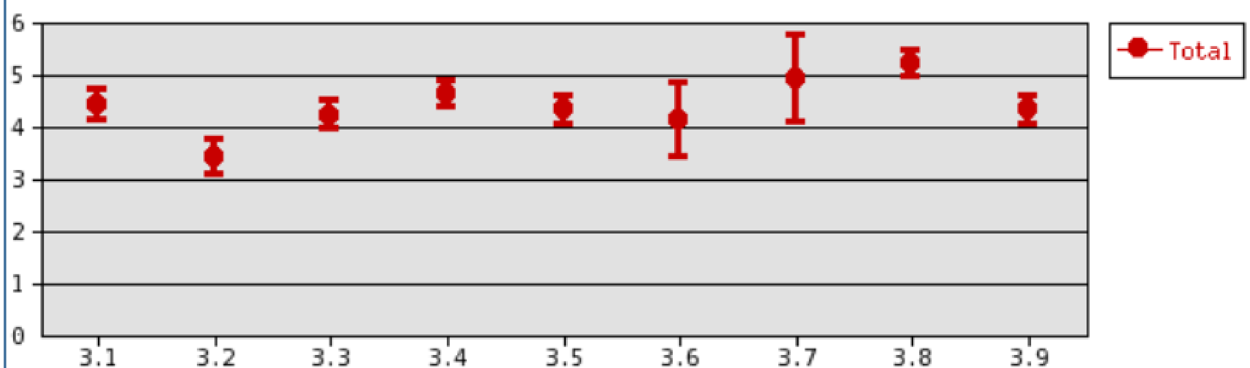


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

Beginning of Semester Attitudes evaluated by the SALG Survey in the Control Group

Attitudes

3. Presently, I am...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
3.1 Enthusiastic about the subject	1%	6%	12%	27%	39%	13%	4.4	66
3.2 Interested in taking or planning to take additional classes in this subject	1%	36%	16%	19%	13%	12%	3.4	66
3.3 Confident that I understand the subject	1%	4%	18%	34%	30%	10%	4.2	66
3.4 Confident that I can do this subject	1%	3%	9%	27%	40%	18%	4.6	66
3.5 Comfortable working with complex ideas	1%	4%	16%	27%	39%	10%	4.3	66
3.6 Comfortable working with technology to help me solve problems	7%	13%	0%	20%	53%	0%	4.1	14
3.7 Willing to seek help from others (teacher, peers, Tutors) when working on problems	7%	7%	0%	13%	20%	47%	4.9	14
3.8 Willing to seek help from others (teacher, peers, tutors) when working on problems	0%	2%	2%	13%	37%	46%	5.2	52
3.9 Comfortable working with technology to help me solve problems	0%	0%	21%	37%	29%	13%	4.3	52

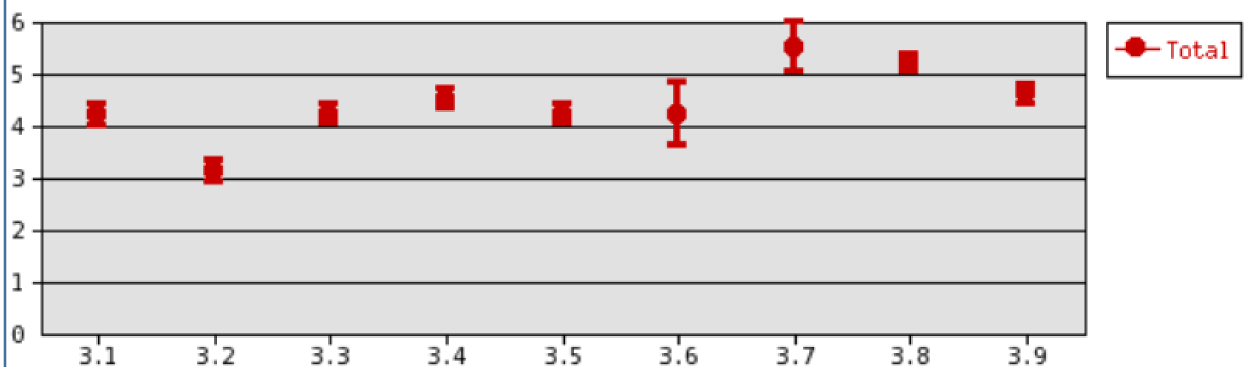


The figure above shows the mean with confidence interval (± 3 times the standard error) for each item.

Beginning of Semester Attitudes evaluated by the SALG Survey in the Treatment Group

Attitudes

3. Presently, I am...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
3.1 Enthusiastic about the subject	0%	9%	16%	33%	32%	10%	4.2	115
3.2 Interested in taking or planning to take additional classes in this subject	0%	39%	27%	19%	11%	3%	3.1	115
3.3 Confident that I understand the subject	0%	4%	20%	40%	27%	9%	4.2	115
3.4 Confident that I can do this subject	0%	3%	16%	29%	34%	17%	4.5	115
3.5 Comfortable working with complex ideas	0%	3%	18%	41%	26%	11%	4.2	115
3.6 Comfortable working with technology to help me solve problems	0%	0%	31%	31%	23%	15%	4.2	13
3.7 Willing to seek help from others (teacher, peers, Tutors) when working on problems	0%	0%	8%	0%	31%	62%	5.5	13
3.8 Willing to seek help from others (teacher, peers, tutors) when working on problems	0%	0%	4%	17%	35%	43%	5.2	102
3.9 Comfortable working with technology to help me solve problems	0%	1%	13%	33%	33%	19%	4.6	102

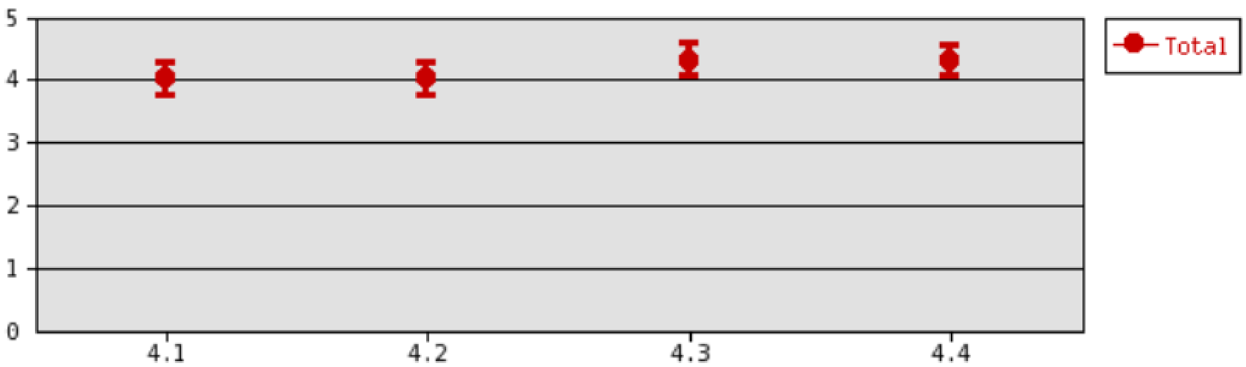


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

Beginning of Semester Integration of Learning evaluated by the SALG Survey in the Control Group

Integration of learning

4. Presently, I am in the habit of...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
4.1 Connecting key ideas I learn in my classes with other knowledge	1%	4%	24%	42%	19%	7%	4.0	66
4.2 Applying what I learn in classes to other situations	1%	9%	12%	46%	25%	4%	4.0	66
4.3 Using systematic reasoning in my approach to problems	1%	4%	12%	33%	36%	12%	4.3	66
4.4 Using a critical approach to analyzing data and arguments in my daily life	1%	1%	16%	37%	33%	9%	4.3	66

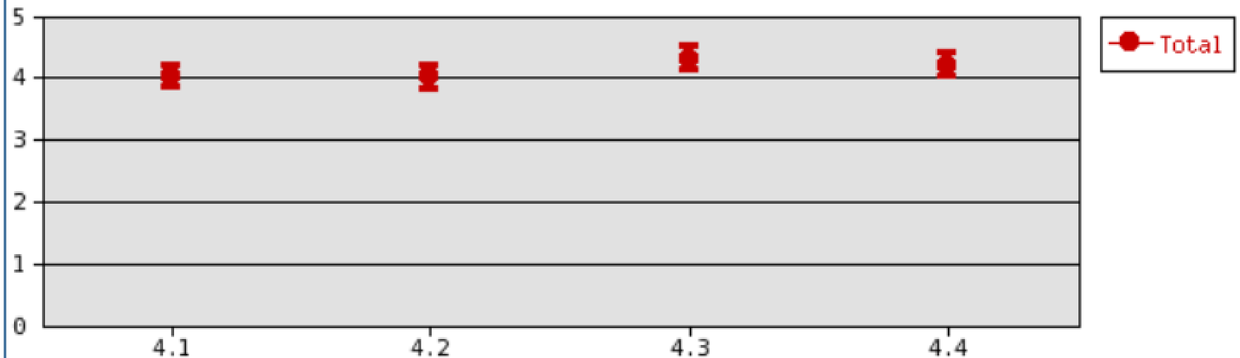


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

Beginning of Semester Integration of Learning evaluated by the SALG Survey in the Treatment Group

Integration of learning

4. Presently, I am in the habit of...	1:not applicable	2:not at all	3:just a little	4:somewhat	5:a lot	6:a great deal	Mean	N
4.1 Connecting key ideas I learn in my classes with other knowledge	1%	3%	27%	41%	22%	6%	4.0	115
4.2 Applying what I learn in classes to other situations	0%	7%	26%	35%	24%	7%	4.0	115
4.3 Using systematic reasoning in my approach to problems	0%	4%	16%	34%	34%	9%	4.3	115
4.4 Using a critical approach to analyzing data and arguments in my daily life	0%	4%	22%	30%	34%	9%	4.2	115

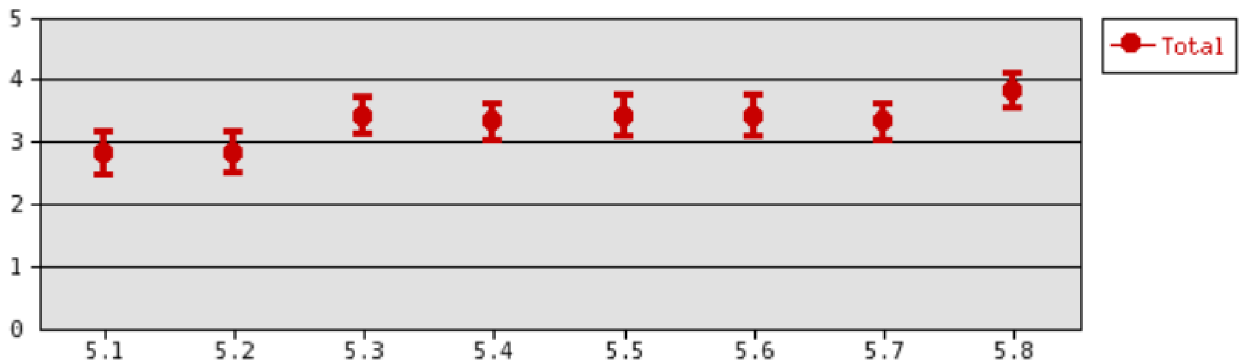


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Skill Gains evaluated by the SALG Survey in the Control Group (61 Student Responses)

Increases in your skills

5. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
5.1 Finding articles relevant to a particular problem in professional journals or elsewhere	18%	18%	21%	17%	9%	9%	2.8	55
5.2 Critically reading articles about issues raised in class	15%	27%	15%	20%	9%	6%	2.8	57
5.3 Identifying patterns in data	2%	24%	18%	30%	17%	2%	3.4	60
5.4 Recognizing a sound argument and appropriate use of evidence	6%	20%	24%	24%	15%	3%	3.3	59
5.5 Developing a logical argument	6%	20%	18%	26%	20%	3%	3.4	59
5.6 Writing documents in discipline-appropriate style and format (e.g. executive summary, appendices, ...)	5%	21%	17%	24%	21%	5%	3.4	58
5.7 Preparing and giving oral presentations	6%	18%	23%	29%	17%	0%	3.3	61
5.8 Using technology (e.g. Mathematica, Excel...) to help me solve problems	3%	11%	14%	36%	29%	0%	3.8	61

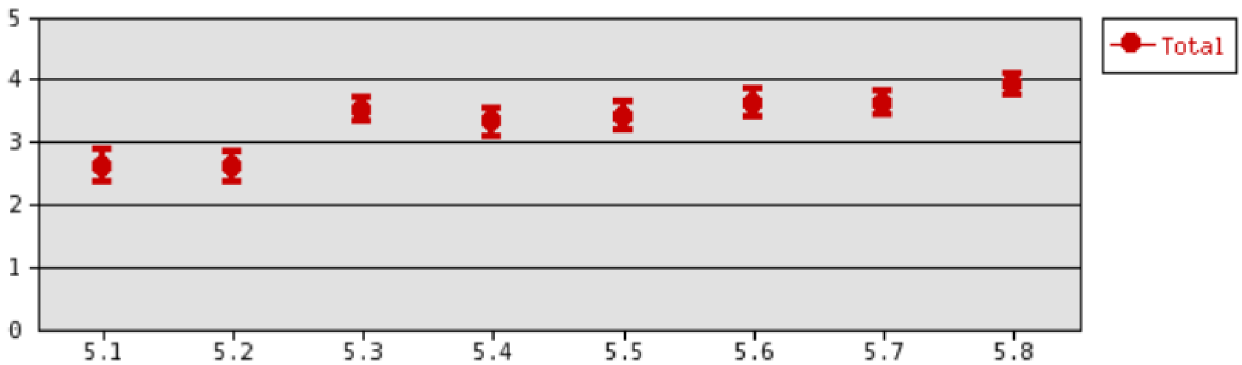


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Skill Gains evaluated by the SALG Survey in the Treatment Group

Increases in your skills

5. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
5.1 Finding articles relevant to a particular problem in professional journals or elsewhere	22%	20%	15%	15%	10%	6%	2.6	109
5.2 Critically reading articles about issues raised in class	20%	25%	12%	18%	7%	6%	2.6	109
5.3 Identifying patterns in data	4%	8%	26%	29%	16%	5%	3.5	111
5.4 Recognizing a sound argument and appropriate use of evidence	8%	14%	20%	26%	14%	5%	3.3	110
5.5 Developing a logical argument	5%	15%	18%	30%	15%	5%	3.4	111
5.6 Writing documents in discipline-appropriate style and format (e.g. executive summary, appendices, ...)	5%	9%	18%	28%	22%	6%	3.6	109
5.7 Preparing and giving oral presentations	4%	8%	20%	35%	17%	4%	3.6	112
5.8 Using technology (e.g. Mathematica, Excel...) to help me solve problems	2%	6%	16%	37%	26%	2%	3.9	115

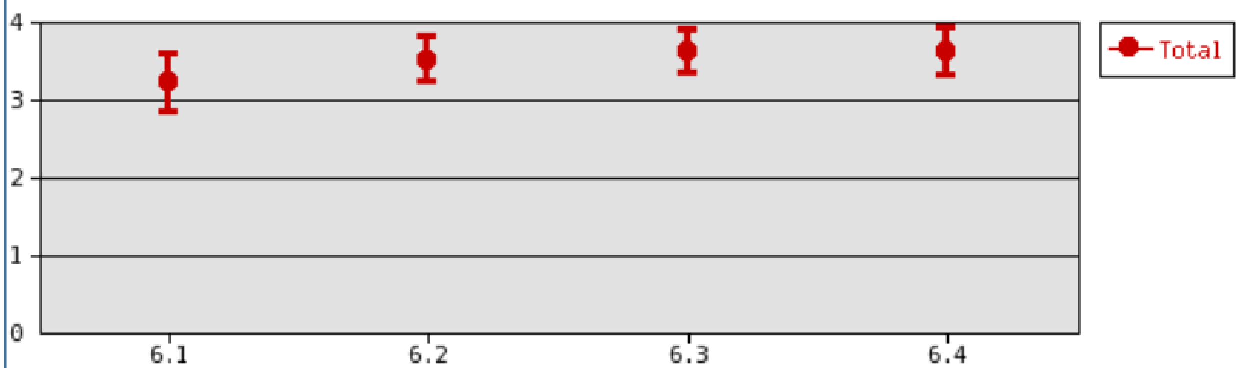


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Attitude Gains evaluated by the SALG Survey in the Control Group

Class impact on your attitudes

6. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
6.1 Enthusiasm for the subject	17%	14%	17%	21%	23%	2%	3.2	60
6.2 Confidence that you understand the material	5%	14%	17%	39%	17%	2%	3.5	60
6.3 Your comfort level in working with complex ideas	3%	15%	18%	36%	18%	2%	3.6	60
6.4 Your willingness to seek help from others (teacher, peers, tutor) when working on academic problems	5%	15%	18%	29%	26%	0%	3.6	61

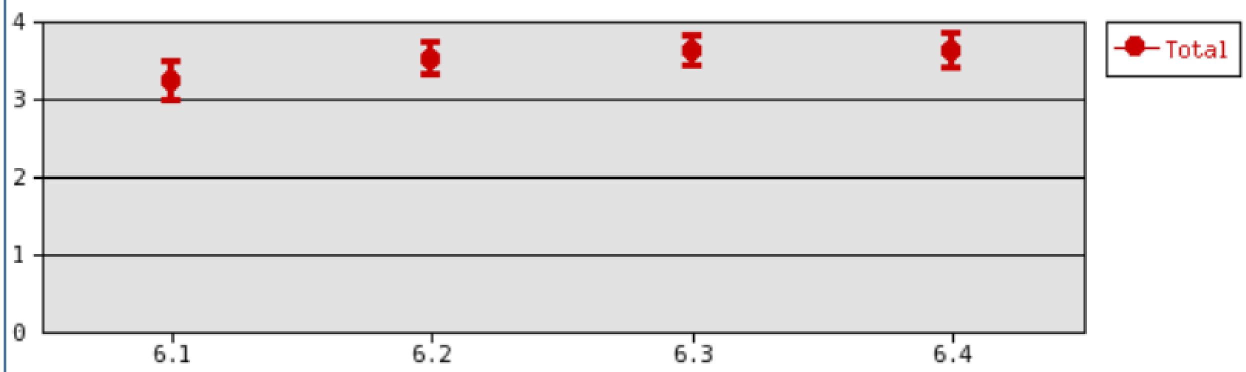


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Attitude Gains evaluated by the SALG Survey in the Treatment Group

Class impact on your attitudes

6. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
6.1 Enthusiasm for the subject	14%	15%	21%	20%	18%	0%	3.2	117
6.2 Confidence that you understand the material	3%	11%	27%	28%	18%	1%	3.5	116
6.3 Your comfort level in working with complex ideas	3%	11%	24%	31%	18%	1%	3.6	116
6.4 Your willingness to seek help from others (teacher, peers, tutor) when working on academic problems	8%	11%	18%	24%	27%	0%	3.6	117

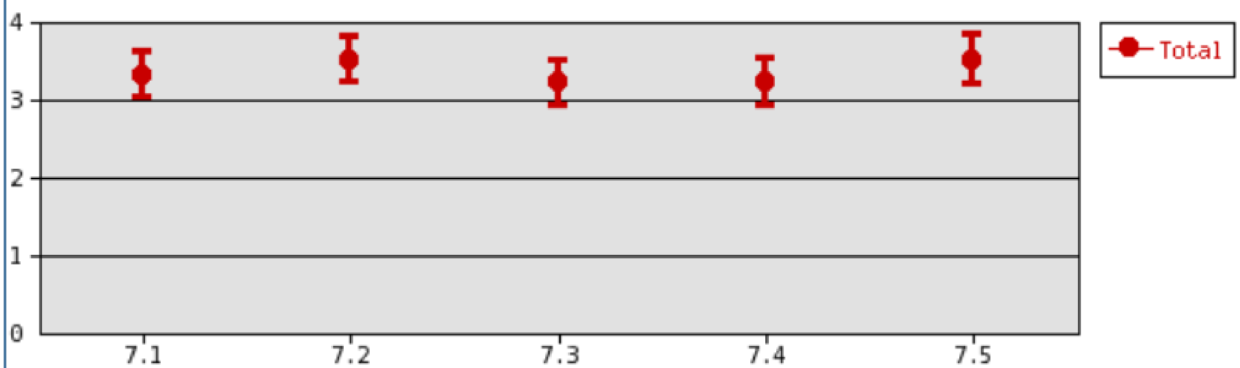


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Integration of Learning Gains evaluated by the SALG Survey in the Control Group

Integration of your learning

7. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
7.1 Connecting key class ideas with other knowledge	9%	14%	23%	35%	12%	0%	3.3	61
7.2 Using systematic reasoning in my approach to problems	6%	12%	27%	27%	20%	0%	3.5	61
7.3 Applying what I learned in this class in other situations	9%	15%	26%	32%	11%	0%	3.2	61
7.4 Using a critical approach to information and arguments I encounter in daily life	11%	17%	24%	27%	12%	2%	3.2	60
7.5 Using feedback provided from quizzes to prepare for future classes or graded events	8%	11%	20%	32%	21%	2%	3.5	60

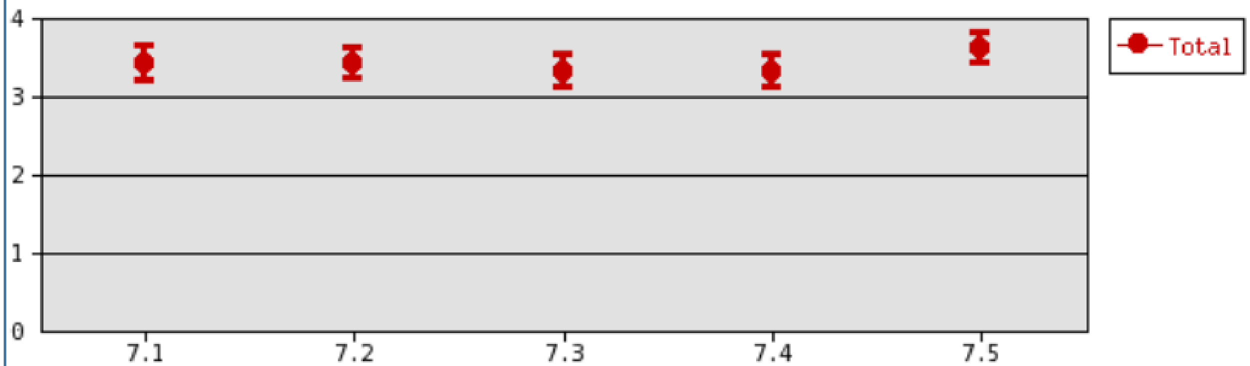


The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

Beginning of Semester Integration of Learning evaluated by the SALG Survey in the Control Group

Integration of your learning

7. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
7.1 Connecting key class ideas with other knowledge	5%	17%	23%	26%	17%	1%	3.4	116
7.2 Using systematic reasoning in my approach to problems	5%	11%	26%	28%	17%	1%	3.4	116
7.3 Applying what I learned in this class in other situations	8%	15%	28%	22%	15%	1%	3.3	116
7.4 Using a critical approach to information and arguments I encounter in daily life	10%	11%	25%	30%	11%	2%	3.3	115
7.5 Using feedback provided from quizzes to prepare for future classes or graded events	5%	8%	24%	29%	20%	2%	3.6	115



The figure above shows the mean with confidence interval (±3 times the standard error) for each item.

End of Semester Control Group Targeted responses

1. Please answer the following questions	1:Yes	2:No	3:It makes no difference to me	Mean	N
1.1 If given the choice (and if the quizzes were identical), would you prefer to take a digital quiz (iPad or computer) over a paper quiz?	3%	79%	11%	2.1	61
1.2 If given the choice, would you prefer to receive your grade and go over problems immediately after the quiz (as opposed to the next class)?	59%	15%	18%	1.6	61
1.3 Did you feel more comfortable asking questions about material when you identified that you were not the only person who got the question wrong?	71%	6%	15%	1.4	61
1.4 If given a choice, would you prefer a multiple-choice quiz over a traditional quiz?	55%	20%	18%	1.6	61

2. Please answer the following questions:	1:When I get feedback immediately after the quiz	2:I like to let it simmer for a day or two then get feedback	3:I don't care because it is done and I can't change it	Mean	N
2.1 When does the quiz feedback help your learning the most?	52%	33%	8%	1.5	61

3. When it comes to feedback following quizzes	1:Much too early	2:Somewhat too early	3:Just right	4:Somewhat too late	5:Much too late	Mean	N
3.1 The timeliness of feedback following the quizzes in your class was	2%	5%	58%	29%	0%	3.2	61

End of Semester Treatment Group Targeted responses

1. Please answer the following questions	1:Yes	2:No	3:It makes no difference to me	Mean	N
1.1 If given the choice (and if the quizzes were identical), would you prefer to take a digital quiz (iPad or computer) over a paper quiz?	37%	25%	26%	1.9	117
1.2 If given the choice, would you prefer to receive your grade and go over problems immediately after the quiz (as opposed to the next class)?	74%	4%	10%	1.3	117
1.3 Did you feel more comfortable asking questions about material when you identified that you were not the only person who got the question wrong?	65%	3%	20%	1.5	117
1.4 If given a choice, would you prefer a multiple-choice quiz over a traditional quiz?	53%	18%	17%	1.6	117

2. Please answer the following questions:	1:When I get feedback immediately after the quiz	2:I like to let it simmer for a day or two then get feedback	3:I don't care because it is done and I can't change it	Mean	N
2.1 When does the quiz feedback help your learning the most?	75%	10%	3%	1.2	117

3. When it comes to feedback following quizzes	1:Much too early	2:Somewhat too early	3:Just right	4:Somewhat too late	5:Much too late	Mean	N
3.1 The timeliness of feedback following the quizzes in your class was	0%	2%	80%	6%	0%	3.1	117

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