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EFFECTS OF THE IMPLEMENTATION OF MASTERY GRADING IN AN INTRODUCTORY BIOLOGY COURSE

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EFFECTS OF THE IMPLEMENTATION OF MASTERY GRADING IN AN INTRODUCTORY BIOLOGY COURSE

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by

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This Project Thesis, directed and approved by the candidate's committee, has been accepted by the Honors College of Abilene Christian University in partial fulfillment of the requirements for the distinction

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Abstract

The purpose of this mixed methods, exploratory study is to investigate what happens when mastery grading is implemented for summative assessments in a majors introductory biology course. Summative assessments included an initial Learning Objective (LO) exam and the opportunity for students to earn a retake exam. First and second iterations of the LO exams covered the same material but did not have the same questions.

Components of this study included a qualitative analysis of students' perceptions of the mastery grading structure as well as quantitative analyses to determine whether correlations exist between factors such as SAT/ACT scores and degree of grade improvement. Quantitative analyses are also included to assess the extent to which retesting improved exam scores.

All student participants were given a Likert scale survey in which they responded to their feelings of the mastery grading structure. A small subset of students participated in a group interview to further understand student perceptions. Common themes emerged such as improved confidence, lessened test anxiety, and perceived mastery of content material.

All quantitative data was analyzed in aggregate, and a third-party de-identified this data prior to analysis. No correlations were found to link ACT scores with degree of improvement, but students averaged a 3.9% improvement on their second LO attempt with a 95% confidence interval of 3.36% to 4.57%. Quantitative analysis indicated that mastery grading structure does not exclusively help predicted high achieving students; however, further research is needed to explore the relationship between mastery grading and lessening the STEM achievement gap.

Dedication

— For my parents who were the first to instill my love for learning.

Acknowledgments

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CHAPTER 1: INTRODUCTION

Students' struggle for effective learning driven by the fear of failure compounded with the deficits of understanding the course learning objectives has permeated the science classroom (Horn, 2003). In order to help students develop higher-order thinking of course learning objectives, educational researchers have advocated for a mastery grading approach to increase rigor, motivate students, and build conceptual foundations in the discipline (Nelson, 2015). Students wishing to pursue a degree in the biological sciences must develop proficiency in foundational courses such as Introductory Biology. Implementation of mastery grading has been successful in a variety of STEM classroom environments (Tsoi, et al., 2019). For example, instructors teaching introductory chemistry, organic chemistry, physics, anatomy and physiology, and calculus have found mastery grading to increase levels of student engagement and positively improve students' intrinsic motivation (Tsoi, et al., 2019).

Not only do biological science students need a strong conceptual foundation, but an indicator of student success also includes a student's own perceptions of his or her learning (Katzman, et al., 2021). While it is important for students to imagine their own success, they also need equitable opportunities in order to be successful. The mastery grading structure may aid in accommodating the unique range of demographics and learning needs of students by allowing for "second-chance" retake opportunities. Because the aim of mastery grading is to increase rigor, motivation, and foundational knowledge for all students, it is important to investigate which students benefit from mastery grading. Although available research points toward an instructional model that guides students to gain mastery of concepts, a scarcity of research has combined both student perceptions of mastery grading as well as quantitative analyses of the

learning gains achieved with a mastery grading structure. In response, this study seeks to explore the effectiveness of the implementation of the mastery grading structure in an Introductory Biology course. The research questions are as follows:

Research Question 1: What happens when mastery grading is implemented in a majors introductory biology course?

Sub Question 2: What are the students' perceptions of their own learning with mastery grading?

Sub Question 3: Did mastery grading improve exam scores, and are there correlations between standardized test scores and extent of grade improvement?

CHAPTER 2: LITERATURE REVIEW

Overview

Introductory STEM courses have a reputation of being intentionally malicious towards first-year students, with the perception that the goal of these courses is to "weed out" students (Weston, et al., 2019). This sentiment is widespread across the U.S. and present within the culture at Abilene Christian University (ACU). When students perceive that their success is not valued, their motivation can be diminished (Grant & Green, 2013). Introductory Biology is one of the largest STEM prerequisite classes offered at ACU, and the first course that students take from the Biology Department. There is a considerable amount of evidence that first-year students are dropping out of these types of classes at high rates (Grant & Green, 2013). Part of the explanation for underperforming students in introductory STEM courses is a lack of foundational learning strategies (Selvaratnam & Mavuso, 2010). When faced with new learning challenges, students who feel unprepared are susceptible to a lack of self-confidence and mental resignation (Selvaratnam & Mavuso, 2010). And so, if students have not been taught specific learning strategies to overcome such learning challenges, then students may begin to resign their efforts. An endeavor to mediate the feelings of resignation, mastery grading attempts to give students the opportunity for a "second chance" in their learning efforts. It is critical for students to take ownership of their learning because academic performance in the first year of college is an indicator of long-term success within the 4 year plan of their major (Dorta-Guerra, et al., 2019). Recognizing that some students are already at a disadvantage because of a difference in educational background, thus heightening their chances for mental resignation, higher education institutions must learn how to accommodate their instruction to best equip students for success.

In light of these current research findings, ACU has redeveloped the course structure for Introductory Biology with the introduction of mastery grading. This exploratory study focuses on the effects of the implementation of mastery grading within this particular context.

Examples of mastery grading

Variations in the implementation of mastery grading have been used across STEM disciplines. One study from the University of Illinois from Emeka et al. (2023), implemented three different mastery grading policies. The first policy used a partial grade replacement strategy with assurance in which students' grades could only improve by taking the second-chance exam, but the first-chance exam always counted for at least one-third of a students' overall grade on the examination. The second policy was identical, but required students to complete a zero-credit, online-homework assignment before being allowed to take the second-chance exam. The third policy implemented full grade replacement (even if the second score was lower) and capped the score that could be achieved on the second exam. Findings concluded that the use of the second-chance exam did not have a statistically significant impact on students' exam performance on the first-chance exam. Students that elected to take the second-chance exam, however, did additional studying between the exams, which improved their overall grade in the course (Emeka et al., 2023).

Another example of the implementation of mastery grading is from the University of Nebraska by Juhler et al. (1998). Researchers studied the course design of an intermediate algebra course. Students in this course were offered one retest of every test on which they had earned a grade less than a B. A significant increase in performance between the initial test and retest was found for approximately 90% of the students who had earned a grade less than B on

the initial test. Within each group of students eligible to retake a certain number of unit tests, the number of unit tests that they actually retook was correlated with their grade on the final course examination. However, none of the correlations were statistically significant. Thus, optional retesting appears to affect initial mastery, but not cumulative mastery. However, if the student chose to enact the retesting policy, there was a significant improvement on their cumulative grades for the course (Juhler et al., 1998).

Question of the correlation between standardized test scores and mastery grading

According to Westrick (2017) students with higher SAT or ACT math scores were more likely to achieve postsecondary STEM success. Westrick (2017) found that high performing STEM majors from 26 four-year institutions had a higher mean ACT score (greater or equal to a concordance ACT score of 26) than those for lower performing students. Moreover, high-achieving students were well above the ACT college readiness benchmark. It was further predicted that students with an ACT score above a 26 were determined to earn at or above a 3.0 GPA. Considering that ACT scores continue to predict college academic achievement levels, Westrick (2017) suggests students' pre-college academic achievement levels are indicative of undergraduate performance.

Impact on student perceptions

According to Katzman et al. (2021), “second-chance” testing led to a 30% reduction in students’ reported test anxiety. Students also reported reduced stress throughout the semester, even outside of testing windows, due to the availability of second-chance testing (Katzman et al., 2021). Additionally, Hsu and Goldsmith (2021) noted that mastery grading reduced stress and anxiety in students because of the increased number of low-stakes assessments, rather than

students' grade hinging on large exams. Students enrolled in a course structured with multiple formative assessments and the opportunity for retesting, can have lower amounts of stress compared to students who are in traditional classroom environments. The mastery grading method encourages individuals to recognize that they can achieve their goals or outcomes with hard work and effort, reinforcing that there are multiple paths that they can take to be successful as long as they give themselves time and are diligent in their studies. This allows the student to view challenges with the hopefulness of possible success instead of hopelessness and the feeling of inevitable failure. Additionally, interventions such as mastery grading can motivate students and improve their perception of academic setbacks, such as failing an exam, thus increasing persistence toward graduation in STEM fields (Hsu & Goldsmith, 2021).

CHAPTER 3: METHODOLOGY

Participants and context

Abilene Christian University is a liberal arts university of almost 4000 undergraduate students. Introductory Biology I (BIOL 121) is the first course in a two-semester sequence of courses that each include a lab component. A "C" or higher is required in both semesters to advance to upper-level biology courses. The students that enroll in Introductory Biology are typically students majoring in biology, biochemistry, kinesiology, agriculture and environmental sciences, and psychology. For example, in Fall 2023, of the 189 students enrolled in Introductory Biology I, 63 were Biology majors, 60 Kinesiology, 24 Biochemistry, 22 Agriculture & Environment, 9 Psychology and 11 were from other majors.

Participants in this study were undergraduate students in four sections of Introductory Biology I taught by three different instructors. Sections averaged 50 students each and the duration of the classes took place during the Fall of 2023. Instructor 1 taught two sections, Instructor 2 taught one section, and Instructor 3 taught one section.

Data collection

De-identified data was obtained from all three instructors for their respective sections and included exam scores (both the original and re-takes), final course grade, GPA, and ACT/SAT score. Quantitative analysis was done using data from all students remaining at the end of the semester. Only data from the 35 students that completed a survey during the semester and agreed to be part of the study out of a total of 120 enrolled students (this is the number of students remaining when the survey was administered) were included in qualitative analyses. Additionally, only 10 students agreed to participate in the focus group interview.

All components of the course were standardized between instructors. Course material was divided into 17 learning objectives, and each LO was tested separately on exam days. Students took three to four LO exams on exam days. Exam questions were all selected-response questions and included questions at multiple levels of Bloom's taxonomy. All four sections of the course taught by the three faculty generally followed the same teaching model. Instructional time was split between direct instruction and active learning in which teams of three to four students completed a worksheet designed to promote higher-order thinking skills.

In accordance with IRB protocols, course instructors were not involved in recruiting student participation in order for students to feel as though they could participate freely without concern about the instructor's knowledge of participants. As the student researcher on this project, I introduced students to the research study during class sessions to gather informed consent and explicitly stated the option to decline participation in the study. Students were provided with a consent form to sign if they chose to participate, and additional confirmation of consent was attached prior to participating in the survey. All communication regarding the survey and the focus group interview was through email to myself, the student researcher, in order to keep all knowledge of student participation anonymous to the instructors. The Abilene Christian University Institutional Review Board approved this study (IRB 2023-251).

Mastery Grading Structure

At ACU the Introductory Biology course implemented mastery grading through the division of content into Learning Objectives, or LOs. Usually each Learning Objective corresponded to a chapter of the textbook. Therefore, each of the five units consisted of several LOs and chapters. Furthermore, each LO had a corresponding practice and mastery quiz and as

well as the option to do a "retake." Summative assessments were administered roughly every two weeks with students taking three to four LO exams during the allotted instructional time. Students were permitted to choose one to two LOs and retake the desired exam approximately one week after the initial test date. In order to qualify for a LO "retest" the student must have attended either a one-on-one or group tutoring session.

Data Analysis

Qualitative

An inductive qualitative design was used to determine students' perceptions of the mastery grading structure. The inductive approach is data-driven and works from the specific to the general, searching for patterns (Hendricks, 2017). In this way, knowledge about how students' feel can be generated directly from the students themselves. A focus group interview along with survey responses were used to gain insight on the students' perceptions.

All student participants were given a mastery grading survey. This survey consisted of sixteen questions relating to students' preferences of mastery grading. Students responded to each question using a five point Likert scale with the options of strongly agree, agree, neutral, disagree, and strongly disagree. An additional open-ended question was optional at the end. The list of questions used for the survey can be found in Appendix B.

As for the focus group interview, I chose a sample of students to interview based on their responses to the perceptions of the mastery grading survey. I used purposive sampling (Patton, 1990) to select four students who indicated they preferred mastery grading, three students who indicated they found mastery grading challenging, and three students who indicated indifference towards mastery grading. The interview was a single, one-hour-long focus group with all ten

students. The interview was semi-structured, with pre-planned but open-ended questions (Hendricks, 2017). Additional questions were asked to clarify the responses of the participants.

All participants were assigned a pseudonym. A key with participants' real names and corresponding pseudonyms has been kept electronically under password protection.

The semistructured interview guide consisted of open-ended questions aimed at capturing students' perceptions. Examples of questions were, "How do you feel about the mastery grading structure?", "Do you feel as though the mastery grading structure has helped you better understand how you learn?", "Tell me about the relationship between mastery grading and your grade. Do you feel as if it is an accurate representation of what you have learned?", and "When was a time you noticed mastery grading helping you understand a concept?" A full protocol of the interview questions can be found in Appendix A. To obtain an informative and deep understanding, questions such as "Please tell me more" and "What do you mean?" were posed. The focus group interview was conducted during finals week during school hours on ACU's campus in one of the biology classroom spaces. The focus group interview was audio-recorded, lasted 60 min, and were transcribed verbatim.

Qualitative data from the survey and focus group interview was analyzed using initial coding followed by creating hierarchies of categories and supporting codes (Hubbard & Power, 2003). The transcribed text from the group interview was analyzed using qualitative content analysis (Hubbard & Power, 2013). This is considered an appropriate approach for analyzing interview data and systematically interpreting its meaning by focusing on relevant data. Content analysis focuses on variations in respondents' experiences. The analysis started with reading each focus group interview transcript to obtain a comprehensive sense of the overall situation.

Subsequently, all text was read again to identify common themes related to the aim of the study. Afterwards, the common themes were condensed, and labeled considering the text as a whole. The codes were compared based on their differences and similarities, and were sorted into subthemes which were categorized under a single theme. Quotes from the interviews are presented in the results section to illustrate the theme and subthemes.

Quantitative

Quantitative data collection included collection of mastery exam grades from Canvas and SAT/ACT scores. All quantitative data was analyzed in aggregate and a third-party de-identified this data prior to analysis. In order to differentiate between students who tried on their first LO attempt and students who were not prepared on the first attempt, the student's score was compared to determine if it was greater or equal to 80% of their average exam score. If the student's score on the LO was greater or equal to 80% of their overall average exam score, then that student was classified as "trying" and we determined that the student was putting forth effort rather than just disregarding the exam. This calculation was done for each student on each of the 15 testable LOs. Once we knew which students were "trying" on their first exam attempt, then students were further separated if they attempted a retest opportunity for that specific LO. The difference between the questions answered correctly between the first and second attempts was calculated and then divided by the total number of possible questions. Once this number was calculated, it was turned into a percentage. This percentage represents the average improvement out of 100 questions for "trying" students. A 95% confidence interval of the proportion of improvement out of the total number of questions was calculated using the GraphPad QuickCalcs Web site: http://www.graphpad.com/quickcalcs/ConfInterval1.cfm (accessed April 2024).

In order to determine the correlation between standardized test scores and the percentage of improvement between the first and second LO exam attempts, each student's percentage of improvement was correlated to the student's standardized test score. If the student only had a SAT score, then a concordance ACT score was assigned as a replacement. If a student had both an ACT and SAT score, then no concordance value was assigned and the given ACT score was used. Both Spearman's and Pearson's correlation analyses were conducted using PAST software (Hammer, Harper, & Ryan, 2001) in order to determine the correlation between retesting and percentage of improvement for "trying" students.

CHAPTER 4: FINDINGS

RQ1 What happens when mastery grading is implemented in a majors introductory biology course?

The effects of the mastery grading structure vary in the perceived benefits and drawbacks. According to the survey (*n*=35), 74.3% of students reported that mastery grading improved their learning with only 22.9% indicating mastery grading was not influential or was detrimental in their learning and 2.9% reporting mastery grading did not improve their learning whatsoever. Additionally, 60% of students expressed "strongly agree" that the use of retakes improved their grades, 20% expressed "agree" and only 20% expressed retesting neither improved or impaired their grade, thus indicating that the majority of students found the opportunity for retesting useful and beneficial for improving their grade.

There were instances when students explained they could essentially "play" the system in which they would knowingly only study for two of three LO exams. Students expressed purposefully sacrificing one of the LO exams because of the opportunity to retake it at a later date. Students who thought this structure was useful noticed that the structure and the ability to do retakes significantly helped their grade and their learning. One student mentioned that they *"really know the material now because I was able to try again."* The complete set of survey responses can be found in Appendix C.

RQ2 What are the students' perceptions of their own learning with mastery grading?

Feeling overwhelmed

Part of the structure of mastery grading is the use of multiple formative assessments to prepare students for summative assessments. Often students expressed that adjusting to this new

way of learning caused initial waves of feeling overwhelmed. Two students expressed their initial feelings:

> *"At first I felt overwhelmed because there were so many things to do before and after class and as well as during the class…it left me with a lot of choices, I got so overwhelmed."*
>
> *"In the beginning it was a little difficult to do, but as we went through the units it became easier to understand and find how I could later use the resources to study for the exams."*

Another student expressed the difficulty balancing multiple assignments by mentioning how it feels stressful to *"make sure you're catching everything."* As the feelings of stress and anxiety continued to arise, several students disclosed that they felt stressed most of the time. For instance, one student said:

> *"I think we're all stressed, pre-med or anyone generally who's doing science, there's that pressure to perform. I think it's also an internal thing that most people carry in their lives anyways."*

This student's response indicates that the levels of stress appear to be closely interrelated with their chosen STEM major. Students continued to express the difficulty of the course and related their feelings of anxiety as a consequence of the continuous cognitive load they feel they must bear. As one student noted,

> *"I feel like this class requires you to put a lot of effort in regardless of what system you use. I feel like it's well known that this is a weedout class"*

As students' responses indicate, there appears to be an initial period of uncertainty at the start of the course. However, it is important to note that the majority of first-year students are navigating the social and academic environment on a university campus for the first time. As the students

allude to, there are additional factors that cause students to feel anxious such as the pressure to perform and the looming pressure to maintain high grades for future graduate school admissions. However, students also expressed the benefit of retesting helped mitigate the feeling of being "doomed."

> *"I feel like this class does help with the stress levels somewhat though. It puts the ball in your court and even if you don't do well there's a second chance around the corner…I'm not doomed if I do really poorly one day because I can do a retake. There's always another chance"*

Feelings of anxiety around science courses are well known, but as this student noted, mastery grading offers a reliable system for students to depend upon as well as grade security if they do not do well on the initial exam. In some cases, such as the previous student's sentiment, retesting may aid in alleviating levels of stress. Another student mentions a similar benefit of mastery grading,

> *"I knew going into it, it was going to be stressful. I know it's still hard to deal with but I feel like if you prepare with what's given then it's easier"*

As this student shared their thoughts, others agreed that mastery grading made them feel at ease because the opportunity for retesting allowed for a second chance. While there are still percolating feelings of anxiety mixed with the reputation of Introductory Biology being a weedout class, the majority of students agreed that when given the opportunity for a second chance, they felt less overwhelmed.

Mastery grading helps build students' confidence

When discussing mastery grading, students consistently expressed the benefit of building confidence.

> *"I liked how many times we were questioned before we went for the test because I knew going into it what I was going to be tested on, well not exactly, but I had a more narrowed scope versus if I just had the book."*

Students admitted that the structure would "force" them to engage with the material, and often they would not have spent the extra time studying if it were not for the assignments keeping them accountable. Additionally, formative assessments provided the opportunity to retake them as many times as needed. As one student noted,

> *"I liked it because you could practice the questions over and over again until you figured it all out."*

Students agreed that they felt intimated learning the material on their own, and so the use of a variety of formative assessments increased their own understanding of where potential gaps of knowledge might be before taking an exam.

> *"The repetitiveness really helped me feel confident. I was able to get it into my brain so I could remember it for the exam."*
>
> *"I agree, it's gotten to the point where even if I did the bare minimum, I started having dreams about biology. So I think it does a good job hammering it into you through brute force."*

Students repeatedly expressed the benefit of retests impacting their ability to "try again," thus indicating that students felt a greater sense of accomplishment in their learning ability when having the opportunity for a second chance.

> *"My pattern was that I would do really good on one [LO exam], good on another, and be bad on one. So it was dependent on each one. But I did feel like I was given the tools to be able to do well, so it was just up to my understanding."*

As students progressed through the course and gained comfortability with the mastery grading structure, students were able to develop a deeper understanding of the content or at least recognize which areas of content needed to be readdressed.

Frustrations with instructional time

The mastery grading structure is not exempt from difficulties. One perceived downfall of the mastery grading structure is the hyperfixation on completing formative assessments, thus unintentionally diminishing the quality of instructional time.

> *"The structure of the course made it more difficult for me to fully understand the material. I felt like I was prepping for quizzes and exams the whole time."*

Often students felt that instructional time was dedicated to "checking off the boxes" rather than engaging with the material.

> *"It felt like the teacher was simply just doing and not teaching. In class the worksheet was done in small groups and I learned nothing from them. They did not go in-depth on the things that needed to be gone into depth. It felt unnecessary."*

Students expressed the lack of clarity when searching for the right answers, and felt the need for further discussion behind the meaning of a particular concept.

> *"There could have been more time spent going over study guide questions. Sometimes I felt like if I didn't know the answer to a study guide question, I wasn't sure if I ever got it right."*
>
> *"Often I felt like instructional time was not productive, I sometimes never got the why behind the stuff we were studying"*

Students expressed they lost motivation as they progressed through the semester because the lectures followed the same routine and class worksheets were graded based on completion rather than demonstration on depth of thought. While students expressed frustration doing completion

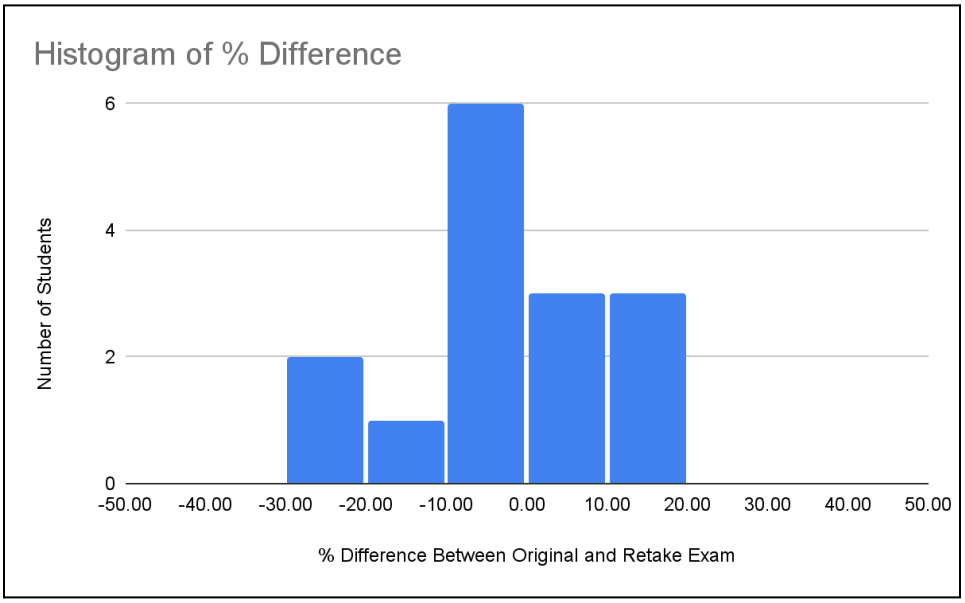
assignments, it is important to note that they were still engaging with the content. Part of the strength behind these completion assignments were the dynamic and collaborative efforts done by the student teams. Not every group was inherently efficient and collaborative as the instructor would have desired; however, students may have overlooked the value of teamwork and low stake assessments.

RQ3 Did mastery grading improve exam scores and are there correlations between standardized test scores and extent of grade improvement?

Mastery grading through the use of retesting improved student exam scores on average by approximately 3.9% with a confidence interval of the proportion ranging from 3.36 to 4.57. In other words, for every 100 questions that students would answer, there would be roughly four questions that they would gain back through retesting.

However, it appeared that LOs that covered less content and therefore had fewer numbers of questions had a higher percent improvement compared to LOs covering more content and with greater numbers of questions. Considering 13 was the median number of questions with a range of 8 to 18 across LOs, the percent average improvement of LOs with more than 13 questions was 3.22%, while the percent average improvement of LOs with less than 13 questions was 9.95%. The percent difference between the original and retake exams for each LO were averaged across 'trying' students and plotted as histograms. All LO histograms are shown in Appendix D, and one histogram from a lower content LO (LO16 = 10 questions) and one histogram from a higher content LO (LO13 = 17 questions) are shown in Figure 1.

LO13



LO16

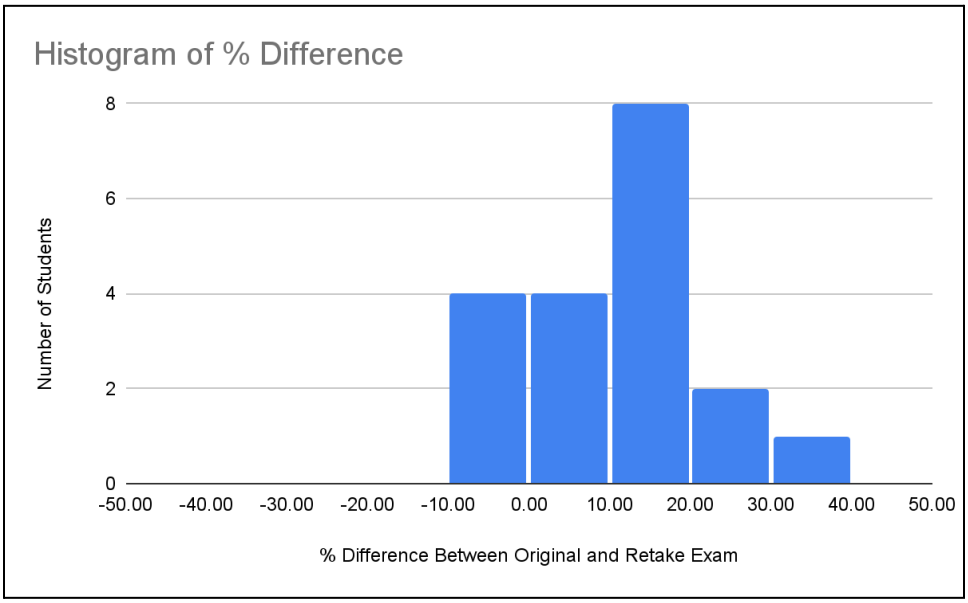


Figure 1. Histograms for LO13 and LO16 showing the percent difference between original and retake exam scores averaged across students.

There was not a significant correlation between ACT scores and degree of improvement. For the Pearson's correlation analysis, a *p*-value of 0.536 and an *r*-value of 0.076 was calculated. Additionally, Spearman's correlation analysis found a *p*-value of 0.243 and a *r*-value of 0.144.

CHAPTER 5: DISCUSSION AND IMPLICATIONS

The study aimed to delve into the effects of implementing a mastery grading structure within an introductory biology course setting. Results suggest that mastery grading exhibits potential in catering to students across a broad spectrum of abilities and may contribute to enhancing subsequent academic advancement. Although the quantitative analysis did not reveal a major increase in overall improvement rates, students exhibited an average improvement of 3.9% on their second learning objective attempt, even a small percent increase indicates there were learning gains that were achieved through the mastery learning structure. Furthermore, the qualitative data suggest intangible benefits of the mastery learning structure such as increasing student confidence, lessening perceived anxieties, and promoting deeper learning. Not surprisingly, students were able to make the most gains on LO exams that covered less content and therefore had less questions, indicating that exam performance is highly dependent on content volume.

One concern of mastery grading was if high-achieving students were the primary benefactors from mastery grading. As the literature references, ACT scores continue to provide a consistent indicator of first-year collegiate student success. Our analysis indicated an absence of discernible correlations between ACT scores and the extent of improvement, thus suggesting that mastery grading does not exclusively benefit high-achieving students. In other words, ACT scores do not predict if or how much a student will improve if they choose to retest.

This study identifies the need for further investigation into the relationship between mastery grading and narrowing the achievement gap, particularly in STEM disciplines. Future research could explore variables such as the number of test questions and their impact on student

improvement, as well as the influence of intrinsic versus extrinsic motivators on student engagement—a crucial aspect for informing instructional strategies.

Although the mastery grading structure has only been newly implemented, the study emphasizes the importance for institutions, like ACU, to prioritize the development of equitable course structures. By embracing methodologies that accommodate diverse learning needs and foster academic growth across all student demographics, educational institutions can cultivate a more inclusive and effective learning environment.

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APPENDICES

Appendix A: Focus Group Interview Protocol

1. How do you feel about the mastery grading structure? What do you like/dislike about the way the class is structured?

2. What is your favorite way to learn the material? Do you feel drawn to a particular activity (study guide, worksheet, practice quizzes)? How come?

3. How do you feel when you take an exam?

4. What motivates you to study the material?

5. Tell me about a time when you decided to retake an exam.

6. What do you think about metacognition? Do you feel as though the mastery grading structure has helped you better understand how you learn?

7. How did you prepare for an upcoming exam?

8. How do you feel about taking more biology classes in the future?

9. Tell me about the relationship between mastery grading and your grade. Do you feel as if it is an accurate representation of what you have learned?

10. When was a time you noticed mastery grading helping you understand a concept?

Appendix B: Survey Questions

Mastery Grading Survey

1. I clearly understand the structure (e.g. due dates, grading, etc.) of the Introductory Biology I course.

Strongly disagree Disagree Neutral Agree Strongly Agree

2. I understand the steps I need to take in order to be successful in Introductory Biology.

Strongly disagree Disagree Neutral Agree Strongly Agree

3. Completing the pre-class readings helps my understanding of course material.

Strongly disagree Disagree Neutral Agree Strongly Agree

4. Answering study guide questions helps my understanding of course material.

Strongly disagree Disagree Neutral Agree Strongly Agree

5. Completing worksheets in small groups helps my understanding of course material.

Strongly disagree Disagree Neutral Agree Strongly Agree

6. Taking practice quizzes helps my understanding of course material.

Strongly disagree Disagree Neutral Agree Strongly Agree

7. Taking the mastery quizzes helps my understanding of course material.

Strongly disagree Disagree Neutral Agree Strongly Agree

8. Which of the following activities helps prepare you the most for exams?

Study guides Worksheets Practice quizzes Mastery quizzes

9. Which of the following activities helps you the least when preparing for exams?

Study guides Worksheets Practice quizzes Mastery quizzes

10. How many times throughout the semester did you take a mastery exam retake?

0 1 2 3 4 5 6 7

11. The use of retake exams helps in my learning.

Strongly disagree Disagree Neutral Agree Strongly Agree

12. The use of retake exams improves my grade in Introductory Biology I lecture.

Strongly disagree Disagree Neutral Agree Strongly Agree

13. How many times throughout the semester did you attend a group tutoring session?

0 1 2 3 4 5 6 7

14. Attending group tutoring helps prepare me for mastery exam retakes.

Strongly disagree **Disagree** **Neutral** **Agree** **Strongly Agree**

15. I found it difficult to prepare for retakes while also learning new course material.

Strongly disagree **Disagree** **Neutral** **Agree** **Strongly Agree**

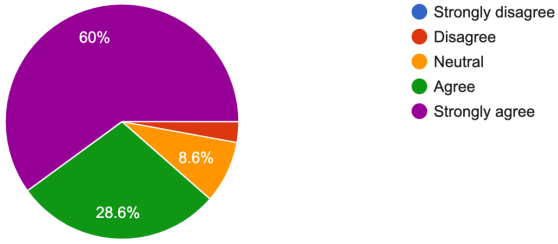
16. I would enjoy taking another biology course that was structured the same as Introductory Biology I.

Strongly disagree **Disagree** **Neutral** **Agree** **Strongly Agree**

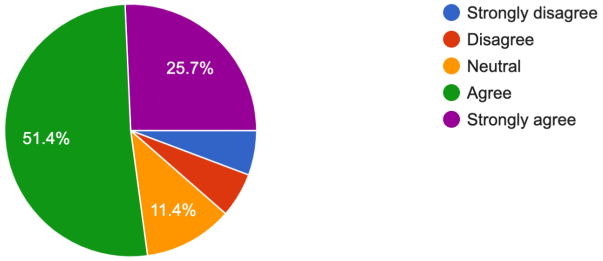
Are there any other comments on how the structure of the course influenced your learning in the Introductory Biology I course?

Appendix C: Survey Responses

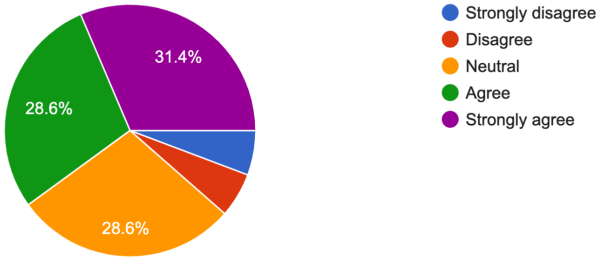
I clearly understand the structure (e.g. due dates, grading, etc.) of the Introductory Biology I course.
35 responses



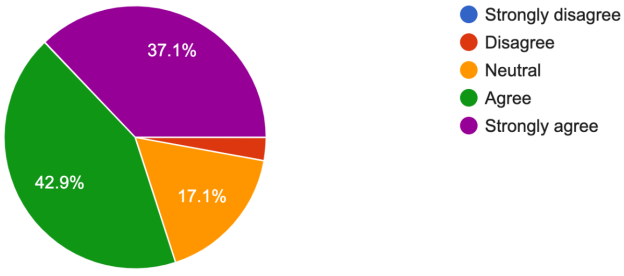
Completing the pre-class readings helps my understanding of course material.
35 responses



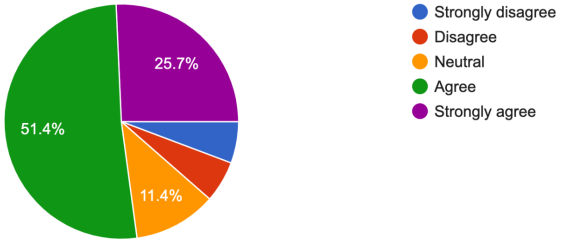
Completing worksheets in small groups helps my understanding of course material.
35 responses



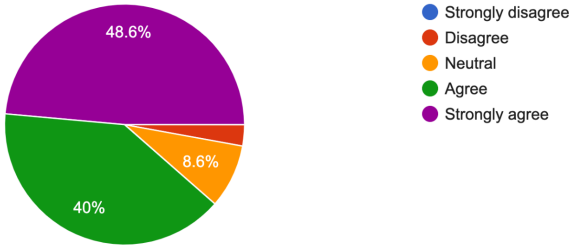
Taking the mastery quizzes helps my understanding of course material.
35 responses



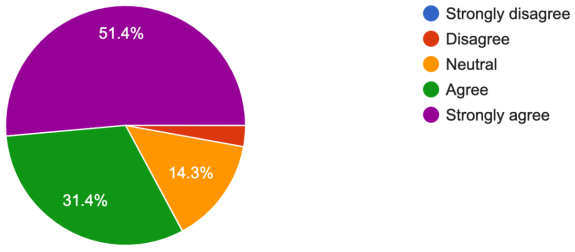
Completing the pre-class readings helps my understanding of course material.
35 responses



Answering study guide questions helps my understanding of course material.
35 responses

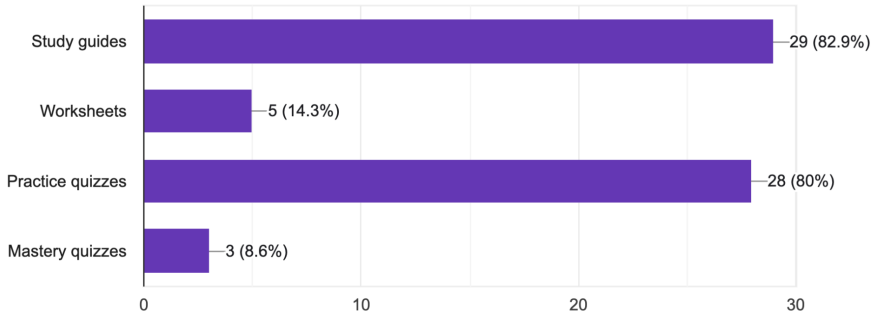


Taking practice quizzes helps my understanding of course material.
35 responses



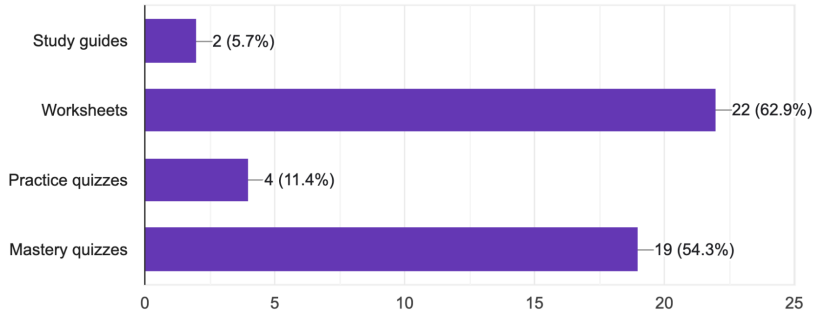
Which of the following activities helps prepare you the most for exams?

35 responses



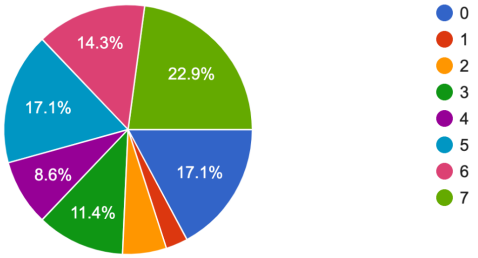
Which of the following activities helps you the least when preparing for exams?

35 responses



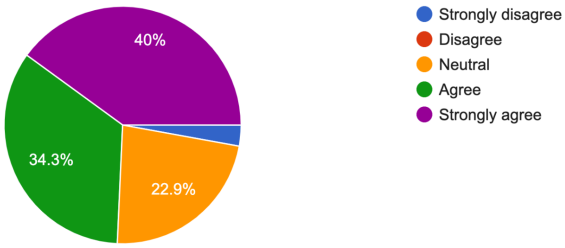
How many times throughout the semester did you take a mastery exam retake?

35 responses



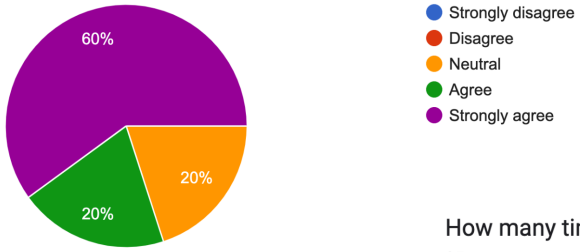
The use of retake exams helps in my learning.

35 responses



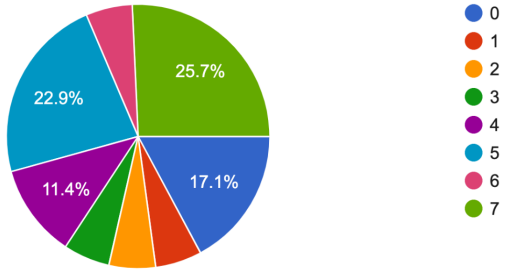
The use of retake exams improves my grade in Introductory Biology I lecture.

35 responses



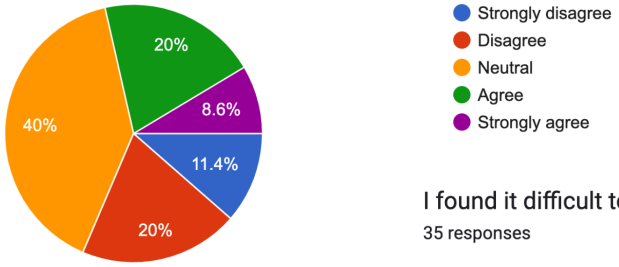
How many times throughout the semester did you attend a group tutoring session?

35 responses



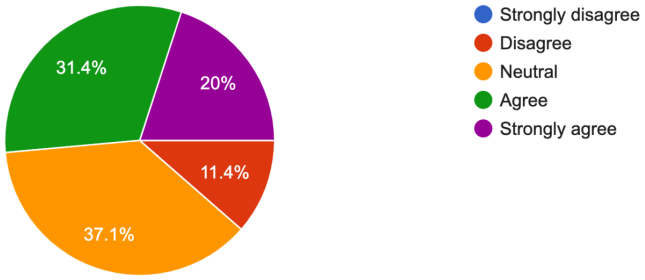
Attending group tutoring helps prepare me for mastery exam retakes.

35 responses



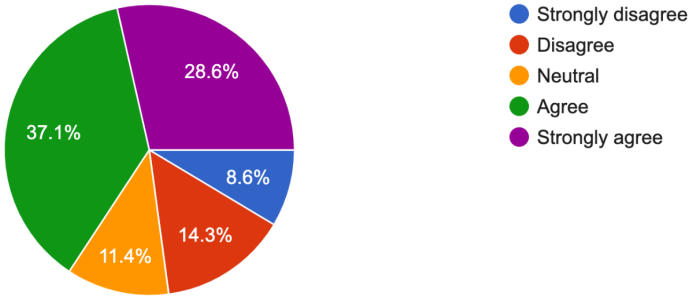
I found it difficult to prepare for retakes while also learning new course material.

35 responses



I would enjoy taking another biology course that was structured the same as Introductory Biology I.

35 responses



Appendix D: Histograms

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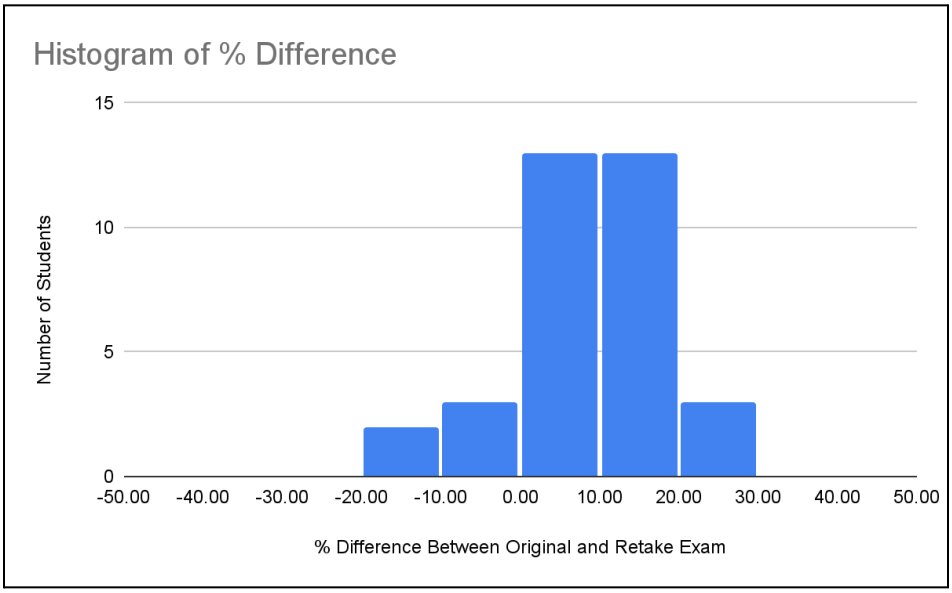

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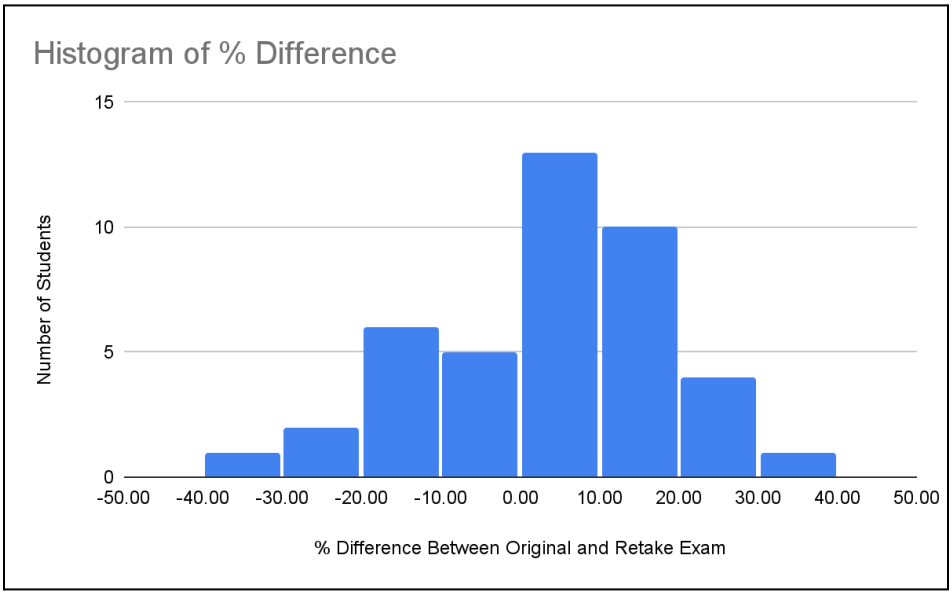

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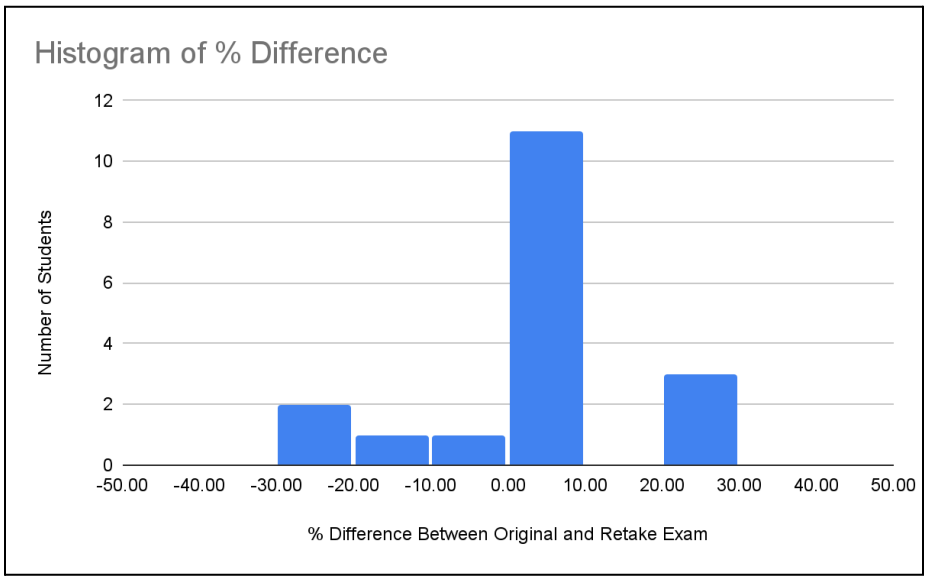
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50.00
% Difference Between Original and Retake Exam

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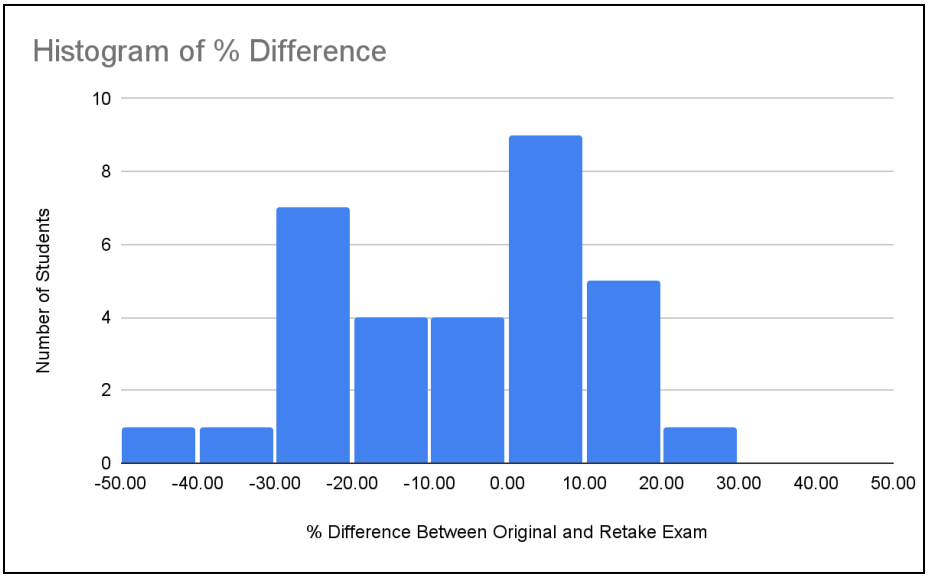
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% Difference Between Original and Retake Exam

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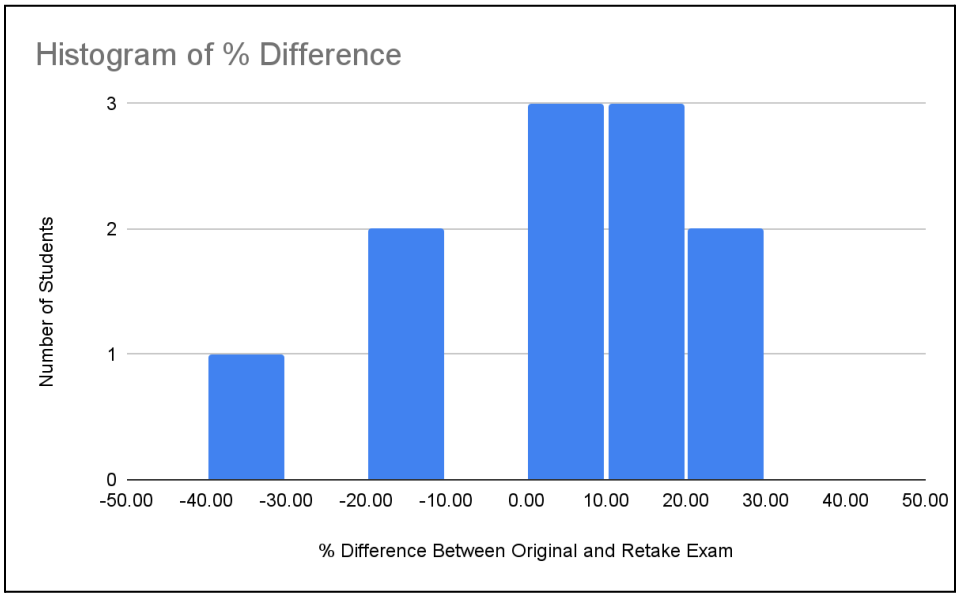
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% Difference Between Original and Retake Exam

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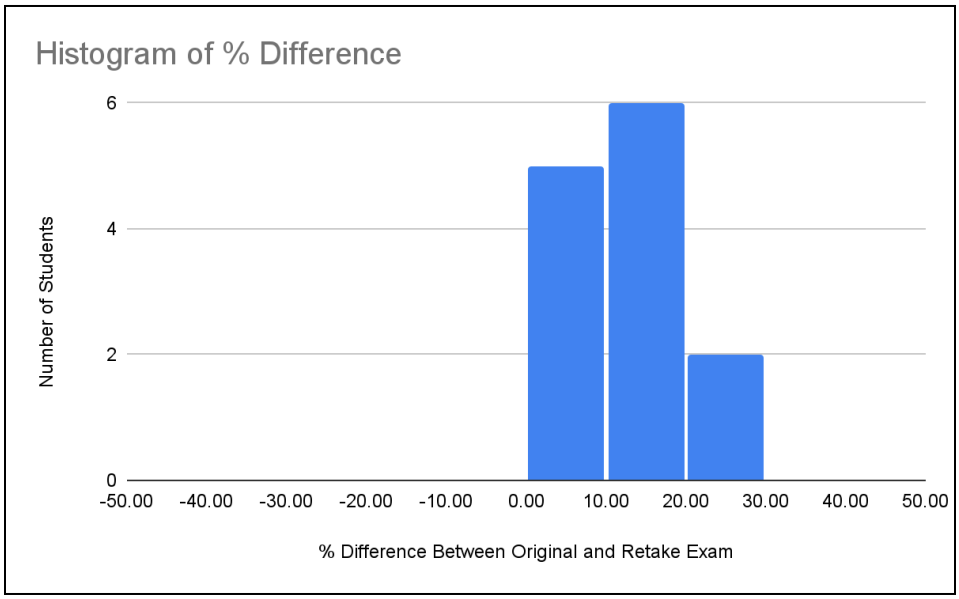
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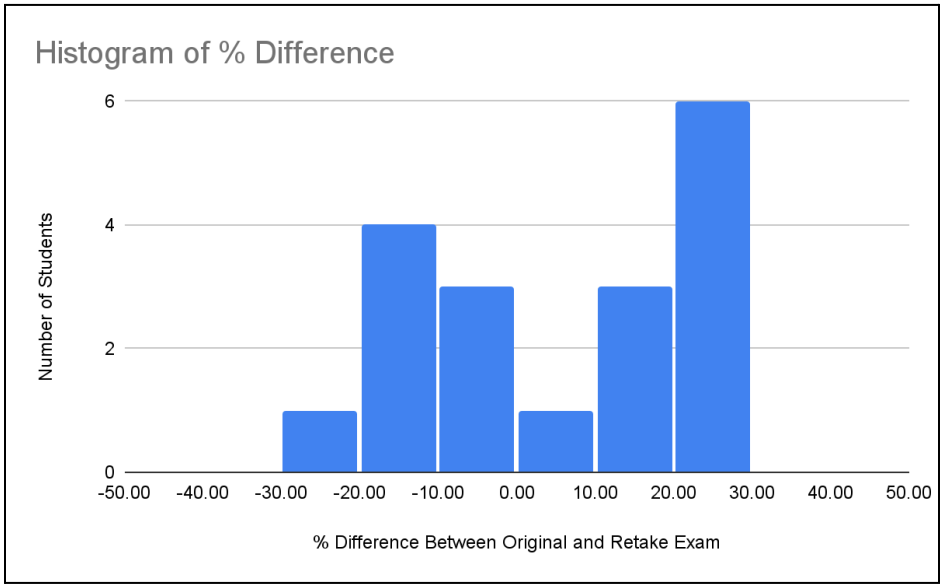
% Difference Between Original and Retake Exam

LO8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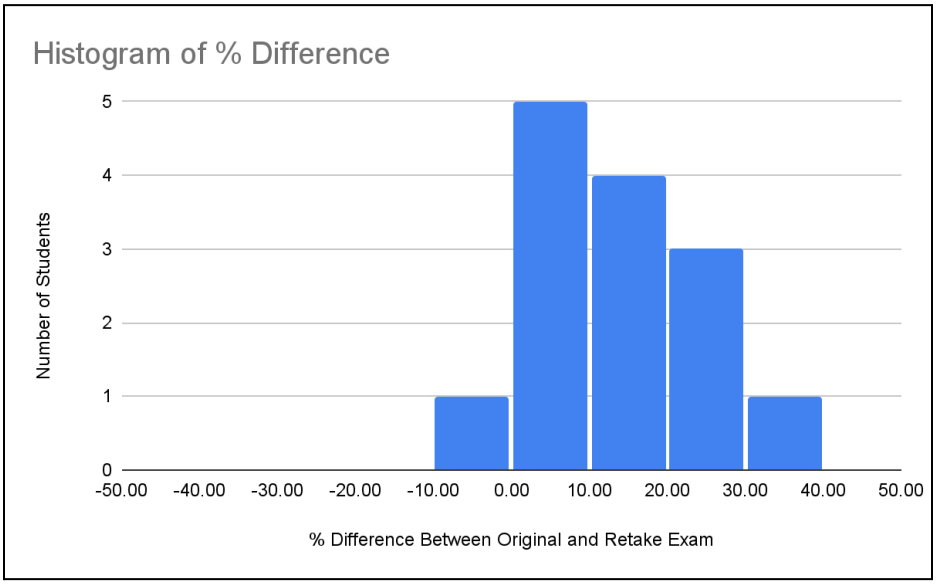
% Difference Between Original and Retake Exam

LO9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% Difference Between Original and Retake Exam

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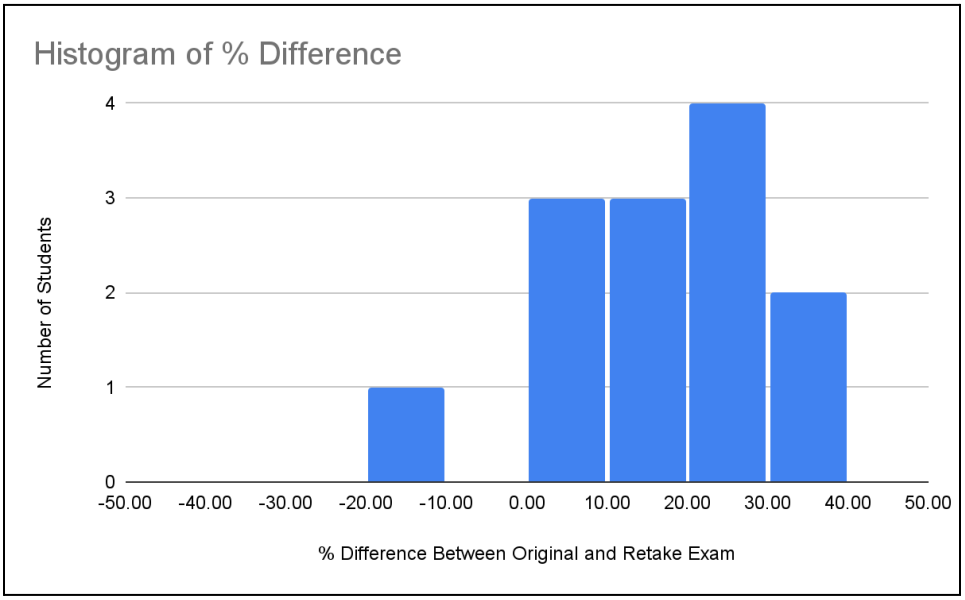
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% Difference Between Original and Retake Exam

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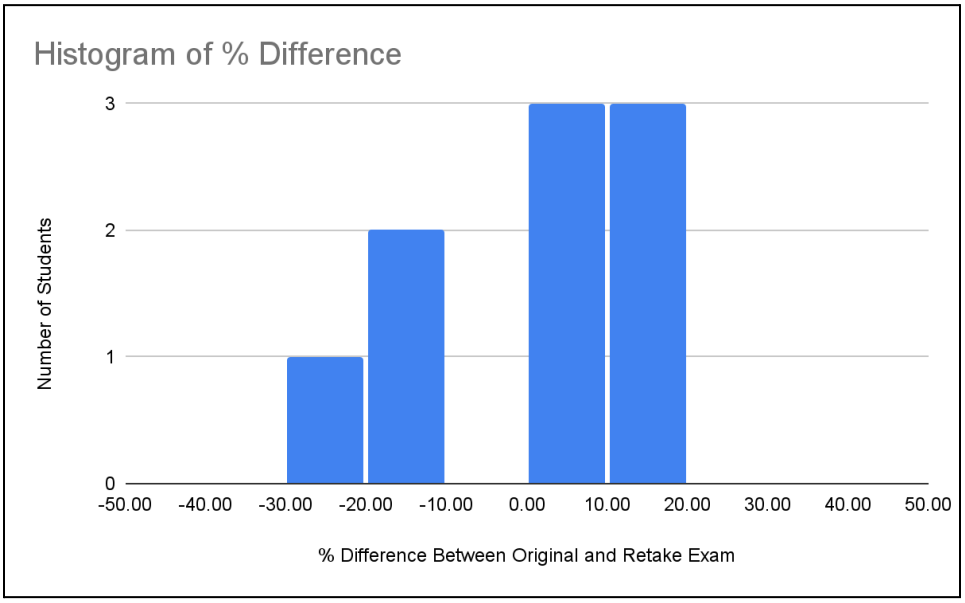
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% Difference Between Original and Retake Exam

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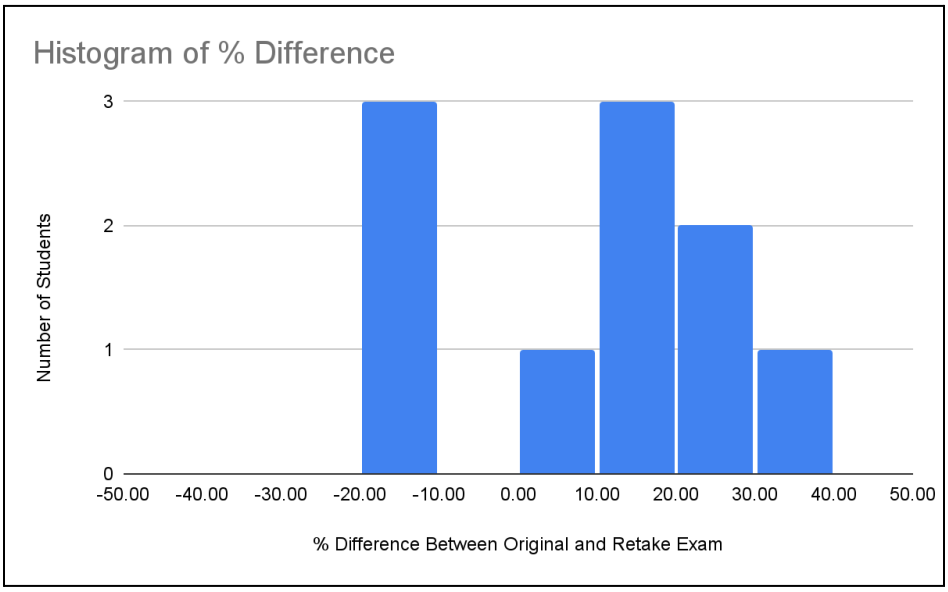
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% Difference Between Original and Retake Exam

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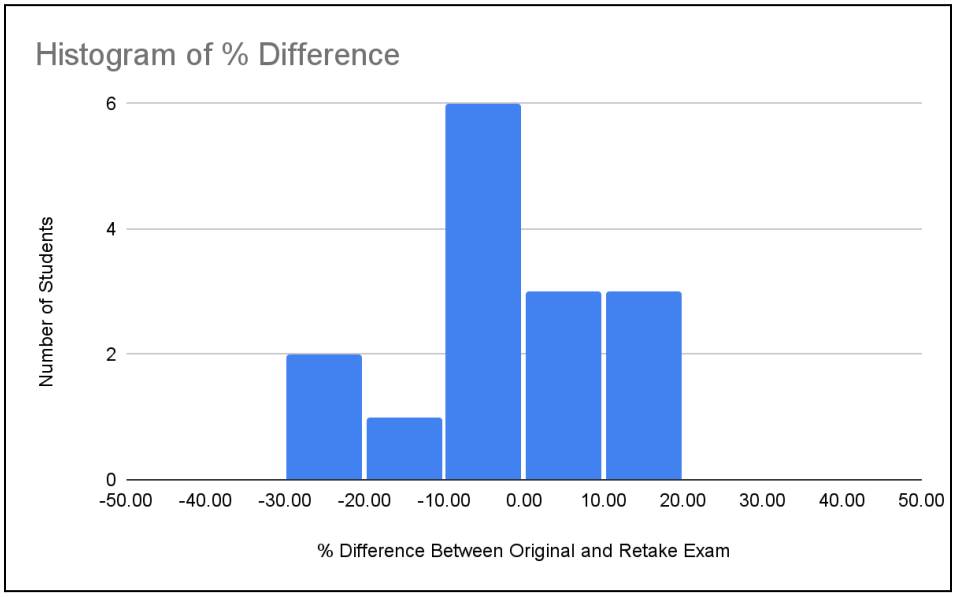
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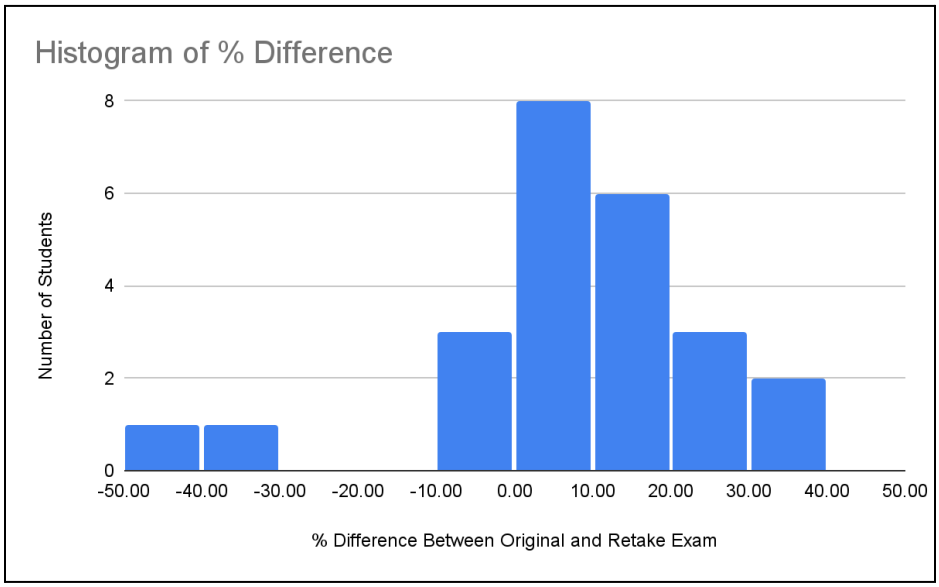
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% Difference Between Original and Retake Exam

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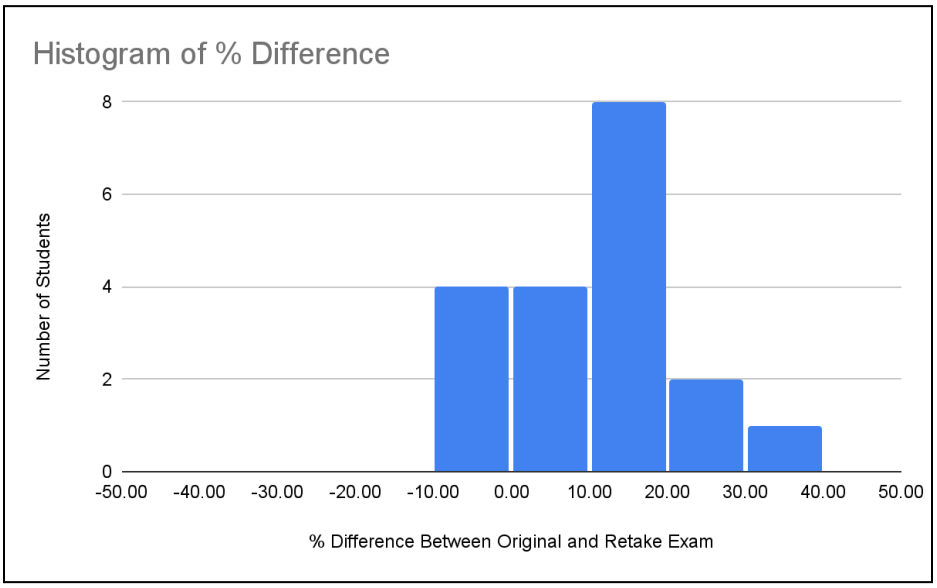
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% Difference Between Original and Retake Exam

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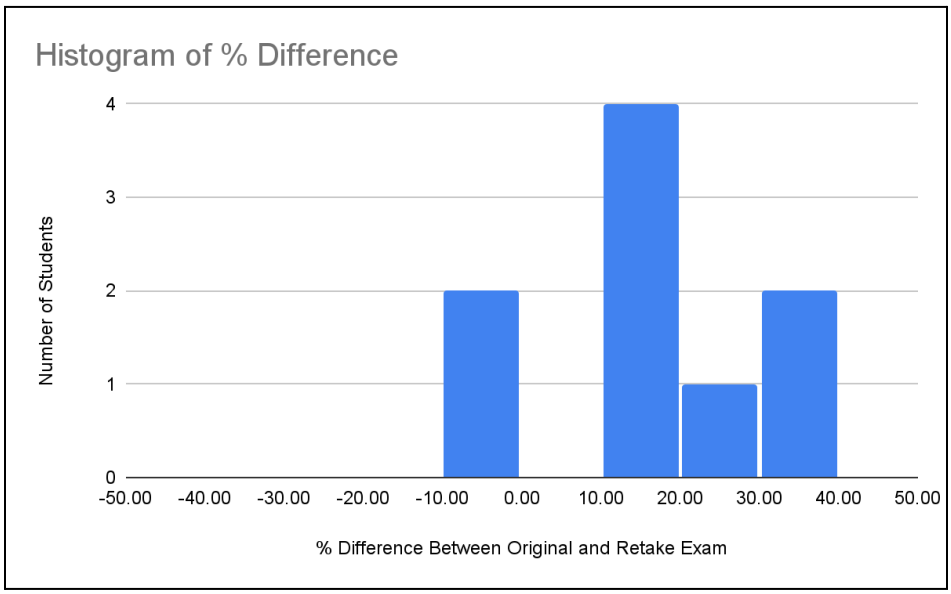
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% Difference Between Original and Retake Exam