Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
ASEE
Paper ID #47813

Alternative Assessment in ECE - Diving Deep into Course Topics

Dr. Ilya Mikhelson, Northwestern University

Dr. Ilya Mikhelson is an Associate Professor of Instruction in Electrical and Computer Engineering at Northwestern University. His technical work focuses on signal processing and embedded systems. Besides teaching, Dr. Mikhelson has worked with dozens of students on independent projects, and has created 3 brand new, projects-heavy courses in Electrical Engineering. He is constantly experimenting with pedagogical innovations, and is very passionate about engineering education.

Alternative Assessment in ECE - From Building Circuits to Writing Children's Books

Abstract

This work presents a novel assessment modality for an introductory electrical engineering course. The assessment is a deep dive into a topic in the class, which opposes the traditional breadth-based examination. The deep dive is a multi-day, take-home assessment, where students can choose one of several prompts, thus allowing for multiple means of expression as per Universal Design for Learning (UDL) principles. Furthermore, this method allows students to show comprehension at the highest levels of Bloom's Taxonomy, by creating and analyzing in a minimally-constrained setting, both in time and direction. To assess the efficacy of the proposed assessment modality, the author examines the tool's fairness and its ability to test knowledge. The findings demonstrate that this is a viable tool for assessment.

1 Introduction

Introductory classes are hard to get right. On the one hand, students should become excited about the major. On the other, they should walk out prepared for the rest of the curriculum. These are often at odds with each other. An instructor can get students excited by showing the cutting edge, but there is nowhere near enough time to properly formulate how to get from the students' current knowledge to that point. An instructor can introduce proper rigor, but then the class can only explore the most foundational topics. This is true across engineering, but especially true in electrical engineering, where the applications require great amounts of background.

In an introductory class that the author has developed [1], a curriculum was explored that allowed (in the author's opinion) a good blend between the two extremes. The formal education focused on classroom lectures and laboratory-based exploration. However, even though the lectures allowed for decent breadth while the laboratory allowed for decent depth, there was still a need for deep, less-structured exploration. This piece seems to be missing in most introductory curricula, and is of the utmost importance to allow students to really solidify their knowledge.

This is where the idea of the Deep Dive comes in. The thinking was that students get lots of practice at the lower-middle levels of Bloom's Taxonomy [2] through homework assignments, showing that they understand the topics and can apply them. And they get lots of practice at the middle-upper levels through laboratory assignments, especially with a push toward laboratory-first classes [3]. However, it is very difficult to practice at the highest level, creation, in an introductory class. Furthermore, many traditional examinations in such classes test students only at the lowest levels [4].

The Deep Dives are a multi-day, take-home assessment, which takes the place of examinations. For the assessment, students can choose one of several prompts. The goal was to create something using various modes of expression (per Universal Design for Learning (UDL) [5] principles) to allow students to really express their knowledge. While there is literature on take-home assessments [6] and UDL in assessments [7], the author has not found any assessments similar to those proposed in this paper [8, 9, 10]. The goal is to be able to assess just how deeply students grasp introductory concepts (like an examination), all while minimizing time pressures.

The rest of the paper will show how this goal was accomplished. Section 2 will present the design of the Deep Dives. Section 3 will present a discussion around the efficacy of this modality of assessment. And Section 4 will summarize the findings and present next steps.

2 Deep Dive Design

The goal of the Deep Dive is to challenge students to independently and individually create something novel using the limited knowledge that they have gained in an introductory class. Additionally, in recognition of the fact that not everyone feels comfortable expressing their knowledge in the same way, several options were provided for each Deep Dive. Finally, in order to alleviate time pressure, several days were allowed for completion.

While the multiple means of expression along with the take-home nature of the assessment serve to elicit the best work from each student, they also come with challenges.

1. Each assessment must be similar in difficulty and scope.
2. Each assessment must be able to be evaluated fairly relative to each other.
3. Catching academic dishonesty can be difficult.

2.1 The Options

Each of the options provided to students will be discussed in the following sections. For all of the options, students are allowed to use any resources they want excluding other people. However, the internet, textbooks, and generative AI are all allowed. Throughout the term, two Deep Dives were assigned.

2.1.1 Synthesis

The first option, which most closely relates to the highest level of Bloom's Taxonomy, is to build something. The idea is that the instructions provide the broad outline, and students have to explore how to implement it, and then document their implementation. At the end, they have a working design, which they showcase through a video.

During the first part of the course, students learn about DC and AC analysis of circuits, semiconductor devices, and microcontrollers. As a challenging homework problem, students analyze and characterize a 2-stage Cockcroft-Walton multiplier [11]. In the first Deep Dive, students are asked to build a 4-stage Cockcroft-Walton multiplier, along with excitation circuitry using a microcontroller and MOSFET. There are also subtle differences between the homework problem and the Deep Dive, and students have to explain those differences. They also have to explain any non-ideal effects that they observe.

During the second part of the course, students learn about operational amplifiers and signal processing, including compression. In the second Deep Dive, there are two building options. The first involves building an electrocardiogram reader using operational amplifiers. As a first step, students are presented the instrumentation amplifier and asked to derive its transfer function. Then, the device is built and tested on the student with provided electrodes. The second option involves designing a compression algorithm in the frequency domain and finding the compression ratio using a sound sample that the students record themselves.

In order to succeed in these tasks, students have to dive below the surface. Each time, they are creating something that was not explicitly taught in class. This often requires experimentation or consultation of outside resources, both of which are very welcome. At the end, each student produces a unique result, which is documented through photos and videos. Due to the nature of these exercises, getting identical (or even very similar) results is extremely unlikely, so finding people who used another's work is easy. However, it is not easy to deduce whether people worked together, but that is the case with any take-home assessment.

2.1.2 Analysis

The second option, which is along the top of Bloom's Taxonomy, is to analyze a circuit. The idea is that we have seen these devices in class, and we even talked about their imperfections, but observing those phenomena in the real world is difficult. Furthermore, students have to create the proper test setup to elicit the necessary effects.

For the first Deep Dive, students are asked to characterize a Schottky diode and a MOSFET transistor. They have to use XY mode on an oscilloscope and resistors for proxies of current, along with a voltage sweep, to draw out the I-V curves of the diode and transistor. Based on these measurements, students are asked questions about their properties. This requires strong understanding of the test equipment as well as the devices in order to create the test setup, as well as strong understanding of the device characteristics in order to interpret the results.

For the second Deep Dive, students are asked to characterize some nonideal properties of an operational amplifier. Specifically, they must find the slew rate and the gain-bandwidth product. For both of these, students must design the experimental setup and find appropriate parameters that will allow them to measure each effect without interference from the other. Additionally, students use their findings to make predictions as to the op-amp's behavior under different conditions and then verify their predictions. If there is discrepancy, it must be explained.

In order to succeed in these tasks, students again have to dive below the surface. The test setups are far from trivial, and really require a strong understanding of the topic. Just like in Section 2.1.1, each student ends up with unique results. This comes with the same benefits and drawbacks as discussed prior.

2.1.3 Children's Book

The third option, which is at the very top of Bloom's Taxonomy, is to write a children's book on a class topic. Students pick one topic from a list of choices, and the book has to be written in language that a 10 year old can understand. Additionally, the book cannot be too surface-level; rather, it has to go into a good amount of detail for each topic.

This option is the hardest to provide clear guidance for. In recognition of the fact that not everyone knows a 10 year old, the instructions state that a good test is to give the book to a non-engineering friend and see if they understand the topic. Additionally, the instructor offers feedback on drafts to guide students in the right direction.

For the first Deep Dive, the topics are KVL, KCL, and Ohm's Law; capacitors and inductors; diodes and LEDs; BJTs; and MOSFETs. For the second Deep Dive, the topics are impedance and phasors; Fourier analysis; sampling and aliasing; compression and JPEG; and machine learning. The course lectures cover each of these topics in broad strokes. No more than a week is spent on any one. Therefore, to succeed, students have to do outside research. The hardest part, though, is to break down the topics in simple language.

As before, each student naturally ends up with a unique product. In this case, academic dishonesty is much easier to find, since even working together will lead stories to have similar themes, and this is easy to detect.

2.1.4 Arguing with ChatGPT

The last option, which is along the top of Bloom's Taxonomy, is to find a misconception in ChatGPT's [12] "understanding" of a class topic [13]. For this option, students can choose any topic from the class. However, there are a few restrictions:

- The minimum version of ChatGPT is specified.
- Catching ChatGPT making oversimplifications is insufficient.
- No purposely incorrect questions are allowed.

After finding a misconception, students have to analyze the error and provide a detailed explanation of what makes ChatGPT wrong. Additionally, they have to explain the concept that would correct its misunderstanding.

For documentation, students must provide a link to the conversation, so that it is impossible to fake. However, there is still room for academic dishonesty, as there is no way to know if the idea was suggested by someone else.

3 Results and Discussion

While the assessment strategy has been well received and enjoyed by students (as opposed to traditional exams), a discussion must be had with regard to its efficacy and fairness as an assessment tool. Furthermore, it is prudent to discuss how such an assessment method can scale to larger classes.

3.1 Student Choices

This form of assessment has been offered over the last five terms, with the latter three offering all of the options presented in this paper. The number of students who have opted for each one is presented in Table 1, and a summary is shown in Fig. 1(a). In order to remove the bias of larger enrollments, the same information is presented as percentages in Table 2, and a summary is shown in Fig. 1(b). As can be seen, no choice was strongly preferred over another, with a slight preference for the children's book option by numbers and a slight preference for the building option by percentage. What does stand out, though, is the relatively small percentage of students choosing the ChatGPT option.

The slight preference for the children's book is an interesting one. It seems that students may believe that writing a book is easier than doing rigorous engineering. Anecdotally, the author has seen numerous books that start out very strong but quickly decay in quality, as the students realize that explaining difficult topics in an easy manner is not straightforward. While students can change their topic at will, the sunk cost fallacy seems to kick in and students submit subpar work. Not surprisingly, the children's book option tends to have the lowest grades.

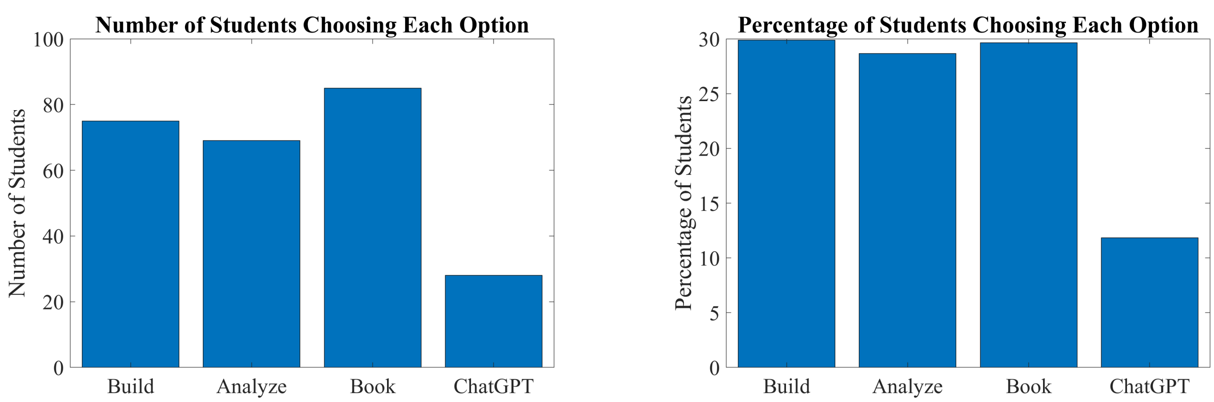
The fear of the ChatGPT option is more surprising. It seems that students overestimate the abilities of generative AI models. Those students who pursue this option tend to do well. However, this may be a self-selection bias, as only the most confident students even attempt this option.

Table 1: Number of students choosing each option over the last three offerings of the course.

Term	Deep Dive 1				Deep Dive 2				
	Build	Analyze	Book	ChatGPT	ECG	Op-amp	Compress	Book	ChatGPT
23 Fall	4	11	6	5	5	6	6	5	4
24 Spring	12	15	29	7	8	10	12	26	5
24 Fall	11	16	10	5	4	11	13	9	2

Table 2: Percentage of students choosing each option over the last three offerings of the course, along with aggregate statistics.

Term	Deep Dive 1				Deep Dive 2				
	Build	Analyze	Book	ChatGPT	ECG	Op-amp	Compress	Book	ChatGPT
23 Fall	15.4	42.3	23.1	19.2	19.2	23.1	23.1	19.2	15.4
24 Spring	19.0	23.8	46.0	11.1	13.1	16.4	19.7	42.6	8.2
24 Fall	26.2	38.1	23.8	11.9	10.3	28.2	33.3	23.1	5.1
Average	20.2	34.7	31.0	14.1	14.2	22.6	25.4	28.3	9.6
Std Dev	4.5	7.9	10.7	3.7	3.7	4.8	5.8	10.2	4.3



(a) (b)

Figure 1: (a) Number of students, and (b) Percentage of students, who chose each category from Section 2.1 over the last three offerings of the course.

3.2 Efficacy as Assessment Tool

The goal of any assessment modality is to discern students' levels of understanding of the course material. One important caveat is that in order to gauge individual comprehension, the work must belong to the student alone. Due to the take-home nature of the Deep Dives, academic dishonesty is facilitated. Some mitigating factors were discussed in Section 2, but it is beyond the scope of this work to debate such matters, as there is an existing literature on take-home assessments [14]. Instead, the focus will be on gauging comprehension, assuming the work was done individually.

For the synthesis options, students cannot succeed without a strong understanding of the methodology and class concepts. Even a slight misunderstanding of a device's operation precludes successful completion. As an experienced engineer, the instructor can very quickly see where any errors stemmed from, and each mistake can be assigned a grade deduction commensurate with the misunderstanding.

For the analysis options, an even stronger understanding is needed. Whereas in the synthesis options, there is room to play around with the devices and find one's way into the right answer after enough experimentation, that is not really an option for analysis. In order to find the desired properties, students have to know exactly what they are looking for and how to expose that property through a proper experiment. As before, grading is relatively easy. To an experienced engineer, the results speak for themselves. Grade deductions are once more based on the level of misunderstanding.

For the children's book options, the strongest understanding is needed. Explaining difficult concepts in simple terms shows the highest level of comprehension. And yet again, misunderstandings reveal themselves readily, perhaps even more readily than the former two options. As the instructor reads the book, it becomes abundantly clear whether the student fully understands the concepts. Some misunderstandings are more significant than others, so once more grade deductions can be computed.

Finally, for the ChatGPT option, an understanding similar to the analysis option is needed. As a student interacts with ChatGPT, its responses are always confident and seemingly-correct. It takes a high level of understanding to confidently declare that ChatGPT is incorrect. By reading the transcript, it becomes clear whether the student knows what they are arguing about. Grading this option is also based on the magnitude of the student's misunderstanding.

Altogether, each option does a great job at exposing the level of a student's comprehension. Furthermore, each option requires students to operate near the top or at the top of Bloom's Taxonomy, hence solidifying their knowledge as much as possible. This makes the Deep Dives a very effective assessment method.

3.3 Fairness as Assessment Tool

While the efficacy of the Deep Dives has been shown in Section 3.2, their fairness has to be evaluated separately. This section will focus on fairness of grading and fairness of knowledge expression.

On the spectrum of objectivity, the Deep Dives leave a lot of room for subjectivity. However, the author has tried to develop rubrics for the options that give similar grades for similar levels of understanding. Of course, the notion of "similar levels of understanding" is itself a very subjective one, but it has not been as difficult as initially thought to gauge this.

In reality, the rubrics are only there because we need to end up with a numerical grade. From taking a quick glance at any of the writeups, it is clear within a couple of minutes what grade the student deserves. The majority of the grading effort is in looking for details that perhaps show that the level of comprehension is higher than the overall product suggests. In this sense, the Deep Dives are very fair, because each option makes it abundantly clear to what level the students understand the classroom topics.

However, compared to paper-based, cumulative exams, there is a much higher chance of a student not understanding many classroom topics and still doing well in the class. The goal of the multiple means of expression is to allow students to showcase their knowledge in their preferred modality, but the options are necessarily non-cumulative, so students can pick the topics that speak to their strengths. But there is a spectrum of assessment types here as well, ranging from surface-level to deep. A cumulative exam necessarily remains relatively surface-level, whereas the Deep Dives go as deep as is reasonable. Therefore, the Deep Dives showcase depth of knowledge as opposed to breadth of knowledge, both of which are important.

As far as difficulty of each option, this is also a subjective matter. However, over the course of five terms running the Deep Dives (three terms offering all of the options presented in this paper), there has not been an option that is significantly more popular than another, as shown in Section 3.1. If clustering had been observed, that would be an indication that some options are easier than others or that they do not represent multiple means of expression as intended. But the fact that no option is strongly preferred is indicative of the idea that students do in fact gravitate toward their preferred mode of expression and explore it deeply.

One more aspect of fairness is related to students' abilities to work quickly. On a traditional exam, there is usually a time burden, which is part of the assessment. For the Deep Dives, ample time is given, and students use varying amounts. In polls, students worked on average around 6 hours, with a wide distribution. By minimizing the time pressure, both fast and slow workers could show their skills to a comparable level.

Altogether, fairness lies in the eyes of the beholder. The Deep Dives leave much room for subjectivity and do not test breadth of knowledge. However, they make up for this by showing very clearly to the instructor students' comprehension levels and allow students to deeply explore a topic of interest. Since everyone gets a choice and can pursue an option that speaks to them, the assessment remains fair, given that the none of the options are strongly favored. Furthermore, with minimal time pressure, students of differing abilities are able to produce their best efforts.

3.4 Scaling

As seen in Table 1, the assessment has been used in classes ranging in size from 26 to 64 students. Each time, the grading was done by the instructor alone. Admittedly, grading the 64-person class was a considerable effort, and a larger enrollment would benefit from distributed grading.

The rubrics for the building and analysis options are mostly objective. Each part of the building and analysis process is documented in the student submission, and each part is assigned a point value. For each part, there are deductions associated with common mistakes, and the only judgment calls are for uncommon errors. This grading could be easily delegated to a teaching assistant, as it is not much different than grading homework assignments, at least in the level of subjectivity.

The rubrics for the children's book and arguing with ChatGPT are more subjective. While some parts are purely objective (e.g. does the children's book contain a given number of pages, did the student include a transcript of their conversation with ChatGPT), the true understanding is assessed subjectively.

For the children's book, the rubric contains items such as "minor conceptual mistake", "larger conceptual mistake", and "major conceptual mistake". And then there is the issue of how to grade someone who includes very little information overall but makes only one conceptual mistake, versus someone who includes a lot of information and ends up making several conceptual mistakes. Because of these issues, which are not unlike those faced by administrators of oral examinations, it would be difficult to assign grading to a teaching assistant. However, as with oral examinations, teaching assistants could step in with proper training, but that is also a time commitment both on the part of the faculty and on the teaching assistants.

The same issues arise with the ChatGPT option, which has a similar rubric to the children's book in terms of misunderstandings. With sufficient training, the grading could be delegated to a teaching assistant.

Overall, given the results in Fig. 1, the assessment can scale well. Even if the instructor is tasked with grading all of the children's books and ChatGPT arguments, teaching assistants can help significantly with the other options. In the case of even larger classes, the more subjective options could be graded by multiple graders as well, provided a very clear rubric is developed and discussed between the graders.

4 Conclusion and Next Steps

Overall, the Deep Dives have been an excellent experiment. They fit much better into an introductory course than traditional exams, since the emphasis is on exploring and creating. Additionally, even though the Deep Dives can be a considerable time commitment, students have consistently reported that they are lower-stress than traditional exams.

For next steps, the author is always looking for new, comparable options. On several occasions, there were options that looked promising, but were proven too simple due to generative AI. Therefore, it is important to always reevaluate the options and to determine if they still make sense in the current technological environment. Alternatively, sometimes new options pop up, like that in Section 2.1.4. One option that seems very promising is an oral examination [15].

Additionally, as hinted at in Section 3.2, this form of assessment would benefit from being in an ungrading [16, 17] structure, specifically using standards-based grading [18]. It is easy to see when a student strongly understands, moderately understands, or does not understand well. Therefore, a simple 3 point scale would be more direct than concocting various rubrics for the different options. Furthermore, this structure would allow students to redo their work, as it should not matter whether students understood the topic on their first try or their fifth, as long as they ultimately mastered it. Finally, this structure would allow for much easier scaling, discussed in Section 3.4, as it takes much less coordination between graders to gauge just three levels of comprehension.

As a further validation of the efficacy of the Deep Dives, a long-term study of knowledge retention would be necessary. Such a study would require at least two sections of this introductory class being taught, one with the Deep Dives, and one without. Then, a longitudinal study could be created to track knowledge retention at various points in the future.

Finally, this form of assessment opens the door to much further study, which will require significant rigor and planning. For example, there is a necessary conversation to be had regarding assessment in the age of ChatGPT [19] and post-pandemic, as the line between honesty and dishonesty is not even perceived by many students [20]. Not only are more robust tools available to students, they also do not always recognize academic dishonesty as such. It will be important to gather faculty and student perspectives to determine an appropriate assessment modality that showcases students' understanding while minimizing the opportunities for academic dishonesty.

References

[1] Ilya Mikhelson, "Introduction to electrical engineering: Empowering and motivating students through laboratory-focused teaching," in *2024 ASEE Annual Conference & Exposition*, 2024.

[2] Mary Forehand, "Bloom's taxonomy," *Emerging perspectives on learning, teaching, and technology*, vol. 41, no. 4, pp. 47–56, 2010.

[3] Juebei Chen, Anette Kolmos, and Xiangyun Du, "Forms of implementation and challenges of pbl in engineering education: a review of literature," *European Journal of Engineering Education*, vol. 46, no. 1, pp. 90–115, 2021.

[4] Arthur James Swart, "Evaluation of final examination papers in engineering: A case study using bloom's taxonomy," *IEEE Transactions on Education*, vol. 53, no. 2, pp. 257–264, 2009.

[5] David Rose, "Universal design for learning," *Journal of Special Education Technology*, vol. 15, no. 4, pp. 47–51, 2000.

[6] Micah Lande, "Roles for take-home exams from the perspective of engineering students and instructors," in *2023 ASEE Annual Conference & Exposition*, 2023.

[7] Swetha Nittala, Sheri D Sheppard, and Helen L Chen, "Inclusive course design checklist: A living document for faculty to create inclusive classrooms," in *2023 ASEE Annual Conference & Exposition*, 2023.

[8] "Universal design for learning," `https://www.northwestern.edu/accessibility/digital-accessibility/training/universal-design.html`, Accessed: 2025-01-13.

[9] "Universal design for learning," `https://teaching.cornell.edu/teaching-resources/universal-design-learning`, Accessed: 2025-01-13.

[10] "Universal design for learning," `https://www.rochester.edu/college/disability/faculty/universal-design.html`, Accessed: 2025-01-13.

[11] Edgar Everhart and Paul Lorrain, "The cockcroft-walton voltage multiplying circuit," *Review of Scientific Instruments*, vol. 24, no. 3, pp. 221–226, 1953.

[12] "Chatgpt," `https://chat.openai.com/`, Accessed: 2024-01-22.

[13] Chung Kwan Lo, "What is the impact of chatgpt on education? a rapid review of the literature," *Education Sciences*, vol. 13, no. 4, pp. 410, 2023.

[14] Lars Bengtsson, "Take-home exams in higher education: A systematic review," *Education Sciences*, vol. 9, no. 4, pp. 267, 2019.

[15] Gina J Mariano, Debra E Allwardt, Paul R Raptis, and Kristine Stilwell, “Reintroducing the oral exam: Finding out what your students really know in the age of chatgpt.,” *Currents in Teaching & Learning*, vol. 16, no. 1, 2024.

[16] Lorenzo Moreno-Ruiz, D Castellanos-Nieves, B Popescu Braileanu, EJ González-González, JL Sánchez-De La Rosa, CLO Groenwald, and CS González-González, “Combining flipped classroom, project-based learning, and formative assessment strategies in engineering studies,” *International Journal of Engineering Education*, vol. 35, no. 6, pp. 1673–1683, 2019.

[17] Michael Trevisan, Denny Davis, Steven Beyerlein, Phillip Thompson, and Olakunle Harrison, “A review of literature on assessment practices in capstone engineering design courses: Implications for formative assessment,” in *2006 Annual Conference & Exposition*, 2006, pp. 11–112.

[18] Danielle L Iamarino, “The benefits of standards-based grading: A critical evaluation of modern grading practices,” *Current Issues in Education*, vol. 17, no. 2, 2014.

[19] Sandra P Thomas, “Grappling with the implications of chatgpt for researchers, clinicians, and educators,” *Issues in mental health nursing*, vol. 44, no. 3, pp. 141–142, 2023.

[20] Talia Waltzer and Audun Dahl, “Why do students cheat? perceptions, evaluations, and motivations,” *Ethics & Behavior*, vol. 33, no. 2, pp. 130–150, 2023.