AC 2010-819: THE DIARY OF A MAD STUDENT: EXAM DIARIES AND OTHER EVALUATION SCHEMES

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Abstract

The human cerebral cortex structure supports functions such as 1) sensing, 2) generalizing and 3) evaluating, which are important to the learning process.[1] This presentation demonstrates reflective activities that support the natural connection between the brain structure and the learning cycle.[2] Activities such as reviewing ideas in journaling exercises for a mathematically rigorous engineering course will be addressed. These techniques are often limited to design-courses that develop "soft-skills" in engineers. Conventional courses, however, subscribe to traditional teaching methods with fewer opportunities for student reflection. Examples of unconventional reflective journaling activities employed in an engineering course that addressed modern physics concepts and semiconductor material topics will be highlighted in this paper.

The teaching and learning model for this course was based on the established theory of the *Kolb's Experiential Learning Cycle*.[2] Exam journaling activities were adopted to support the reflective observation phase of the theoretical model and were directly assessed from the exam performance of the student. The journaling exercise required students to re-work any exam problems that the student incorrectly answered and to provide a brief statement that explains the thought process of the student that led to the incorrect solution in the preliminary computational answers to the exam.

Direct assessments of the reflective learning activities are provided in terms of exam results as well as insight to which activities that are supportive and unsupportive of the learning process. Several schemes were used to support and assess the learning needs of the student including simulation activities, in-class exercises and exams. Our preliminary results show that providing sample exam resources without reflective exercises presents the student with a false sense of learning and ultimately poor exam performances. As expected, when reflective journaling supplemented such resources, exam scores improved. As a result, students began to make the connection between the abstract theoretical concepts and familiar physical phenomena.

1 Introduction

Reflective skills are important to the development of both hard and soft skills of an engineer.[3,4] Such skills can help students practice newly acquired analysis tools as well as assist them in learning from their mistakes. The study presented in this article will provide the results of using reflective activities important to the learning process of engineering students in an advanced technical and mathematically rigorous course. A brief course description is given to establish course expectations placed on the student as well as the practical relevancy of the class. The teaching and learning model presented by *Kolb's Experiential Learning Cycle*[2] and its adaptation in the *Natural Learning Cycle*[1] was employed in this course. This work contains the teaching and learning objectives established in this course and examples of reflective journal activities related to written exams. The methods used to assess the student comprehension of the core concepts of the course and future recommendations to enhance the learning process will be discussed.

2 Course Description

Reflective journaling activities in a technically rigorous course at the undergraduate level were performed. The course was a requirement for the electronic and computer engineer curriculum that is taken during the third year (junior level) of the student matriculation process. The course focuses on topics related to electronic materials and devices such as semiconductor materials, pn junction diodes and transistors. These topics are essential to the design and operation of lasers, liquid crystal display (LCD) panels, solar cells and charge coupled display (CCD) cameras, most of which can be found in common items such as cell phones and cameras to more complex systems such as personal computers. The example journals highlighted in this study are from a recent installation of this 13-week course in the Fall 2008 academic semester and the class was composed of 18 traditional students (17 male and 1 female). The class met for lecture twice a week in 75-minute sessions.

The course was delivered to support the learning needs of the student body. The nature of the material covered in the course is very interdisciplinary with components that are based on chemistry, semiconductor physics and electro-dynamics principles. Many of the topics presented concepts that challenge the common thought process of the undergraduate engineering student. At this point of their academic career, the students have not been exposed to concepts that are contradictory to engineering tenants such as Ohm's Law. The dynamic systems that are explored are also very abstract and are not readily observed in the physical realm. For example, the concept of an electron is familiar, yet the concept of a hole is very unclear to the student. Most of the mental hurdles that the students encounter are related to reconciling such contradictory concepts. However, initially, it is unclear to the student how to achieve this understanding. Unlike the previous course experiences where the electro-dynamic equations where limited to conditions such that only linear equations were required to analyze a system, the course in question presents the Schrodinger equation and Fermi-Dirac statistics. Simple problems and equations that can be generally applied are replaced by equations with system dependent boundary conditions and material specific terms.

3 Teaching Methodology

The teaching strategy for the proposed course had a conventional format during the first four weeks of the semester. A learning centered method was adopted and reflective observation activities were emphasized during the final seven weeks of the course.

3.1 Preliminary Method

Conventional teaching methods were employed, initially. Sample on-the board-problems were performed in-class, homework problems were assigned, as well as, active learning techniques such as computer aided simulations were used to reinforce concepts. The students were given quizzes and exams to monitor their understanding of the course material. Exam reviews were provided with example questions that were representative of the actual exam material. However, this teaching method was not very successful. The students had very low exam scores (<70%). It appears that the exam reviews gave the students a false sense of understanding that crippled them for the actual exam.

3.2 Learning Centered Method

The teaching strategy was revised to include more reflective observation components to support the natural learning cycle.[1] The reflective observation components consisted of homework exercises, in-class exercises and exam journals. The class performance was assessed via homework grades and exam grades. Several schemes were used to support brain physiology and assess student-learning needs such as 1) concrete experiences, 2) reflective observation, 3) abstract hypothesis, and 4) active testing. (See figure 1.)

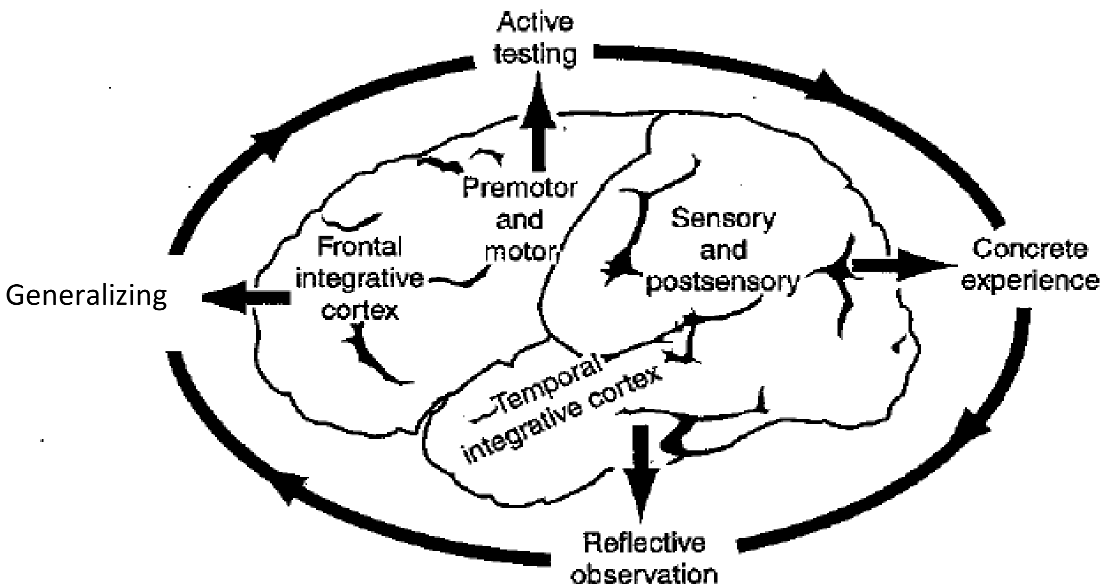

Figure 1. The natural connection between the brain structure and the learning cycle.[1]

Concrete experiences were achieved using computer simulations based on java applets[5] that demonstrate charge carrier dynamics in semiconductor materials and devices in addition to the traditional on-the-board problem solving sessions. Opportunities for reflective observation were provided to students to discuss intuitive descriptions of the simulations. (See figure 2.) Students were then asked to extend their intuitive description to simulations with modified conditions in order to develop abstract hypotheses. Active testing was performed during lecture via simulation-based polling in addition to traditional exams. (See figure 3.)

This is an example of a simulation-based polling exercise that was used to support the concrete experience and the reflective observation stages of the learning cycle:

Example: Formation of a pn-junction
Describe what is happening in the two energy band diagrams in figure 2 in terms of:

- Band edges
- Fermi-levels
- Carrier concentrations
- Charge transport
- E-field and potential

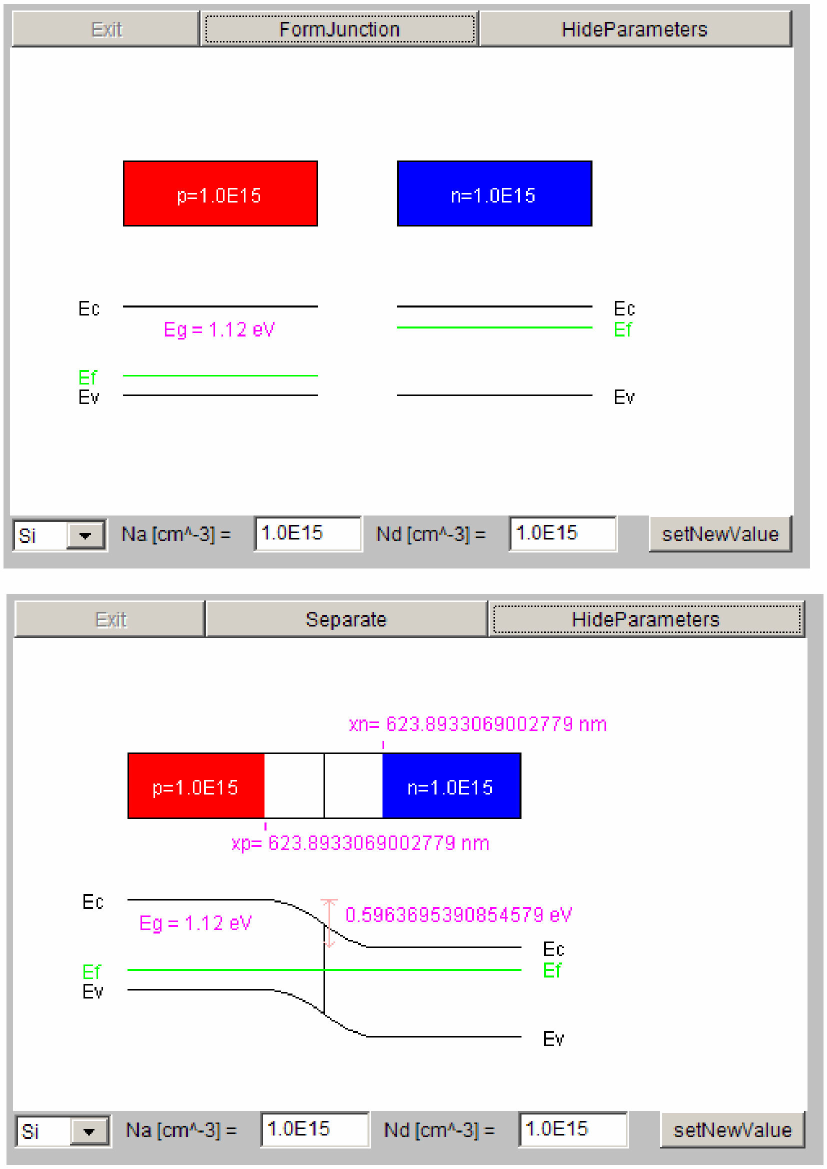

Figure 2. Example of simulation based exercises that were used to support concrete learning experiences important to the learning cycle.

These are examples of exercises that were used to support the active testing stage of the learning cycle:

Example: Charge Carrier Transport

When the junction is formed in figure 3, the large e-/h+ concentration gradients across the junction will cause the e- in the n-type material to:

1. Diffuse → p-type
2. Drift → p-type
3. Rollerblade → p-type

When the junction is formed in figure 3, the E- field causes e-/h+ currents to develop such that e- in the p-type material will:

1. Diffuse→n-type
2. Drift → n-type
3. Drift → p-type

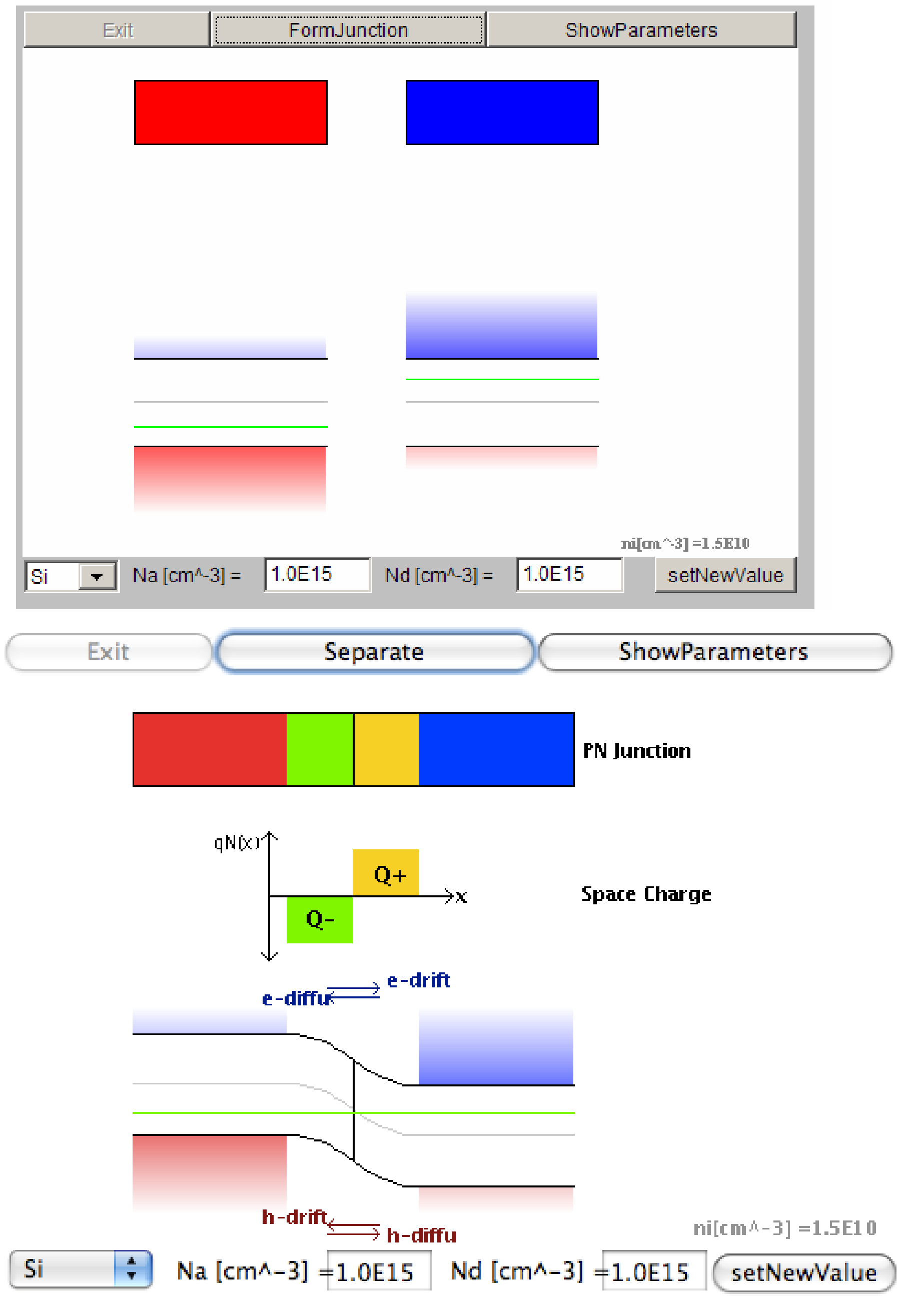

Figure 3. Example of simulation based exercises that were used to support active testing experiences important to the learning cycle.

Both computational calculations and simulation-based in-class exercises were awarded bonus points for working through a problem regardless of it being answered incorrectly or correctly to gain insight into the student thought process. In-class exercises were formatted to deconstruct and demystify the problem solving process for numerical calculations. The problem solving steps included: 1) identify theory or equation governing related process that is necessary to analyze the problem. Sketching was encouraged for applicable problems to aid in analysis. 2) Identify and list parameters that are known and necessary for solving the problem. 3) Combine results from steps 1 and 2 to solve problems. It was observed that step 3 was often omitted and these in-class exercises were not reviewed for homework exercises or exams. Students complained about separating the problem solving process with this type of approach. The students immediately plugged the equations and parametric values into their calculators to find the answer - usually a numerical answer. This behavior was an early indicator that the students would have trouble with problem solving exercises that required assumptions or preliminary decisions to simplify computational problems of the advanced material that the course addressed.

4 Direct Assessment

Materials including the in-class exercises participation, homework grades and exam grades were monitored during the first few weeks of the semester to gauge the student understanding and ability to perform analysis of technical problems. Exams were performed periodically to evaluate the students' understanding of the technical content of the course. Exam questions were similar in format and complexity in comparison to questions presented in homework assignments and in-class exercises. A typical exam was composed of four separate questions and the students were given 3 hours to complete the exam (one hour beyond typical exam requirements). The exam was usually completed by most of the class after one hour and forty-five minutes. The questions were similar to the end-of-chapter problems presented in common course textbooks.[6]

The students were assembled into groups of three or four and were given in-class problems to attempt inside or complete independently outside of the classroom. To promote group discussion and class participation the students received bonus points that would be added to their final grade for completing the exercise independent of it being correct. The in-class work was collected and reviewed by the instructor to gain insight into the intellectual hurdles that existed in the class. Very few of the students participated in the in-class activity. Most students did not write anything until the next class session when the problem was reviewed on the board and then the student would simply copy the correct answer.

The next performance indicators considered were the homework assignment grades. Homework exercises were assigned every two weeks during the course and the students had two weeks to complete the assignments. Most students performed well on the assignments such that the class average was in the 80%-90% range. (See figure 4.) Most of the exam questions were very similar to the homework exercises.

4.1 Lessons Learned from Exam#1

Finally, the exam #1 grades were considered to determine individual student performance at solving both conceptual and computational problems. Unlike the homework results, only 12 students received a grade > 70% nearly 1/3 of the class received a poor grade (i.e.<70%). (See figure 4.) Individual meetings with each student were held by the instructor during office hours to return the graded exam and to discuss their performance. Many of the students expressed during these private meetings that they never saw problems like those asked during the exam, they also admitted to guessing. The students then requested practice exams with questions “just like” the exam problems for future test preparation purposes.

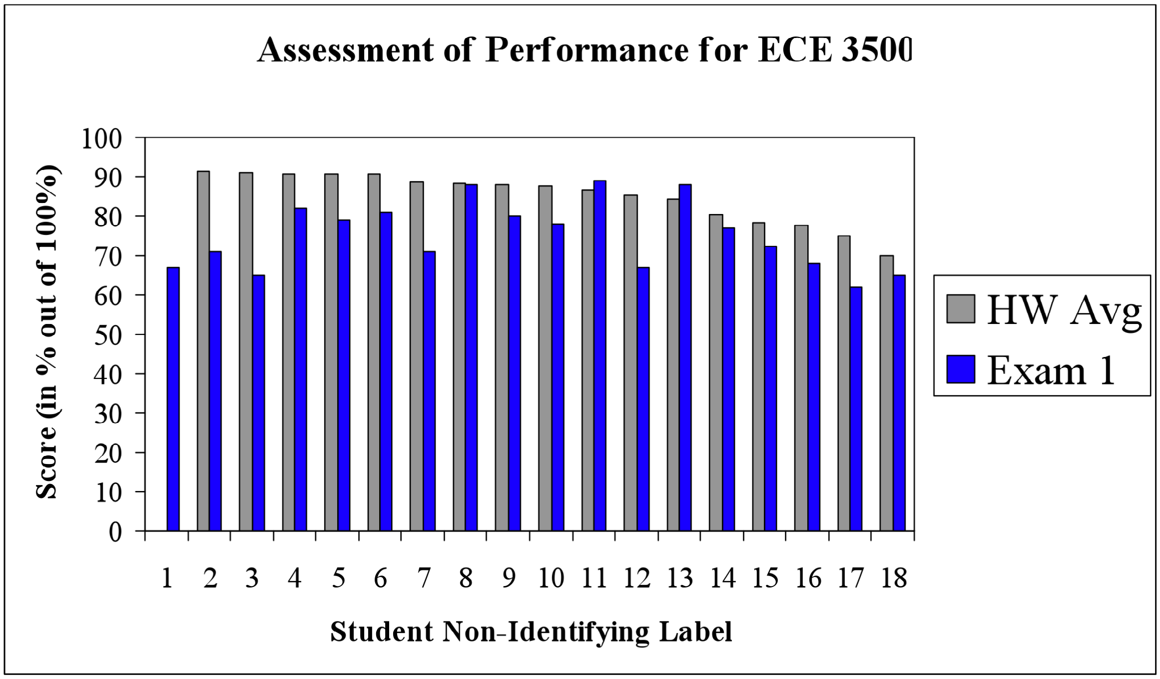

Figure 4. Exam# 1 results compared to HW Avg. The graph indicates that 1/3 of the class is in academic jeopardy.

4.2 Lessons Learned from Exam #2

In response to the student requests and in preparation for exam #2, the class was provided with practice exams that looked “just like” the actual exam in structure and very similar to technical content. In addition to the exam review held during regular classroom sessions, external exam review sessions were held to help address any additional student concerns. During both review sessions, similarities between the exam practice questions and homework exercises were identified and highlighted. This time, half of the class performed poorly on the exam only 9 students score above 70%. It is clear by these results that students rejected the reflective activity components and relied heavily on memorizing the practice exam solutions. (See figure 5.)

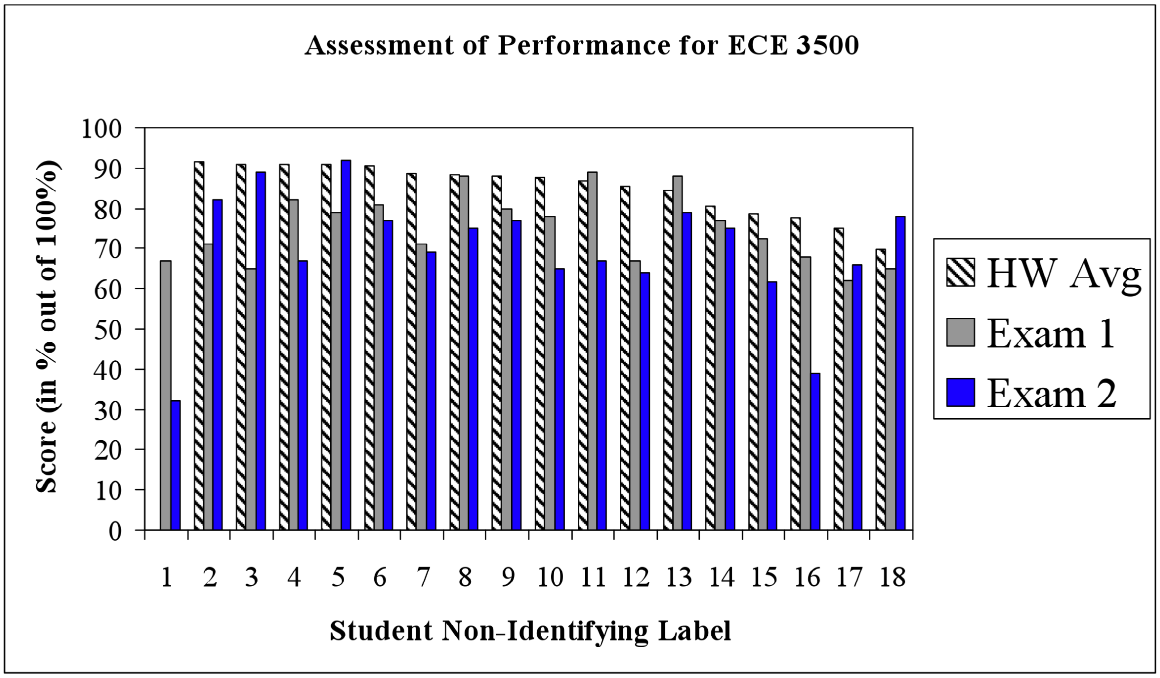

Figure 5. Exam #2 performance compared to Exam #1 and homework (HW) averages. Nearly half of the class performed poorly indicating that more reflective observation was necessary to support the learning process.

5 The Teaching vs. Learning Dilemma

In addressing the learning needs of a class, it is important to reconcile two main issues: 1) the instructor wants the student to learn the course material and 2) the student wants a high grade. In undergraduate college education, there are learning objectives and expectations that the students should meet. Students are expected to learn how to identify a problem, understand general relationships including the order of magnitude of key parameters, present a computational problem for analysis, execute calculations and present conclusions or recommendations based on computational results. However, these objectives are often not adopted by the students. In the case of this study, students did not want to use the new tools and approaches for analyzing a problem but preferred to memorize equations to solve specific problems. This approach was familiar to the student and sufficient for less advance courses but semiconductor material and device analysis requires interpretation and insight to differentiate between equations that are very similar in form yet possess very different material dependent parameters.

It was also observed that students had an expectation that they should not be subjected to critique and correction of their technical work. Students were permitted to address grading disagreements and reconciliation in writing. The grade reconciliation form requested that the student indicate the discrepancy and present external references (i.e. textbooks) to support their argument. For example, one student expressed his concern in writing about the exam grading policy in the following statement:

"My main concern on the grading of this exam deals with the policy of answers in previous parts of a question carrying over to later parts of the same question… In question 3 section c, I made a mistake with the units so my answer was off by a power of six… In part d, I made the same mistake again… I was wrong by a power of 6 again… In part e, it asked for the sketch of the band diagram… Even though the diagram was wrong… I just think that it is common practice for graders to follow this policy [when grading a question of multiple parts, students are not penalized for a wrong answer in a part that uses the answer from an earlier part]. All my other professors [that] I have had follow this policy; even on Advanced Placement tests they follow this policy."

6 Exam Journaling

After much consideration of the performance issues related to the previous exams #1 and #2, the following classroom policy was composed to promote and reward reflective observation. Students were allowed to continue to accumulate bonus points from in-class work as well as receive credit for keeping an exam journal. This approach addressed the dilemma regarding the value of learning versus student fixation on grades. The requirements of the exam journal included the use of a journal template with regions designated to performing computational work and reflective discussion of their previous work. Students were required to re-work the incorrectly answered problems on their exam and explain their initial thought process on the exam. All problems had to be answered correctly in the journal with appropriate references made to the course textbook page or homework solutions. Students were provided with the correct numerical answers for computational problems (by the instructor) and the journals were to be submitted one week after receiving the graded exam. Journal grades were proportional to the original exam grade and no partial credit was awarded. This approach supported the student in order to address any academic weakness presented in the exam results, helped to reinforce concepts that would appear on the final exam and led to the reduction of tension in the atmosphere of the classroom. The journals also helped the instructor to determine the learning needs of the students by considering the following questions:

* Did the student understand what was being asked?
* Did the student study that topic?
* Did we discuss that topic in class?
* Had the student correctly identify the equation choices?
* What makes this problem difficult to solve for the student?
* Where did the student get confused and why?
* What information did the student need to resolve the confusion?

Examples of journal entries for Exam #2 in Table 1 showed that students had trouble with understanding the physical meaning of some equations and parameters while other students chose not to own the responsibility of the incorrect work and blamed their calculator or units for their mistakes.

Exam #2 Journal Entries
a. "[I] didn't know what to do [to determine the quasi Fermi level separation]. Ref: HW#4 problem 4.7"
b. "[I] did not realize that g_{op} [optical generation rate] and tau [recombination lifetime]

	were in different units. Reference: HW#4 problem: 4.7"
c.	*"I used the value of 10^{-7} [u]s for tau instead of 10^{-1} us . Reference: Textbook: pg 143: Example 4-5 and pg. 131: Formula defined."*
d.	*"I forgot how conductivity changed [when excess electrons and holes are created in a semiconductor]. Ref: Text: Pg. 124 and 102."*
e.	*"I ran out of time and didn't know how to do it [determine the quasi Fermi level]. Ref: Textbook pg 142-143"*
f.	*"For some reason I didn't use $n_o*p_o=n_i^2$ [the mass action law], I just assumed they [electron and hole concentrations] were equal. Ref: HW #3 problem 4."*
g.	*"Did not completely memorize the definition [of photoconductivity]. Ref: Text: pg. 124"*
h.	*"In this problem I used the right formulas but forgot to convert kT in the equation for N_c and this messed up my numbers."*
i.	*"I knew how to do this section but typed the number into my calculator wrong so my decimal was off."*
j.	*"I knew how to do this problem but copied tau wrong off the test. I used 10^{-7}us instead of 10^{-7}s."*
k.	*"Besides calculating L_n [recombination length] correctly, I had no idea how to solve [the problem]."*

Table 1. Example of the journal entries for Exam #2.

By the time Exam #3 was conducted, student critical thinking skills began to mature. Nearly 2/3 of the class scored above 70% on the exam. (See figure 6.) Students began to make the connection between concepts and calculations. Students even began to catch their own mistakes during the exam session. Some of the journal entries in Table 2 showed that students had taken the time to identify their weaknesses and found resources to support their corrections. While other entries were written in a detached tone indicating that the student is not comfortable with owning their mistakes.

Exam #3 Journal Entries	
a.	*"I forgot to use the diode equation to find the current flowing through the junction, and I instead found only the reverse saturation current"*
b.	*"I misinterpreted the question and answered for the input voltage not the junction voltage. Ref: Textbook p170-182, 184"*
c.	*"I wasn't exactly sure what it [charge control approximation] meant. Textbook Pg. 190 helped a lot!"*
d.	*"I thought it [charge control approximation] was an approximation based on time. Textbook p. 91"*
e.	*"Miscalculation of W_{fwd} [depletion width, forward biased] resulted in an incorrect answer for E_o [electric field]"*
f.	*"The definition of junction capacitance and storage capacitance were unclear to me."*

Table 2. Example of the journal entries for Exam #3.

Near the end of the course, the journal entries improved and the students were able to use the collected journals to prepare for the final exam. Exam performance improved significantly for the final exam and almost 2/3 of the class received a final exam grade $\geq$ 70%. (See figure 7.)

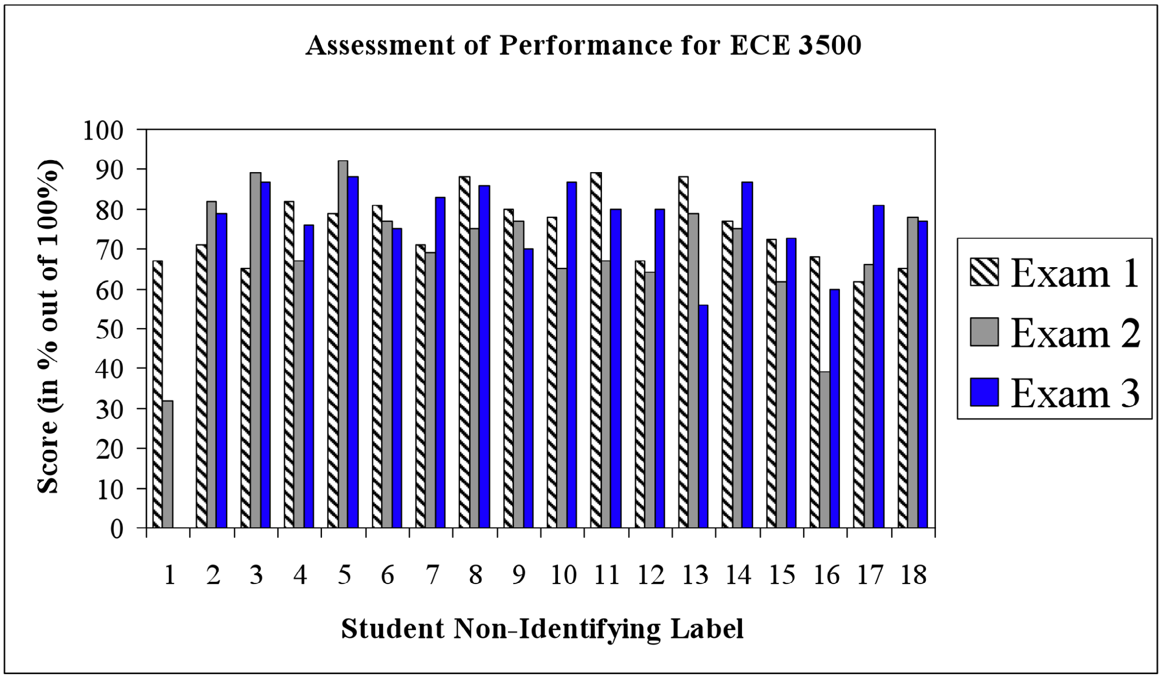

Figure 6. Exam#3 shows overall improvement with only 6% of students performing poorly (15 students score >70%).

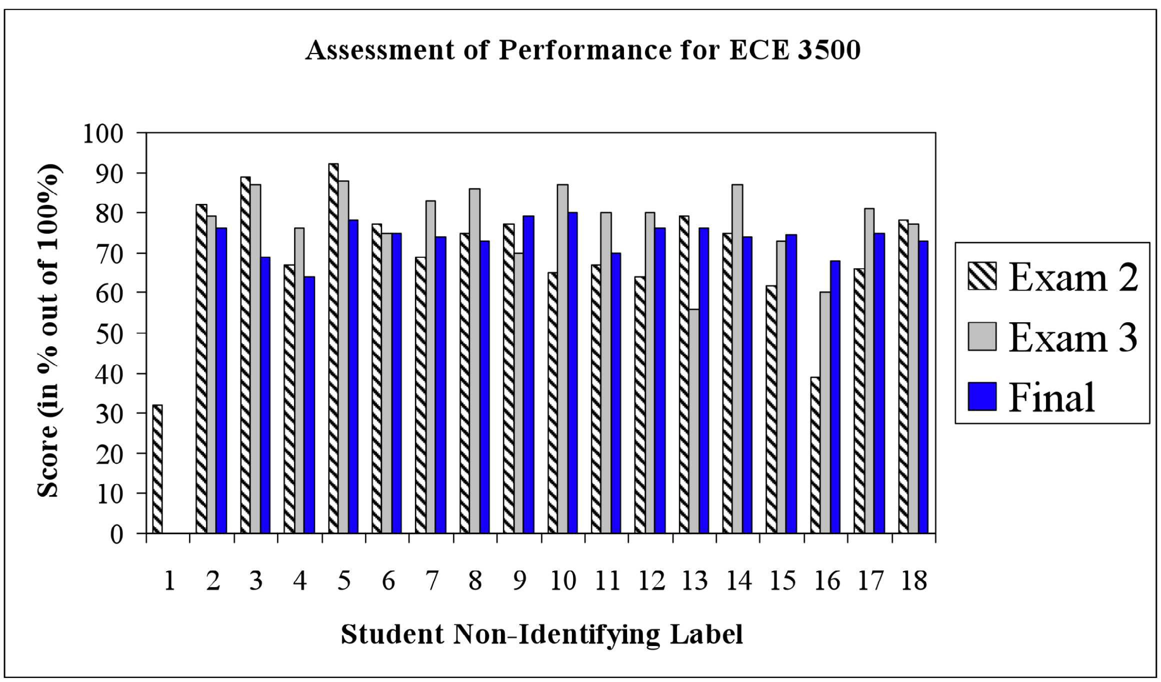

Figure 7. Final exam scores indicate that 14 students scored ≥ 70%

7 Lessons Learned from Exam Journaling and Future Recommendations

A number of observations can be made based on the exam journal feedback from students. The instructor can begin to understand why students misinterpret concepts and which concepts are generally confusing. The journals illustrate that students need help to make the connection between all exercises that they perform (e.g. homework, in-class exercises, etc.). It becomes clear that students do not review materials like homework and in-class exercises before an exam. Insight to the students' internal merit system is also obtained since students only value practice exams, false learning exercises (i.e. memorization) that they considered to be exam reviews. Additionally, exam journaling is equal to grade "redemption". The reflective journaling process allows an alternative mechanism for assessing a students' learning that does not subject the student to test anxiety. A reduction in classroom tension was observed where more students became active and vocal in class participation that had a positive affect on the learning environment.

Overall, journaling can be a useful and effective tool that is beneficial to both the student and instructor. Journaling also helps both parties understand learning styles and encourages students to reflect on course materials. However, instructors should be aware that introducing the concept of reflective observation is unconventional which can lead to student resistance and increases the risk of low course teaching evaluation scores.[4] Considering its positive benefits, journaling has been extended to other exercise materials (e.g. practice exams, etc.) in the Fall 2009 offering of the course and the results will be discussed in future articles. The exam journaling process will be extended to practice exam resources to allow students to identify and reflect on concepts that are difficult for the student to comprehend. Exit surveys examining the student perceived benefits of reflective journaling will also be performed in future courses. Additionally, learning style assessments may be performed at the beginning of the semester to identify individual learning styles and foster "buy-in"[7] from the class.

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