ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36650

Using Mixed Exam Methods to Enhance Students Learning for Electronics Courses

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Abstract

This paper presents several non-traditional exam methods that serve both introductory analog electronics and advanced electronics courses in the Electrical Engineering and Computer Science (EECS) department at the University of Evansville (UE). The study is focused on classes from Fall 2019 - Fall 2020. Despite the COVID disruption in 2020, students' outcomes and final course survey indicated that these methods enhanced their understanding, promoted their interest and motivation in transistor topics.

Background

Before the UE President executed the realignment in Fall 2021, the EECS department has three programs: electrical engineering (EE), computer engineering(CoE), and computer science (CS). EE students must take Electronics sequences: Electronics I (EE342) and Electronics II (EE343) in their Sophmore and Junior year. CoE students are only required to take EE342 in their second Sophomore semester. The typical class size is less than 20 students.

EE342 is an introductory electronics course that discusses the fundamentals of semiconductor devices such as Si Diode, Zener, BJT, and MOSFET. EE343 is an advanced electronics course that focuses on single-stage and multistage transistor amplifiers. Both courses were taught using the traditional lecture method with two take-home group projects. Although the lecture topics were well arranged, the students' learning outcomes didn't yield a very good result. Thus, with the department's support, the author restructured both courses in Fall 2019.

Course Restructure

Many studies have proven the effectiveness of embedding hands-on lab components in engineering courses. The hands-on experience dramatically increases students' engagement, promotes their motivation, and enhances their learning [1][2][3]. Properly designed lab assignments allow students to apply the abstract concept in real life. Seeing the connections can help boost their learning desires. Lab elements also improve students' data collection, analysis, and evaluation skills. Therefore, the author included more lab components for both courses. All lab assignments must be carefully designed to meet ABET outcome 5 and outcome 6. For example, labs will be done in a group of two or three students to reinforce their communication

and collaboration skills. Proper lab reports and data analysis are required for each lab assignment to practice their ability to interpret data and use engineering judgment to draw conclusions.

Other course objectives, i.e., determining the operation regions of semiconductor devices, analysis or design of various single-stage/multistage amplifier topology, etc., will meet the ABET outcome 1. However, all these course objectives fall into different categories in the Revised Bloom's Taxonomy (2001). The Revised Bloom's Taxonomy has six categories: Remember, understand, apply, analyze, evaluate, and create [4][5]. Each category requires a different approach to assess students learning. Table 1 lists the definition for each category and the mapping to some of the course objectives.

#	Bloom's Category	Bloom's Definition	Course Objective	Course
1.	Remember	Recall or Recognize Specific terms, theories	Remember the basic semiconductor terminologies	EE342
2.	Understand	Explain concepts	Understand the basic operation of transistors	EE342
3.	Apply	Use information in a new but similar simulation	Identify and solve single-stage amplifier circuits	EE342
4.	Analyze	Take apart the known and identify relationships	Analyze various single-stage and multistage amplifiers	EE343
5.	Evaluate	Justify a stand or decision	Understand the tradeoff of using different topologies	EE343
6.	Create	Produce new or original work	Design multistage amplifier	EE343

Table 1: Course Objective mapping to the Revised Bloom's Taxonomy

a. Exam methods for EE342

Based on the mapping in Table 1, EE342 is focused on Remember, Understand, and Apply categories. Thus, to assess these objectives, closed book/closed notes midterm exams were administered to encourage students to remember transistor terminologies and practice how to solve simple transistor circuits. There were two midterms in this class. The first midterm covered semiconductor material, diode circuit analysis; The second midterm covered BJT/MOSFET terminologies, operation regions, and CMOS logic implementation. Midterm questions were focused on the first three categories in the Taxonomy. Here are some example questions for midterms: Sketch the I-V curve of a Zener diode; Calculate majority and minority carrier concentration for a given p-type material at room temperature; Determine the operation region of the MOSFET in a particular circuit.

The author also used the exam correction method to encourage students to revisit their midterms and correct their mistakes. After each midterm, an exam correction assignment was administered. First of all, students must review their work and identify the errors. Then, students must clearly explain why their original answer was incorrect. At last, they must use the correct method to fix their mistakes. 50% of deducted points will be "refunded" if they successfully complete this

assignment. The exam correction method transforms students' goal of getting a good grade into understanding the topics. This method also helps students to learn from their failures and reduces students' stress during the exam [6].

At the end of the semester, students should be able to use the terminology they learned in class to describe the semiconductor components or circuits. They also should be able to analyze simple single-stage transistor amplifiers. In future EE343, course material will focus more on Evaluating and Creating level in the Revised Bloom's Taxonomy. Thus, an oral exam in EE343 could better evaluate their higher level of understanding. However, some studies find that anxiety and unfamiliarity during the oral exam will affect students' performance, and the exam result will not correctly reflect students' actual level of understanding. On the other hand, studies also found that using oral exam methods at the Undergraduate level still offers great benefit [7][8]. Therefore, the author introduced the oral exam in the EE342 final to familiarize students with the format.

The final exam was designed to be a combination of written and oral. First, the author assigned a two-week-long, take-home final. Students were allowed to discuss with their classmates or ask instructor questions during that two weeks. They are also required to use LTSpice to validate their exam work in the written exam. Most of the questions were designed based on their students' numbers. Therefore, each student got a unique problem set. Even if they worked together, individual students still need to solve their own problems. A 30-mins oral exam was introduced to students after turning in their written exam. Students were only allowed to use their LTSpice simulation and written exam work during the oral exam. Most students may never have any prior oral exam experience. Thus, it is important to keep the questions straightforward. Those questions were purely based on their written exam, so as long as students understand their work well, they should be able to answer all questions. Of course, these questions should still be focused on the first three categories in the Taxonomy. Here are some oral question examples: What's diode? Name the three terminals and all operation regions of MOSFET. How to find DC bias point in LTSpice? Explain why we need a rectifier circuit.

b. Exam methods for EE343

EE343 discusses a variety of transistor topologies such as various current mirrors, gain stages, and output stages. Students are expected to understand the trade-off of different topologies and make engineering decisions to choose specific circuits to meet the design requirements. The course objectives fall into the last three categories of the Taxonomy (Analyze, Evaluate, and Create). Oral exams can evaluate this higher level of learning, especially can assess their decision-making process. Thus, there were only two exams for this course: midterm and final. Both exams were a combination of written and oral similar to the EE342 final, but the question style was very different. For example: "If this resistor has increased, how will that impact the AC gain, DC bias point, output swing, and the frequency response? Use LTSpice to verify your answer." "If I want to increase the voltage gain of xx amplifier further, what should I do? How does that affect your amplifier's other characteristics (swing, DC bias point)? Use LTSpice to demonstrate your plan." "Explain your design. Why did you choose xx over xx? If possible, use LTSpice to demonstrate your answer." "Why do we need to have this capacitor/resistor in this circuit? If we remove this component, what would happen?"

In Fall 2019, the author assigned this combination midterm to EE343 students for the first time. Students were also required to build one of their designs in the exam as their midterm project. Unfortunately, the hands-on project portion was canceled for the Fall 2020 group due to the COVID-19 concern.

Discussion

The exam correction method can transform the entire class atmosphere into a learning community. Exams typically serve as a critical assessment function in the engineering area. It is a summative assessment used to evaluate students learning outcomes and is often directly related to their grades. It also can be treated as a formative assessment that provides students feedback to correct their misconceptions and improve their future learning. Unfortunately, the formative aspect is not widely recognized by our students. This method allows students to see the formative aspect of taking an exam. In addition, knowing that they will have a second chance will relieve lots of stress yield better overall performance when taking the exams.

The combination exam offers many benefits to students too. They can use the written exam as a formative assessment tool to enhance their understanding. The Instructor can provide immediate feedback during the oral exam to correct their misconceptions. On the other side, the Instructor will also get valuable feedback about the teaching effectiveness. The Instructor will better understand individual students' learning outcomes, weaknesses, and strengths through this direct verbal interaction. It also provides an opportunity for the Instructor to get to know each student, especially those who are too shy to speak in class. This exam method is also suitable for online remote learning during the pandemic. Because the written exam encourages communication between students and the oral section helps limit possible academic dishonesty.

There are several issues with using these non-traditional exam methods. First of all, both methods are extremely time-consuming. Instructors have to grade students' midterms twice. During the final exam time, the Instructor has to schedule a 30 mins oral exam for each student. If there were 20 students enrolled, the Instructor would spend 10 hours just on the oral exam portion. Thus, this method will face a great challenge for larger classrooms. Fortunately, in this case, the author has a much smaller classroom, and most students who attend EE343 took EE342 from the previous semester. Therefore, offering an oral exam in EE342 helps the author establish a solid and healthy faculty-student bond that will benefit EE343. Another notable issue is students' poor time management skills. Although the author gave students two weeks to complete the written section, some students were still working on the material at the last minute. Rushing the written exam may also result in poor oral exam performance. Thus, it is recommended to "force" students to start working on their written exam early, i.e., students must attend the last class and are only allowed to work on their written exam. Lastly, the oral section can be too hard for international students as they do not have the same communication skills as the domestic students. International students may have to handle more stress in preparing for oral exams. Therefore, the author does not recommend having challenging oral questions in Sophomore level courses, such as EE342.

Students Outcome

The author taught electronics sequences from Fall 2019 to Fall 2020 with the new structure. Unfortunately, the future study was disrupted by the University realignment plan. Therefore, this paper only focuses on discussing the outcome from these three terms. Group 1 students took the EE342 in Spring 2019 with the old course structure and took the EE343 in Fall 2019 with the new structure. Group 2 took the new electronics sequences in Spring 2020 and Fall 2020. Students final exam results are listed in Table 2 below:

	Written Exam		Oral Exam		Total 70% written, 30% oral	
Groups	Mean	Median	Mean	Median	Mean	Median
Group 1, EE343	82.6%	85.7%	62.8%	68.3%	76.7%	78.5%
Group 2, EE343	82.7%	82.9%	76.0%	80.0%	80.7%	78.0%
Group 2, EE342	75.0%	82.1%	73.0%	83.3%	74.5%	78.0%

Table 2: Students Final Exam Grade

Note, Group 2 students took both courses during the COVID-19 pandemic, and their performance in EE342 was significantly impacted by switching to online lectures in March 2020. Fortunately, the author effectively interacted with every student during their oral session to correct their misunderstandings, creating a solid foundation for EE343. Indeed, group 2 students performed better than group 1 students in EE343, especially in the oral exam section.

Another interesting finding is the correlation between written exam scores and oral exam scores. Around 50 % of students from group 1 and 20% of students from group 2 did much better in written than the oral exam. Their oral exam was more than 20% lower than the written part. Those students had the correct calculation steps and answer; however, they failed to explain the reason behind it. They know how to solve problems by following examples but did not truly understand the concepts. The oral exam helps recognize this group of students. The author believes that group 2 has a lower percentage is because they had the oral exam in EE342.

On the other hand, about 20% of students in both groups did far better on the oral exam than on the written exam. Their poor written exam scores were due to calculation errors or similar simple mistakes. Their oral exam showed they had a good grasp of the course material. The author believes the combination of written and oral exams accurately indicates the level of understanding compared to only having the written exam.

Students' Reaction and Instructor's Observations

The final course evaluation is very positive. Students liked the instructor-guided lab sections. These labs helped them see how transistors work in reality. In the final course evaluation survey, many students stated that they had learned a lot from the exam correction assignments. Compared

to curving grades, this method motivated them to revisit the topic and figure out concepts they had not fully understood.

Based on the author's personal experience, the classroom atmosphere was much better after the oral mid-term. Students tended to be more willing to ask for help after the midterm. In addition, students indicated that they were motivated to learn deeper about the course material by working on the take-home exam. Similar to [7], the author also found that students were spending more time preparing for oral exams and asking more questions during the final week. Most students showed up during office hours to ask questions regarding their written exams.

Table 3 lists some results from the course final survey. The total responding rate is 24 / 30. Most students feel the class challenged them to learn, and increased their confidence in topics.

Survey	Strongly agree	Agree	Neither agree nor disagree	Strongly disagree
As a result of this class, my knowledge of this topic has increased	16	8	0	0
The Instructor challenged me to learn more than I expected	17	6	1	0
The Instructor displayed an interest in my learning	16	8	0	0
Overall, the course was an excellent course	16	8	0	0

Table 3: Items From the Course Final Survey

Conclusion and Future Work:

In this paper, the author discussed the reconstruction of the electronics sequences (EE342 and EE343). In addition to adding more instructor-guided lab sections, the author used mixed exam methods based on the Revised Bloom's Taxonomy to evaluate students' learning outcomes at different learning objective levels.

To help students remember and understand the concepts, the author used the exam correction assignment in the EE342 course. It teaches students to treat exams as a feedback tool. From the author's perspective, this method does not require too much extra work compared to the combination exam method. It can also be used for other lower-level courses such as DC circuits. The author will explore the possibility of using this method for different classes.

The combination of the written and oral exam requires tremendous time from the Instructor. However, it is an excellent assessment tool for higher-level courses. It provides instant feedback to both instructors and students. In addition, it can evaluate a student's higher level of understanding, such as decision-making and critical thinking skills. However, oral questions must be carefully prepared that map to different levels of learning objectives. Based on this initial experience in executing a combination exam, the author will attempt to apply this method to other advanced courses.

Acknowledgment:

I would like to express special thank to the former department chair, Dr. Anthony Richardson who supported me making these course changes. I also would like to thank Dr. Dick Blandford, Dr. Deborah Hwang, Dr. Don Roberts, Mr. Mark Randall, Dr. Mohsen Lotfalian, Dr. Ying Shang, Mr. Jeff Cron, and Mrs. Vicky Hasenour, for providing me resources needed for this research.

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