Why Think about Learning? The Value of Reflective Learning in First Year Engineering Design

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Abstract

The current generation of college students is on a quest for meaningful knowledge and relevance in learning, and educators are continually challenged to meet these needs. Students will no longer accept the necessity of learning copious amounts of technical and scientific information "just because." Faculty often attempt to provide relevance by presenting real-world examples, but even these are not "real" to a student who fails to identify the connection or usefulness of the subject.

During the 2013-2014 and 2014-2015 academic years, we implemented a simple, weekly reflective journal assignment in our first year, project-based engineering design course, which consists of three questions: *What did you learn? Why is it important for you to learn it? How else could you use it, in other courses, work or home (be specific)?* The fifty students in each semester's course described one or more skills and reflections for each week of the semester, and received grades and feedback every 2–4 weeks.

In addition to allowing students to identify what they learned and its relevance (thereby reinforcing skills and insights and promoting their retention), we were able to determine particular skills or insights throughout the course that students found to be useful in some of their other courses taken concurrently. Not only does repetition promote retention, but the use of a particular piece of knowledge or skill in more than one course further emphasizes its importance to the student.

Final grades and reflective journal data have been evaluated for five cohorts. Three of the cohorts completed reflective journal assignments, and two did not, the latter serving as a control group. We identified the following research questions, in order to determine the effect of this type of reflective journal on overall student learning in our course:

- Is there a difference in final course grades between students who completed the reflective journal assignments and those who did not?
- Is the relationship between course grades and reflective learning the same for men and women?
- Does this practice of reflective learning correlate to individual improvement in course assignment grades over the course of the semester?

Final grades for the course were determined through two individual assignments (20% of the final grade), and five team assignments (40% of the final grade), where every team member receives the same grade. The remaining 40% consisted of a combination of individual- and team-based grades: reflective journal, peer evaluation, mentor evaluation, and engineering graphics. Because assignments in engineering graphics contribute 20% to the final grade, and were graded on a pass/fail basis, we compared student performance both with and without the graphics grades.

On an overall basis, we have not found a dramatic difference in course grades, both with and without the reflective journal assignment and when graphics grades are included. However, there are differences among men and women students that more or less offset one another; i.e., women's grades increased and men's grades decreased by similar amounts. When graphics grades are not included, overall student performance in final course grades increases with the inclusion of the journal assignment, and increases for women but not for men. Results for individual improvement in course assignment grades over the course of the semester are inconclusive. We suspect that this result occurs because only two individual project-based assignments, nine weeks apart, can be compared directly.

Introduction

Reflective learning methods helps students to realize that "real engineering" is more than graphs and equations, and involves the sharing of ideas [1]. The reflective journal has been, and will continue to be, a useful tool that helps students to discover the relevance of their education, as well as to promote the type of intellectual development necessary to become effective engineers [1]. We used a simple reflective learning template, in the form of a weekly 3-column table, since the fall 2013 semester at our technically based institution.

While all of our degree programs strive to develop and strengthen creative and critical thinking skills through instruction and practice in increasingly complex technical problems, this development begins in the student's first year of engineering education [2], if not beforehand. In addition to the potential benefits to student learning, reflective journals have provided useful feedback to our course instructors as to which fundamental engineering skills were considered by students to be the most useful at this stage of their education. In this way, we obtain additional data for assessment of course effectiveness against learning objectives or outcomes.

Background

Our one-semester, first year design course is taken by nearly 800 students. The typical class size is 50 students with two instructors per class. These classes may also contain small numbers of second- or third-year students, who were not able to take the course during their first year. The course learning outcomes include the ability to exercise creative and critical thinking skills to solve open-ended engineering problems through collaboration on a team, an ability to select an optimal solution, and an ability to effectively communicate the design solution and its intermediate stages: graphically, orally and in writing. [1-2] Reflective learning relates to the development of creative and critical thinking skills, by revealing knowledge or skills that might not be immediately evident, but often turn out to be useful, creative and/or innovative.

Another major motivator for students to learn and use any skill or insight is their own perception of its relevance. The work of Turns et.al asserts that it is necessary to employ reflection to discover the "deep lessons" of engineering design, implying that reflection helps to provide relevance.[3] Similarly, Palmer et. al. identified the role of reflection as providing "new understandings" that students would add to their own accumulated knowledge and experience, thereby adding relevance on a personal level. [4]

To benefit from reflection, students need to refine their learning skills by realizing that not all knowledge is absolute; much of it is uncertain and depends on context. [5-6] This is a major

developmental step for many students, as they realize that it is up to them, not their instructor, to determine what to do under what kinds of circumstances, as well as how to choose among several possible courses of action.

Since our classes contain both men and women, and a number of studies exist about the manifestations of each gender's respective learning style, we noted a study by Stump, Hilpert, Husman, Chung and Kim [7] about collaborative learning techniques and their more extensive use by women students than by men students. What does collaborative learning have to do with reflection, since one is a group activity and the other is individual? The relationship between the two lies in the fact that collaborative learning often leads to a revelation of gaps in knowledge, a subsequent expansion of knowledge, and an increase in self-efficacy, all of which can also be gained by reflection [7]. Given these gender differences in collaborative learning, and the similarities between collaborative learning and reflective learning, we were curious to see if men and women students would show differences in course achievement as a function of whether or not they were engaged in reflective learning.

Finally, we are also dealing with a student population belonging to the "millennial generation", who were born between 1993 and 1996, which is either near the end of this era or in the middle of it, depending on how it is specified. [8, 9-17] This generation is characterized as being self-centered, narcissistic and financially insecure [10-12], which might cause them to place a heavy emphasis on receiving very high grades for their course work due to a sense of entitlement and the necessity to repay large student loans after graduation [11-12]. At the same time, "millennials" are lauded for their enthusiasm and optimism for their work,[16] as well as exhibiting more of a willingness to be open-minded, energetic and adaptable.[16] Their strong sense of collaboration and interdisciplinary acceptance has been attributed to an intrinsic familiarity with network computing and other group-oriented aspects of the Information Age, such as social networking.[9,14,16] Thus, we were particularly interested to see how students from this generation would engage with a reflective learning assignment.

We recognize that, for better or worse, we need to address the attributes of the millennial generation, both positive and negative, in order to deliver the type of education that they will find meaningful, without letting them totally "run the show." Therefore, reflective learning can provide a powerful way to discover what is meaningful for students, both in its practice and in its results.

Objectives for This Study

We concentrated our efforts in this particular study on the following research questions:

- Is there a difference in final course grades between students who completed the reflective journal assignments and those who did not?
- Is the relationship between course grades and reflective learning the same for men and women?
- Is this practice of reflective learning associated with any amount of individual improvement in course assignment grades over the course of the semester?

By focusing on performance on graded assignments, as well as overall course grades, our emphasis becomes the influence of reflective learning on an aspect of college where students of

the millennial generation place primary importance, because of their overwhelming concern to secure an engineering position with a high salary after graduation.

Reflective learning skills could also influence the quality of both individual and team-based course assignment deliverables, provided that students considered the meaning and importance of what they were learning as a way to add value, such as including a description of the long term benefits of the design solution to the client and end users. These descriptions, justifications and evidence are gained through thinking, in a reflective manner, about the ramifications of what the students are designing to solve the problem(s) presented by the project client.

Research Methodology

A weekly reflective journal assignment was given to approximately 50 students during each of our fall and spring semesters, using a template containing sixteen rows and three columns. Each row corresponded to a specific week in the semester. The columns contained responses to these questions: *What did you learn? Why is it important? Where else could you use it?* During each week, students identified a specific skill, concept or insight that they learned during that week, explained its importance to them, and gave an example of where else they could use it, e.g., in another course, on the job or at home. Each 3-4 week submittal was graded utilizing a qualitative assessment of the student's level of effort and insight. The sum of the five intermediate journal grades comprised 5% of the student's course grade.

Final course grades were determined through a combination of individual (55%) and team-based (45%) assignments over the course of a 16-week semester. Individual assignments consisted of the following:

- project clarification statement
- subsystem analysis report
- peer evaluation against team contract
- final average peer evaluation score
- mentor evaluation score
- graphics homework and exams

Team based assignments included the following:

- project letter of understanding
- project plan
- team contract
- final design report
- final graphics portfolio

Data Collection

Data were sourced directly from the completed grade sheets after all individual and team grades had been entered. Grades from certain semesters (labeled in graphs presented below) were chosen specifically for this study. The semesters were chosen on the basis of having had no reflective journal assignment, versus having had a reflective journal assignment. The last requirement, when selecting the semesters to analyze, are that they had to have had similar

instructors to remove the variable of content having been taught, presented or graded differently. This mitigated the effect of the teaching style of the instructor on the way that the course material was presented as a whole and limited the effect that changes in grading style would have had on the dataset.

We also compared average final grades for entire classes and for men and women separately, without the inclusion of the graphics grades, which comprised 20% of the final course grade. In addition to the fact that the graphics lessons were taught by a different instructor, grades varied widely among all students in any one class because of the fact that some students need much more time than others to master visualization and graphic depiction – sometimes more time than the course duration allows.

Data Analysis

Grades were processed by calculating normalized averages for the following categories:

- the overall average grade for the entire class
- the overall average grade for the entire class without graphics
- the overall average grade for the entire class without the reflective journal
- the overall average grade for the entire class without both
- the overall average grade for women
- the overall average grade for women without graphics
- the overall average grade for women without both graphics and journal
- the overall average grade for men without graphics
- the overall average grade for men without both graphics and journal

Table 1: Full Data Set

Semester	F2011 CD	F2012 CD	S2013 CD	S2013 IJ	F2013 CD	S2014 CD
Data Label						
Overall average final grade	84.85	91.39	88.90	88.68	84.18	88.61
Average, no graphics	86.83	92.54	89.89	90.50	86.83	92.54
Average, no journal					86.16	85.73
Average, no graphics or journal	86.83	92.54	89.89	90.50	89.76	87.43
Women's average final grade	86.63	94.52	88.11	86.33	84.45	92.01
Women's average, no graphics	87.74	94.65	91.75	90.04	88.81	94.15
Women's average, no graphics or journal	87.74	94.65	91.75	90.04	91.75	89.23
Men's average final grade	83.81	90.61	89.07	89.90	84.06	86.84
Men's average, no graphics	86.30	92.01	89.95	90.74	85.99	88.88
Men's average, no graphics or journal	86.30	92.01	89.95	90.74	88.90	86.33

Note: "CD" and "IJ" are course section designators.

Table 1, shown above, contains all normalized calculated grade averages for the overall data set. Each category is presented with all available data. Final grades for semesters Fall 2011 CD through Spring 2013 did not have the reflective journal exercise, leading to the statement of non-applicability. This also means that the averages shown for the average without both, and the average for women and men without both are duplicates of the scores shown for the values of the average without graphics, since there was no further removal and recalculation possible due to no journal assignment. These duplicates are shown in italics and were removed during the graphing phase of analysis as they would have merely produced a duplicate point.

The removal of a particular score or scoring category, such as graphics or the journal, was compensated by recalculating the overall total of possible points and the subsequent "new" percentage that emerged, thereby allowing for direct comparison of a full or partial score through normalized percentages. All percentages were normalized from a full semester of one hundred as the full possible percentage.

Particular grades or grading categories which were removed were chosen based on their relevance to the process of reflective learning, as well as by instruction delivered by a different instructor in the graphics portion of the course, as well as student performance based on an innate talent for visualization, or lack of it, as mentioned above. By removing the journal itself, and the grades earned by the effort put into the entry and significance of the reflections stated, the benefit that the journaling process had would be more apparent within the data sets by the effect it had on the grades. By removing the grades earned in the graphics portion of the course, the remaining grades and their influence could be compared on an equal basis. In addition, while some students chose to reflect on the skills that they had learned in graphics, reflective learning instruction and practice were not included as part of graphics instruction.

Results

Figures 1, 2 and 3, below and along with Table 1, indicate that students who practiced reflective learning received higher scores, on average, than those who did not. We can state this because, when scores for reflective learning are removed from total scores for the "reflective learning" cohort, the average of the normalized scores is still higher than for the students without the reflective learning opportunity. This also indicates that, when students were encouraged to reflect on what they had taken away from a given lesson or topic, they did better than when they were not given that assignment.
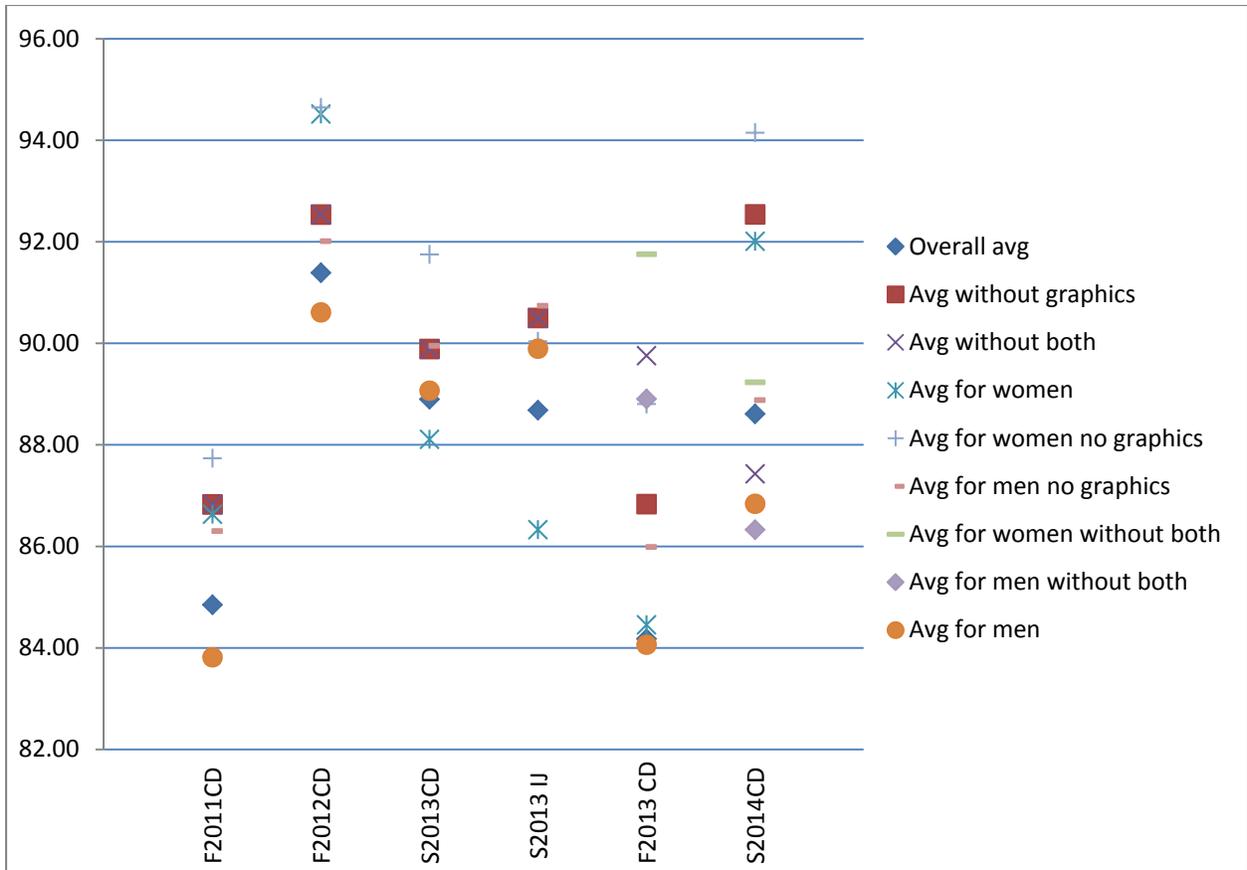
Figure 1: A plot of all values, normalized to reflect their relation to a full score of 100%. Trends are mapped and are listed to the side.
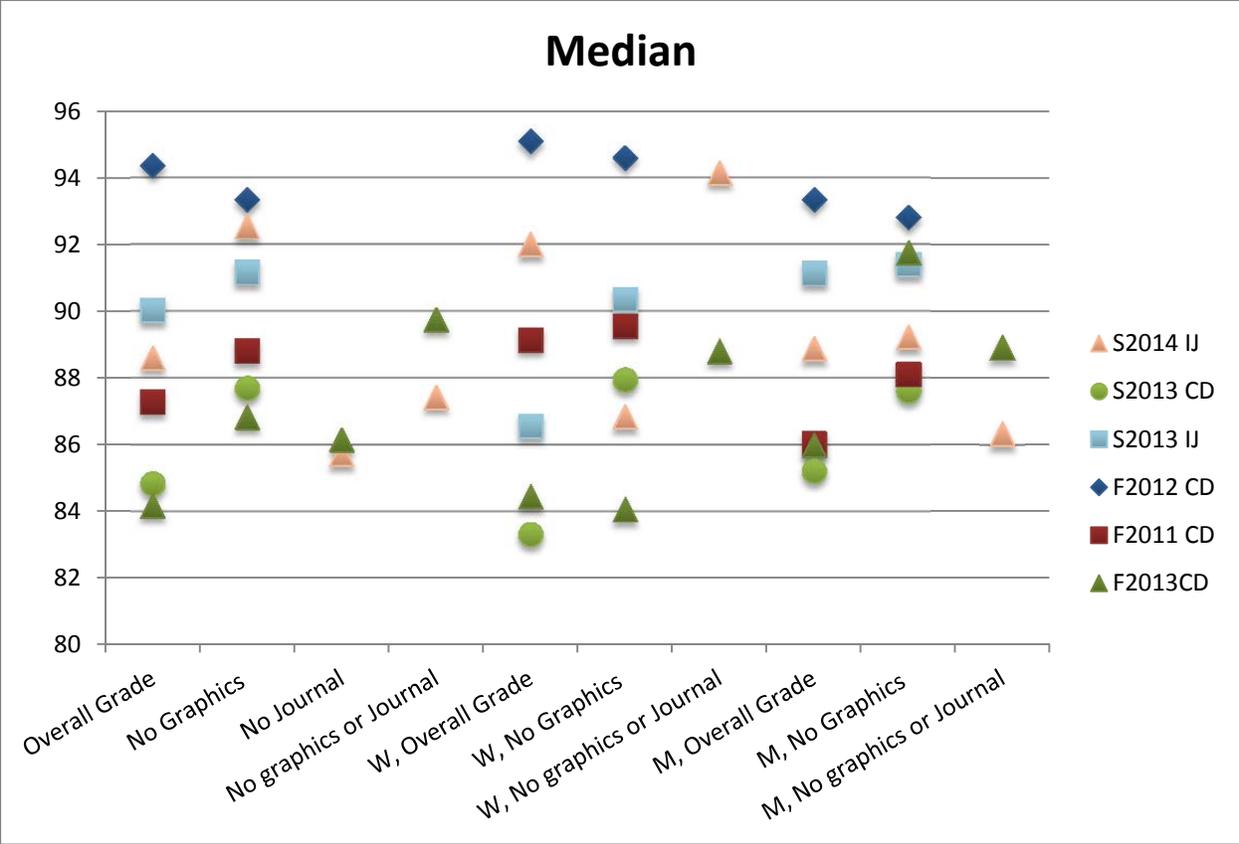
Figure 2: A plot of the median value for each of the designated scoring categories, with each series marked. "W" stands for women and "M" for men along the x-axis labeling to keep the chart from becoming cluttered.
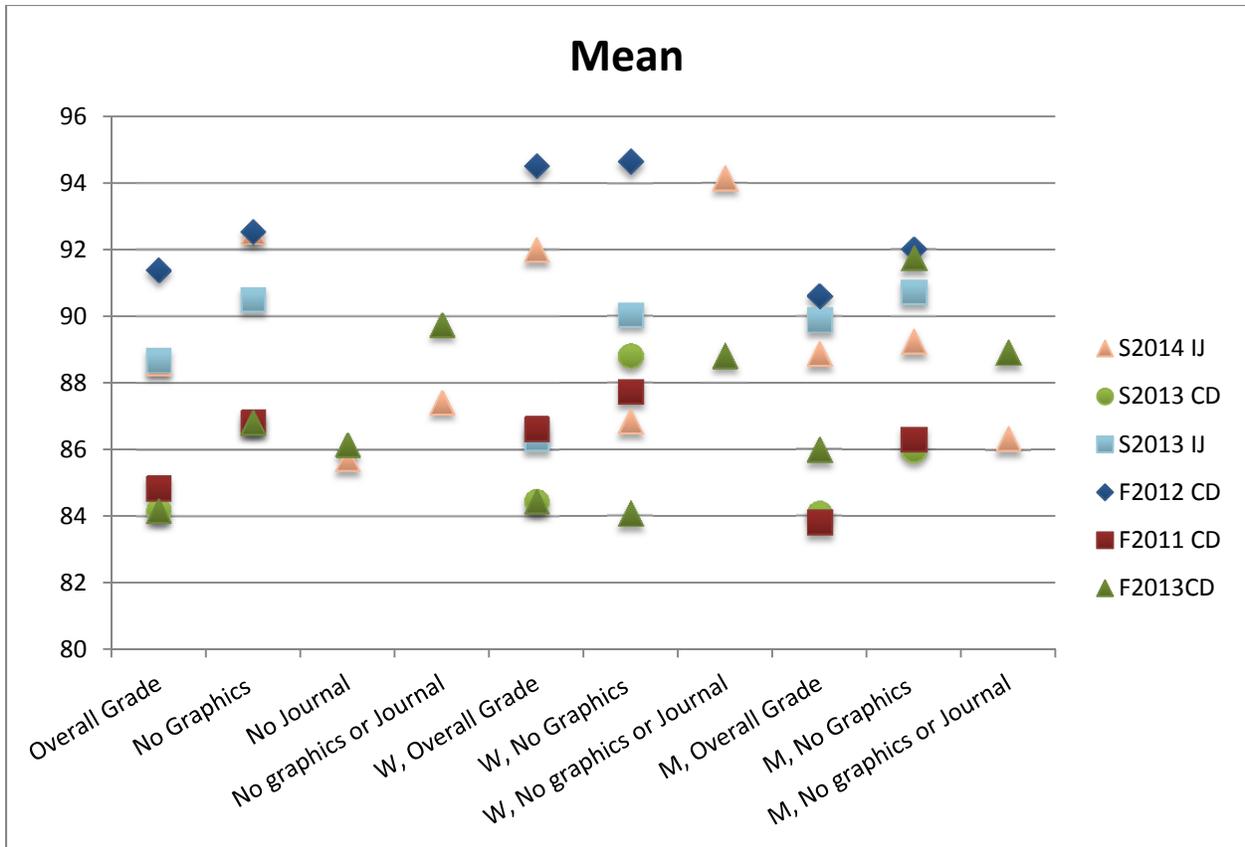
Figure 3: A plot of the mean value for each of the designated scoring categories, with each series marked. "W" stands for women and "M" for men along the x-axis labeling to keep the chart from becoming cluttered.

A more noticeable improvement in scores, shown in Figures 1, 2 and 3 above and Figures 4 and 5 below, shows the difference between the grade ranges of men and women with and without the reflective journaling opportunity.
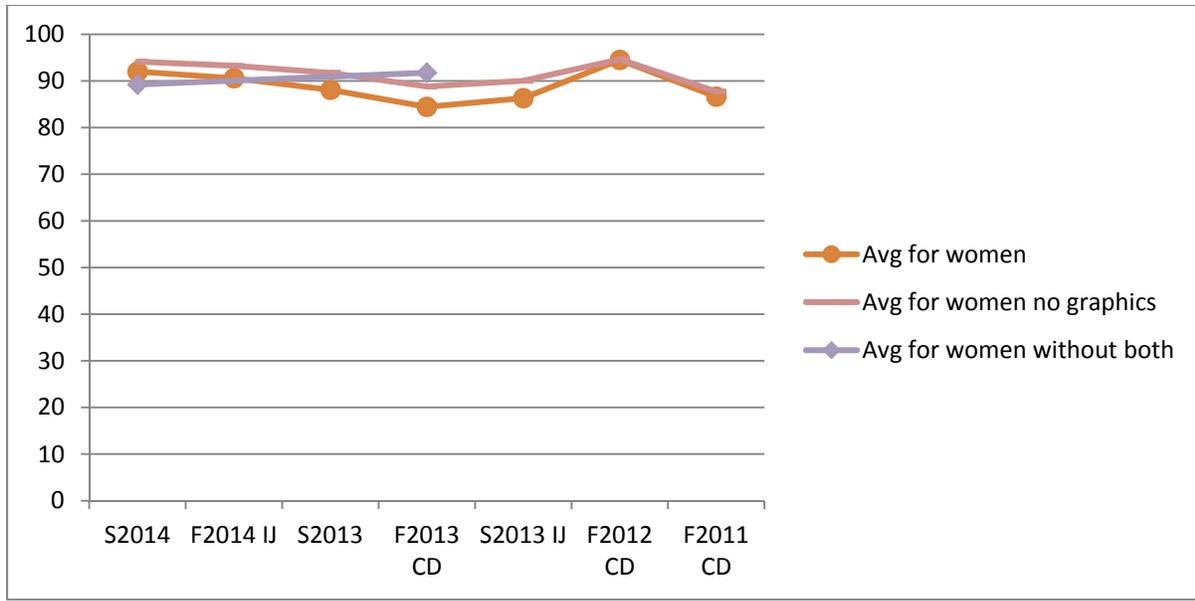
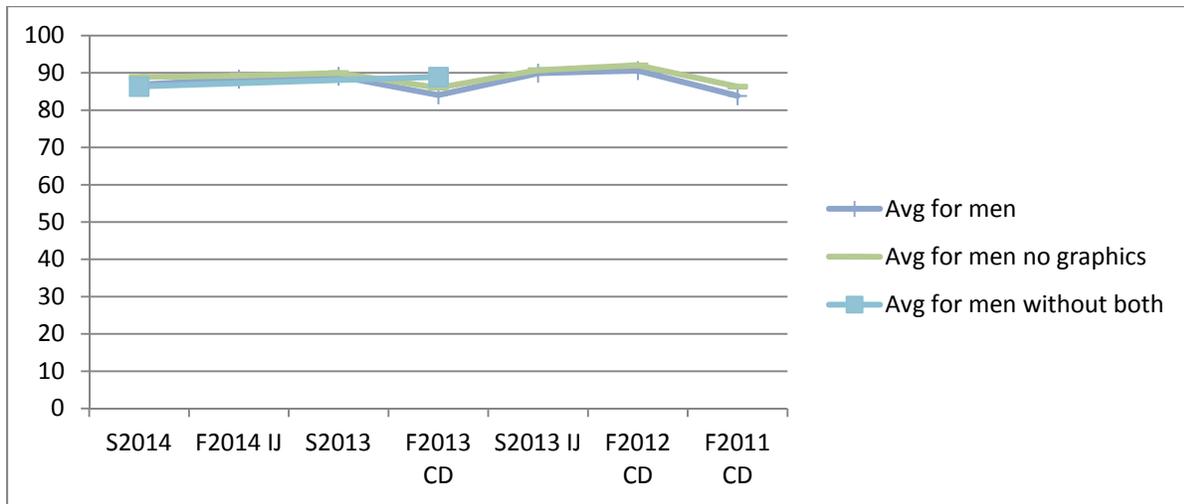Figure 4: Overall scoring trends and grades for women.

Figure 5: Overall scoring trends and grades for men.

Women show an overall improvement in final grades with the reflective journal included in their curriculum, while men show no improvement in their final grades, instead presenting with a lower than average final grade. Reflective journal entries were not graded based on grammar, spelling or use of proper English, but instead on the reflections stated within and the relevance of those reflections towards the student's ability to use what had been taught in the academic and professional setting. This grading scheme removed the higher scores that the women may have had purely based on that most women have higher scores in English than their male counterparts. Instead, this shows that the women were benefiting more from the journal and the ability to draw connections between the given lesson and the relevance on future assignments or career related items.

This improvement becomes more noticeable when comparing the median and mean scores as opposed to the complete table of data. In Figures 2 and 3, showing the median and mean plots, women's scores, from semesters Fall 2013 and Spring 2014, are seen to be significantly higher than the scores from previous semesters. Likewise, the scores of men are shown to decrease or remain static. These trends are highlighted in Figures 4 and 5 above.

Discussion

We have not found a dramatic difference in course grades, on an overall basis, both with and without the reflective journal assignment and when graphics grades are included. However, there are differences among men and women students that more or less offset one another; i.e., women's grades increased and men's grades decreased by similar amounts. These differences may be attributed to the characteristics of the men and women students in any particular class, as well as a greater willingness among the women students to take the reflective learning assignments more seriously and invest greater effort in producing thoughtful entries. This is not to say that certain men students were not equally thoughtful, but it is possible that the women students used their reflective skills to a greater extent in their project-based individual and team-based written assignments.

When graphics grades are not included, overall student performance in final course grades increases with the inclusion of the journal assignment, and increases for women but not for men. Historically, women's final grades have been negatively affected by the inclusion of graphics assignment and exam grades, although exceptions exist when we have women students who have prior graphics-based experience.

Results for individual improvement in course assignment grades over the course of the semester continue to be inconclusive. We suspect that this condition occurs because only two individual project-based assignments, nine weeks apart, can be compared directly. Graphics grades are only given for individual student work, and graphics assignments consist of weekly homework and in-class exams, while the project side of the course contains written documents with graphical illustrations, produced by either individuals or teams, along with other written assignments such as team contracts and peer evaluations.

Conclusions and Recommendations

A number of changes have been made to our first year design course since these data were collected, including a greater emphasis on individual development in the form of graded design logs kept by each student throughout the semester, and an increase in graphics grading weight from 20% to 25% of the final grade. Both of these changes are intended to promote more individual thought and reflection, intended to be shared for the benefit of the project team and a more successful solution to the semester's design problem.

Beginning in the spring 2015 semester, we also incorporated a weekly in-class reflective learning exercise, using the same questions as in this study, which was not graded, but whose contents would contribute to a journal containing cumulative reflections over several weeks at a time. We This graded journal contains questions about which skills the students found most interesting, most difficult and most likely to reveal the role of uncertainty in knowledge. We made this change, in part, to encourage deeper reflection, as well as to eliminate the tendency of students to enter several weeks' reflections at the end of the final week before the journal is due. While we cannot guarantee that most students will not write in the journal at the "last minute", we can require that what they record what they learned in a particular week at the time that they learned it, as well as in the context of the last several weeks' progression of course knowledge.

Our future work will involve a more in-depth analysis of student journal entries to discern patterns of learning and why certain students may identify certain types of knowledge as more meaningful than others, such as graphics skills vs. writing, individual progress vs. team-based learning, the identification of "conditionally-true" insights and other evidence of higher-level critical thinking skills. Even at the first year level, with its limitations in intellectual maturity, it is possible to find ways to prompt our students to develop certain higher level thinking skills which will be beneficial to them at any stage of their academic career.

Acknowledgment

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