120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7531

Promoting Metacognition through Reflection Exercises in a Thermodynamics Course

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Promoting Metacognition through Reflection Exercises in a Thermodynamics Course

Chemical engineering thermodynamics is a core course in the undergraduate curriculum, but its seemingly unintuitive nature makes it a challenge for novices to understand. At our institution, student feedback for the past several years has included complaints about having to "know" too many equations, the existence of an apparent disconnect between theory and real world examples, and a textbook they do not enjoy using. We believe that focusing on how students understand their own work with the textbook addresses not only the last complaint, but also the other two, and to that end have modified our thermodynamics course structure with an emphasis on reading activities and self-reflection.

Now in class, students practice regular reflection through a short weekly assignment that we call "the reflection paragraph," which supplements the regular problem solving homework. Students are instructed to write 200 words to explain what they have learned and to provide evidence of that learning. They are also given a series of prompts designed to explore the way they study for the course and to encourage them to make more direct connections between theory and their own experiences and learning. Students also self-assess their reflection using a provided rubric. The course instructor provides comments as feedback for the first few iterations of this assignment without an impact on the grade before starting to numerically assess the student responses and self-assessment for the rest of the semester.

Further, in-class activities include regular use of a reading activity, in which students take time to explain to one another the most important details of the week's textbook reading, then discuss why those details are important and relevant. This reading activity leads into a short assignment of listing what points are unclear about the current problems worked in class, which helps to guide the examples and mini-lectures conducted by the course instructor.

In this paper, we discuss in more detail the logistics of administering, collecting, and assessing student reflection exercises, as well as discuss the importance of self-reflective activities. We will explore the correlations between student self-assessment and instructor assessment on the reflection paragraphs, and provide the results of an attitude survey regarding the incorporation of reflection exercises into the course. Most importantly, we will report the impact of this required reflection activity on traditional exam performance in thermodynamics.

Introduction

The Chemical Engineering Thermodynamics course in our University is taught in the first semester of the junior year. The pre-requisites for this course are Material and Energy Balances, Organic Chemistry, and Multivariable Calculus. This course is taught co-currently with Fluid Mechanics as the other required core course in the major. The course is taught in one semester and is a pre-requisite for Reaction Kinetics and Chemical Process Control (both taught in the

second semester of junior year). In our past experience we have observed that students perceive that the material covered is non intuitive in nature and there are few practical pieces to relate to. Students' feedback at the end of the year (2006-2009, 2011) noted disconnects between theory and real world examples, complaints about the mathematics/equations used throughout the course, and finally not enjoying the textbook by Smith and Van Ness[1]. During the Fall semester, 2012, we developed a new approach to the course with two goals: 1) students will actively read the book[2], 2) students will reflect on thermodynamic learning[3] and also self-assess learning techniques.

In previous years, the Thermodynamics class at our University would consist of a typical lecture, followed by solving problems in group format. This semester, class time changed to a reading activity, followed by a concept clarity feedback, and then solving problems based on the students' feedback. In terms of assignments, in the past a student would complete 7-10 homework problems per week, and over the course of the semester, one additional written assignment and one project. This semester, students did three homework problems and one reflection paragraph per week, frequent discussion-board posting, and one project.

The class met twice a week for a period of 75 minutes with a weekly two hour discussion session; class and discussion session attendance was not mandatory. Homework, reflection paragraph and discussion board postings were submitted individually, while the project was done in predetermined groups.

A typical class this Fall consisted of the following: students were asked to sit within their reading groups, and in turn choose what they perceived to be the most 'important' section from the assigned reading and discuss. This exercise was timed: each student had one minute to share their opinion or ask for clarification without interruption, and after the timer beeped the student that was allowed to talk would switch. The instructor would move around the room, but would not participate in the discussion. This exercise would take around 15-20 minutes. At the end, each student would individually fill out a piece of paper, explaining on one side one concept that was still unclear to them, and on the other side discussing a new concept the student learned from the activity. These two activities were inspired from previous work designed for immediate feedback between students and instructor[4]. While the students returned to their seats the instructor would quickly browse the unclear concepts side and then choose two problems that would reinforce the concept that appeared the most. Students would be encouraged to work in groups and the instructor would now move around the room and participate in the problem-solving discussion. Depending on how much time was left, the problem would be discussed in detail or briefly with the class as a whole.

Methods

Students submitted weekly reflection paragraphs. The instructions and template given to the students are included in the Appendix.

Students self-graded based on a provided rubric, and if desired they could briefly explain their reasoning. Students submitted twelve reflections throughout the semester. The first three reflections of the semester were used as calibration (self graded but the grade did not count). The remaining nine reflections were self-graded and the best six counted towards the students' final grade, a total of 6% of their course grade, making these exercises a low stakes assignment. Students received feedback from the instructor for every written paragraph.

In assessing the effectiveness of this new assignment, we compared students' final grades (as percentages) to their score on the reflection paragraph assignment (converted to a percentage). We also provided a brief survey to students to ask them about the reading exercise and reflection paragraph assignments, asking them to rate on a Likert scale of 1 to 10 (1=completely ineffective or negative, 10=completely effective or positive) how the activities affected their attitude and learning in the course, as well as whether they believed the assignment should be continued in the future.

Results and Discussion

The 53 students taking Thermodynamics during the Fall of 2012 were 70% male and 30% female. The ethnicity distribution was 50% white, 24% black, 16% Asian, 2% Hispanic, and 2% Native American; 6% did not report ethnicity.

Final Grades Vs Reflection Grade

Figure 1 Shows final overall grade plotted against reflection grades. In terms of reflection grades, there were seventeen students who received 100%, 13 received between 90-99%, eight received between 80-89.99%, five students received between 70 – 79.9%, four between 60-69.9%, one between 50-59.9%, three 30-39.9% and two students received 0 %. The correlation coefficient *r* for this data is 0.64 and the R^2-value for this data is 0.41, which means there is a statistically significant positive correlation (α=0.003) between the reflection grade and the final grade, but one cannot be reliably used to predict the other. Additionally we acknowledge that hard working students would be expected to spend more time and effort on the reflections and other class assignments.

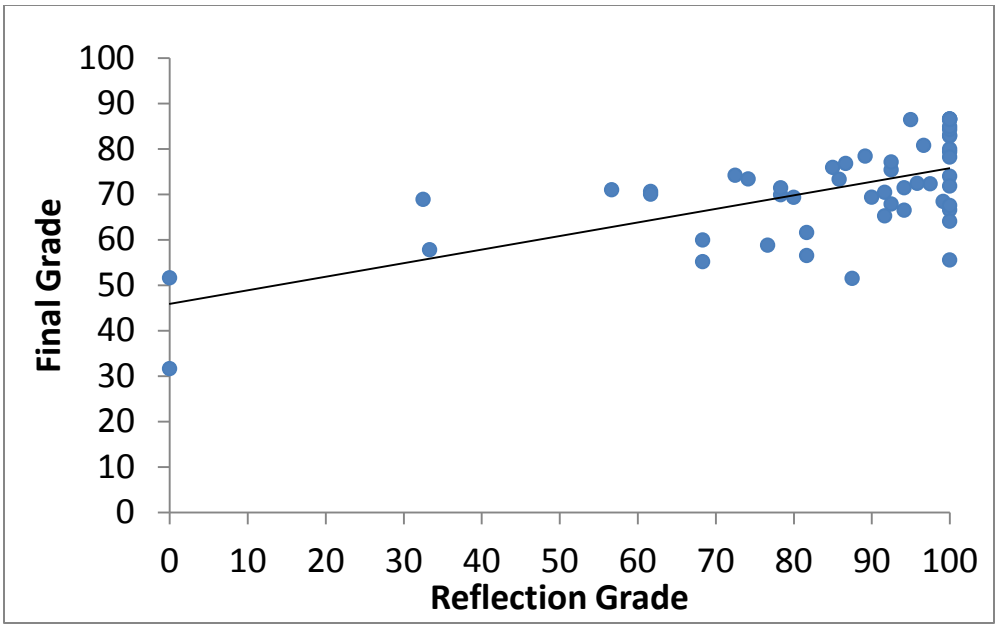

Figure 1. Positive Correlation between Student Reflection Grades and Final Course Grades

Reflection paragraph submission

The reflection paragraph was designed to be a low stakes assessment, as it only accounted for six percent of the overall grade. Submission of the reflection paragraphs varied widely; two students did not submit any of the paragraphs required and there was one student that only submitted two paragraphs. Figure 2 shows the percentage of students in the class and the paragraph submitted by the percentage of students. It is clear from the data that a low percentage of a class submitted the paragraphs regularly and that many students missed quite a number of submissions.

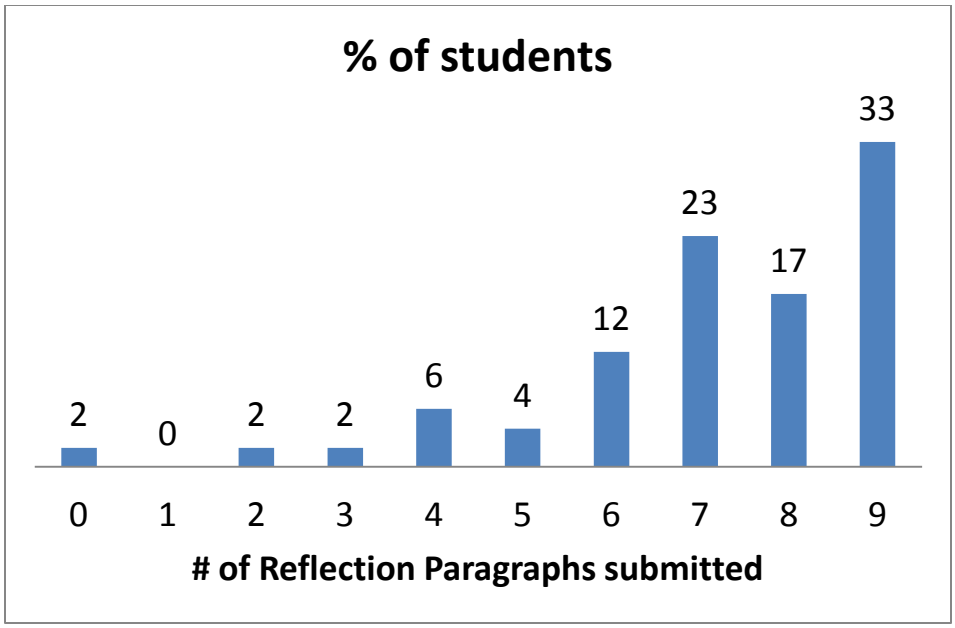

Figure 2. Proportion of Students Submitting Reflection Paragraphs

We also looked at the final grade of each student and how many reflection paragraphs were submitted throughout the course of the semester that would contribute to their final grade. Figure 3 shows the average grade of the students that submitted zero, two, three, etc. reflection paragraphs. There is no statistically significant difference in the averages shown, except for the students that barely participated in the assignment.

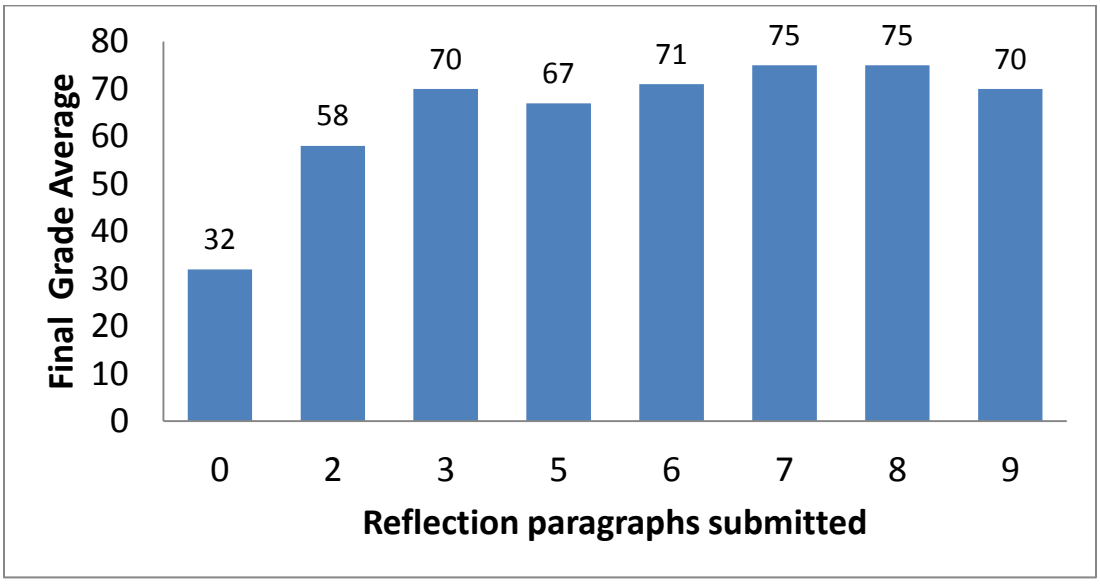

Figure 3. Average Course Grade among Students Submitting the Same Number of Reflections

Self-assessment while reflecting

Reflection paragraphs were self graded as part of the exercise, the paragraphs were graded and students received feedback on the writing and level of reflection and a final grade for that particular paragraph. We gathered the data of paragraphs submitted and calculated the difference between the self grade for each student and the instructor grade. For example, if the self-grade of the student was equal to the instructor grade that difference equals zero; the possible maximum difference is 20. In this analysis, we did not include the "calibration" paragraphs, since they could not affect the students' final grades. Figure 4 shows the overall grade and the average of the difference between their self grades and the final assigned grades for the paragraph each student submitted. The correlation coefficient *r* for this data is -0.64 and the R^2 value for this data is 0.41, which suggests a statistically significant negative correlation between the difference in grading and a student's final grade in the course. Self assessment is a useful skill that in general improves with experience and the passing of time. This skill is hard to teach in isolation. Students that are good at self-assessing can concentrate on their weaknesses and use their strengths wisely and improve their academic performance. It has been observed that US college students rate themselves above average or in the top ten percent compared with their peers in intellectual self - confidence [5]. We do not have quantitative data for our institution but through student interactions, both in class and advising, there seems to be a disconnect between the students perception of themselves and their academic performance.

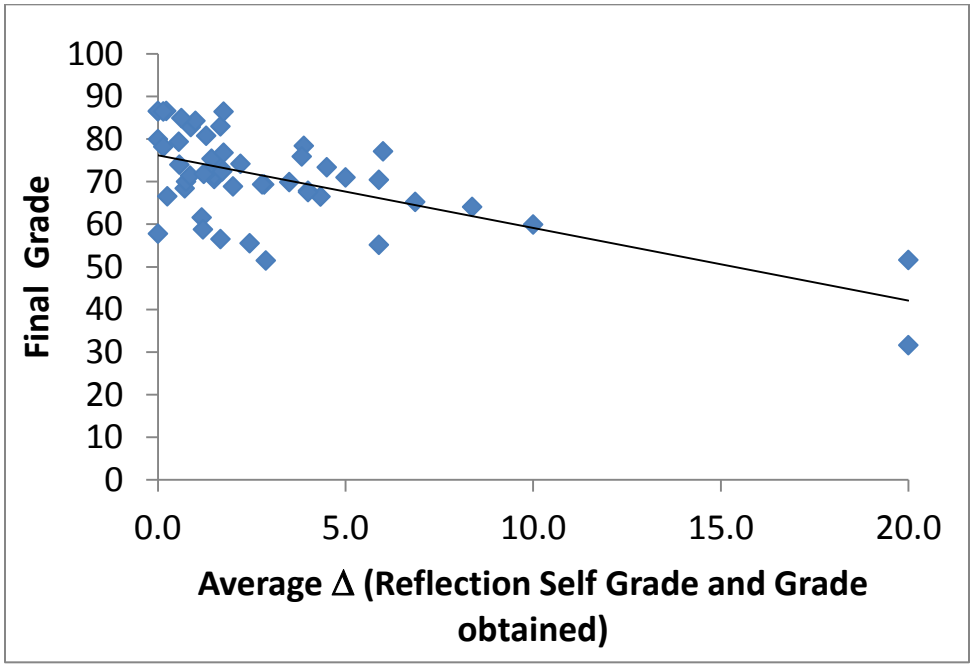

Figure 4. Negative Correlation between Discrepancy in Self-Evaluation and Final Course Grade

End of the semester survey results

The students were also asked to fill out a survey at the end of the semester. The students rated the reflection paragraph in three categories: a) continuation in future thermodynamics courses; b) attitude towards the course because of the activity; c) potential for learning. They were also invited to comment on what could be done differently with the reflection paragraph exercise. The results are shown in Table 1, 2, and 3. Overall, we can see a slight positive perception from the student population (a perfectly neutral response would be a score of 5.5), but in many cases these perceptions are not statistically significant.

Table 1. Overall survey results

	Scale 1-10	
Continuation	1-strongly disagree to 10 –strongly agree	6.27±0.79
Attitude	1-negatively to 10 – positive effect	5.98±0.68
Learning	1-decreased potential to 10 –increased potential	6.06±1.54

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Table 2. Survey results by gender

	Female	Male
Continuation	6.53±1.21	6.20±0.68
Attitude	6.1±1.14	5.94±0.68
Learning	6.27±0.74	5.97±0.57

Table 3. Survey results by ethnicity

	White	Asian	Underrepresented minorities	Not reported
Continuation	6.32±0.93	6.63±2.18	6.07±1.42	5.33±4.25
Attitude	6.16±0.81	5.88±1.47	5.50±1.39	5.67±4.25
Learning	5.92±0.72	6.25±1.47	5.92±0.75	6.00±2.63

What did the students write in the reflections?

The students produced a total of 372 reflection paragraphs that could potentially earn points towards their final grade. We analyzed the content of the last three paragraphs submitted. We sorted the responses into two main categories in terms of how students engaged in the course content: summary (reiteration of a textbook section, lecture, or homework problem) and application. The category of “application” was further divided into technical concepts in the class

setting, technical concepts outside the classroom, non-technical discussion, and meta-cognition ("thinking about thinking"). To turn this data into numerical values we determined the words that belonged to each category and then divided by the total number of words to obtain the percentage devoted to each category for that particular paragraph; the results are shown in Table 4. From this data students used the reflection paragraph to write about their overall experience and thoughts about the class and technical content was not the main focus of the exercise. The type of thoughts the students shared associated with this category: personal experiences as they worked though an exam, anxiety in school, working in groups, emotions, and time spent working in the class. The authors attribute the presence of meta-cognition as a result of requiring students to answer question prompt 6 (see Appendix).

Table 4. Percentage of Words Used for Each Category of Reflection. Reflection Paragraphs (RP) 10, 11 and 12; represent the last three paragraphs students wrote.

		RP10	RP11	RP12
Summary		0%	2%	5%
Application	Technical class	21%	27%	26%
	Technical out of class	0%	0%	2%
	Non-technical	64%	56%	44%
	Meta-cognition	15%	16%	23%

Reflection exercise – do we see a difference?

Finally, we looked at previous years' final average grades. In the years of 2006-2009 and 2011 the course was taught by the same instructor, class activities did not differ much, with the project theme as the only item that varied. Additionally, we also looked at scores from the fourth exam and the closed book exam. The technical content of this course has been divided in four sections and students are technically evaluated in an open book exam. For the years in this paper three of the four questions in Exam 4 have been exactly the same, and the fourth question was the same for years 2011 and 2012. The closed books exam has not varied much through the years (at least 85% of the questions remain the same), this exam consists of multiple choice, short answer, fill in the blanks, and simple calculations questions. Figures 5, 6, and 7 show the average course grades, exam 4 scores and closed book scores for five years; ANOVA tests for each set of data suggest that the averages are statistically different from one another with a p value of 0.05. The statistical analysis considered the 2012 group versus all others .

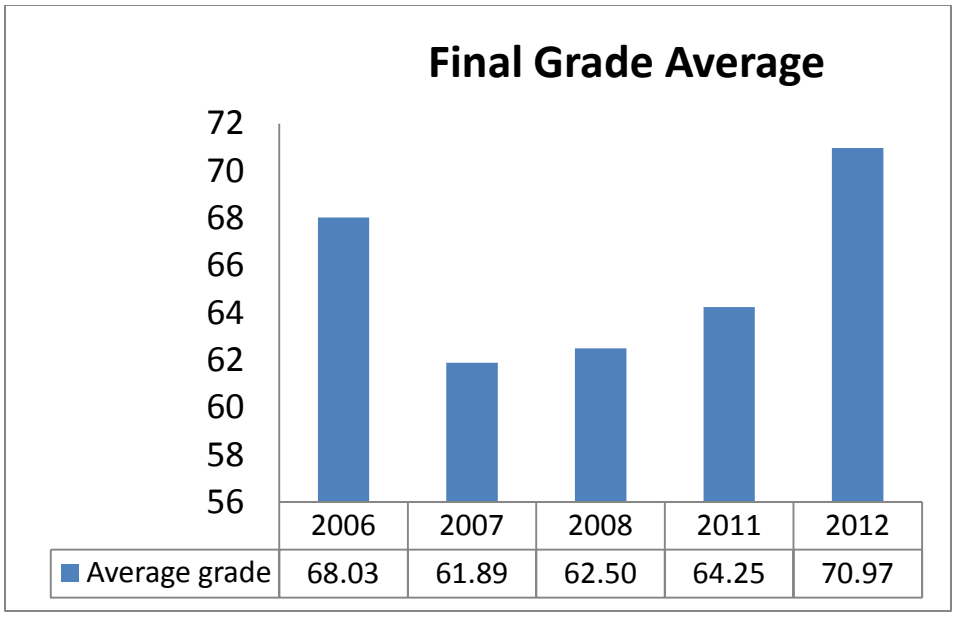

Figure 5. Final Course Grades over Five Years

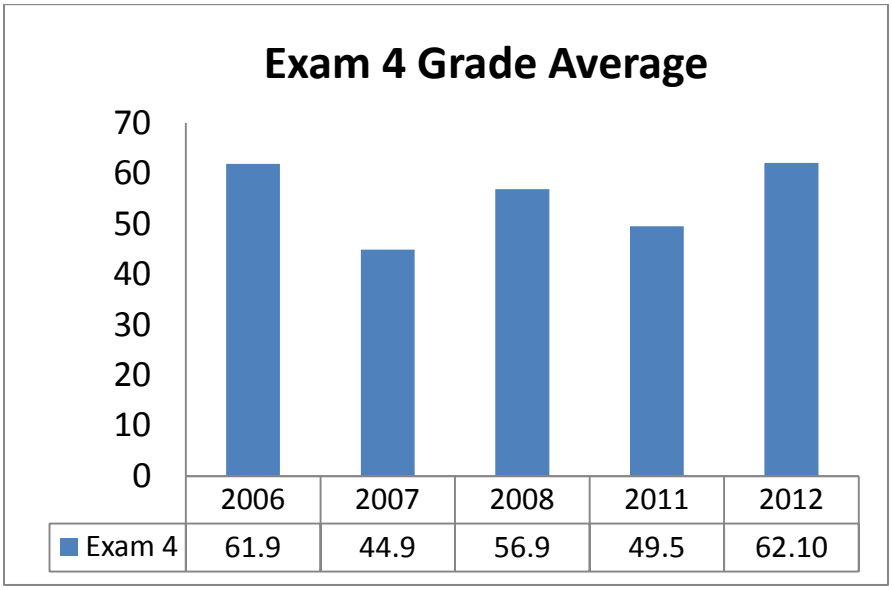

Figure 6. Final Exam Grades over Five Years

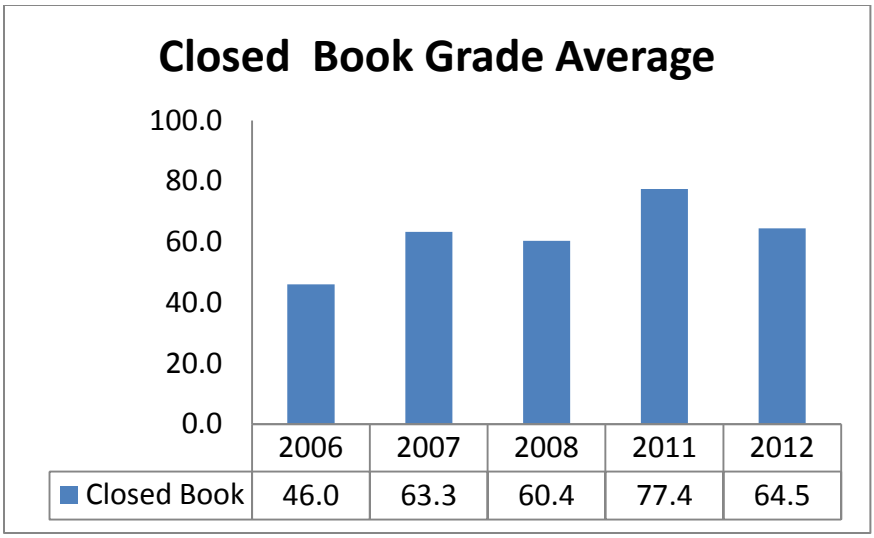

Figure 7. Closed Book Grades over Five Years

Conclusion

The main purpose of this paper was to determine if reflecting would be a worthwhile exercise for junior chemical engineering students and what effects might reflecting bring to the overall Thermodynamics experience in our University. We showed that there is a positive correlation between final grades and reflection grades, however being able to reflect in weekly 200 words assignments does not guarantee a proportional score on the technical exercises. We also observed that self-assessment capabilities also correlate with final grades, but the same applies, being able to self-assess does not secure a high score at the end of the semester.

We performed a survey at the end of the semester and observed that the reflection exercise was not enthusiastically well received by the students, but in some cases we observe a positive attitude towards the continuation of the exercise, positive posture towards the class due to this exercise, and a perceived positive effect on their learning.

We also observed that students did not use the writing to digest technical content as expected, but to relay their experience during this Fall semester.

Finally, we wanted to evaluate if encouraging our students to think and write about their thinking in thermodynamics would have any effect versus not having this experience. We see a statistically significant difference between the means of final scores, exam 4 and closed book exam. (Author's note: we are working on further statistical analysis to discern the effect).

References

[1]Smith, J. M.; Van Ness, H. C.; Abbott, M.M.; Introductions to Chemical Engineering Thermodynamics, McGraw Hill, 7th Edition, February 1 2005.

[2]Bruneau J.; Techniques to increase student reading, Wakonse, May 24-29, Muskegon, 2012.

[3]Fry, S. W., and Villagomez, A. Writing to Learn: Benefits and Limitations. College Teaching, Vol 60, No 4, p 170-175 (2012).

[4]Mosteller, F., The "Muddiest Point in the Lecture" as a Feedback Device. On Teaching and Learning, Volume 3, ege Teaching, Vol 3, p 10-21 (1989).

[5] Pryor, J.H., Eagan, K., Palucki Blake, L., Hurtado, S., Berdan, J., and Case M.H. The American Freshman: National Norms Fall 2012, Los Angeles: Higher Education Research Institute, UCLA, 2012.

Appendix

2012 Chemical Engineering Thermodynamics *Reflection*

Name:

HW: (Insert HW number)

Readings: (Indicate pages read)

Problems, Examples: (Indicate problems worked in class/discussion and problems/examples worked independently)

Questions: (Bold the questions you are answering)

1) What did you learn? How do you know you learned it?
2) What components were easy? Why?
3) What inspired you to learn? Why?
4) Why was the experience significant? Why?
5) What there a particular piece of thinking or realization that provided a change of perspective?
6) How does reflection help your learning?

Paragraph: (Include your paragraph – make sure it does not exceed the maximum number of words allowed, 200)

Self grade based on the rubric below, bold your selection.

Requirements	(20 pts)	(15 pts)	(10 pts)	(5 pts)	(0 pts)
Reflection Paragraph	A thoughtful narrative answering the 3 questions, relating the material in the week.	Quality narrative – mixing thoughts and facts; answering 3 questions.	Stating facts, answering 3 questions.	Poor quality analysis and did not answer all required questions.	Not taking the exercise seriously.

If you believe you deserve points in between the sections ie. 12 or 9, briefly explain your reasoning (does not count as part of your 200 words allowed).