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Identifying the Optimal Pedagogy for Preparing Undergraduates for the MCAT Exam

Alyssa J. Black

ACKNOWLEDGEMENTS

I would foremost like to thank Dr. Himes for his undying patience and insight as we have collaborated on this project for the last three years. I would also like to thank all who have believed in me these past four years as well as the Honors Program for giving me this opportunity.

ABSTRACT

Excelling on the MCAT is an essential step for undergraduate students preparing for a future as a physician in the medical field. Previous research has made links to MCAT performance and success in the medical field, yet there is a lack of research on how to best prepare undergraduate students for this extensive exam. Various research has been done on assessing the most effective studying strategies for undergraduates on typical collegiate exams, which students often translate to their MCAT studying. To assess the effectiveness of these practiced pedagogies on the MCAT, a social science experiment using a pre- and post-test format based upon MCAT questions and test conditions was used to support or negate the ability of reading text, using memorization tasks, test-enhanced learning, and instructor-led courses to improve MCAT performance. Forty students were recruited from Olivet Nazarene University to participate in one of five experimental groups testing these researched methods. Using a t-test and Bonferroni correction to assess pre- and post-test average, the only strategy that made a statistically significant difference in pre- and post-test average was using an instructor-led course to enhance performance. The findings of this study could encourage students and universities to begin using instructor-led course material to improve MCAT performance for students aspiring to be physicians.

Keywords: MCAT, study, pedagogy, strategies, test-enhanced learning, memorization, instructor-led course

INTRODUCTION

The Medical College Admission Test (MCAT) is a graduate-entry exam that assesses a student's scientific knowledge and critical analysis skills to act as a predictor of success in medical school (Swan Sein et al., 2020). In rare cases, students are not required to take the MCAT exam to receive acceptance into medical school. Students who apply and get accepted into BA/MD or BS/MD programs will be automatically placed into medical schools contingent on their ability to maintain the academic and extracurricular standards of these programs (International Medical Aid, 2022). Despite the existence of these programs, most students who pursue a medical degree will be required to take the MCAT, as BS/MD programs have excessive requirements for their incoming classes to ensure they have the leadership, academic, and research experience required of prospective medical students. Though the MCAT is one of many factors used to access medical school acceptance, most schools require the exam and use it as a measure of knowledge learned from a student's undergraduate degree to predict success in medical school (Murphy, 2019). The exam itself includes four sections: chemical and physical foundations of biological systems; critical analysis and reasoning skills; biological and biochemical foundations of living systems; and psychological, social, and biological foundations of behavior. Because the exam is so information heavy, it typically lasts around seven hours. There is not a lot of published research about MCAT preparation, particularly for the newest version, which was revised in 2015. Much of the research surrounding the MCAT involves ensuring the test remains fair and maintains a certain level of equity for all students who take the exam rather than the most effective preparation strategies (Girotti et al., 2020).

Lack of proven preparatory strategies

The majority of the information concerning how to prepare for the MCAT includes non-scholarly blogs and non-peer reviewed articles about how to set deadlines for the amount one should study, ensuring that the quality of study is better than the quantity, and other general tips that do not explicitly state how to learn the information for this exam. Furthermore, students do not always have access to low-cost, proven, direct instruction on how to study. For example, students who understand and apply retrieval strategies, or tasks that enhance memorization by repetitive exposure, are proven to perform much better than those who do not, but students lack the ability to effectively use these strategies when they experience illusions of competency by simply rereading their notes or class texts (Karpicke et al., 2009). Because of the evident lack of MCAT preparatory research, the topic is open for investigation. Without evidence-based research, students often misuse study time or suggested preparatory methods. This often results in lower scores and therefore lower potential for medical school acceptance (Jones, 1986). Researching the best methods for preparing for the MCAT is fundamental to student success in their future medical careers.

General overview of studying strategies

Some common methods of studying for the MCAT include completing a set of books that overview and discuss the MCAT topics, pre-made flashcards or student-made flashcards, practice exams or section bank questions, and even preparatory courses offered online or in-person. All these strategies come with a cost from tens to hundreds of dollars depending on what materials each student desires and can afford. These strategies also vary in length of time to complete. The longest strategy is likely reviewing the textbooks and practice exams, as reviewing the textbooks takes months and each practice exam is about seven hours in length. Some of the shorter strategies can include reviewing flashcards or brief problem sets. Each strategy mentioned is modeled off commonly used study methods such as retrieval strategies, test-enhanced learning, and instructor-led courses.

Research assessing the best general methods of studying for undergraduate students does exist. A study found that self-testing, scheduling time to study, and rereading notes and text had a large contribution to undergraduate students' GPA and overall success in college; most notably when self-testing was used, over 86% of students who reported using self-testing had a GPA of 3.7 or above (Hartwig & Dunlosky, 2011). Though this research did not directly address graduate-entry standardized testing, these results offer useful information on what methods may enhance studying habits, further improving overall test scores on the MCAT. Furthermore, some universities have already incorporated instructor-led courses with the intent of earning higher MCAT scores, demonstrating a potential method to boost scores for the students who participate. Because of the proven efficacy of repeated testing, information review, and time management, these methods offer an ideal model for research that involves the relearning and retention of information that must be recalled for standardized graduate-entry exams such as the MCAT (Karpicke et al., 2009; Roediger & Karpicke, 2006; Roediger & Butler 2011).

One of the strategies implemented in instructor-led courses is called a "test-enhanced learning cycle," which includes studying with a set of topic-specific MCAT questions to begin, reviewing weak areas based on results from the questions, summarizing the learned material, then taking a cumulative test including many topics, and, finally, repeating the process as needed (Swan Sein et

al., 2020). Because of the wide range of concepts that the MCAT entails, this study strategy is beneficial for students as they prepare and will be utilized within this study. In addition, instructor-led courses, whether they are online courses or in-person, have been shown to improve student confidence about MCAT topics; when an instructor-led course is offered, 89.9% of students report a higher confidence level concerning their understanding of MCAT material while also having access to an array of study materials and practices within the concise, convenient format of a classroom setting (Shipley et al., 2019).

Potential improvement for underprivileged individuals

A prevalent issue with the MCAT is that accessing the highest quality preparatory material requires a large monetary commitment. Underprivileged students, with low socioeconomic statuses, may not be able to invest the minimum amount of money to acquire materials that would enable them for success. If a preparatory strategy can be identified that may be offered at low or no cost, then students should have an equal opportunity to demonstrate their scientific knowledge and critical thinking skills, which are necessary for success on the MCAT and in medical school.

Overview of the study

This study will focus on how undergraduates prepare for the test by gathering data through five test groups (four experimental groups and a control) that could answer questions about performance on the MCAT, explore the effectiveness of MCAT study sessions and materials on students, and yield data that contributes to the benefits of beginning an MCAT preparatory course at Olivet Nazarene University, a small private Christian university in the Midwest. The experimental groups included a reading-text group, a memorization task group, a test-enhanced learning group, and an instructor-led group that were compared to the control that did not use any study method. With changes in the most recent version of the MCAT such as extending the previous three sections, adding a fourth section, and a heavier emphasis on biochemistry, research is needed to understand how these changes have affected scores. Currently, there is a gap in the research concerning the newest version of the MCAT and how college students can most effectively prepare for it. Upon investigation, it was noted that most studies assess MCAT performance relating to future success in the medical field or medical school. Whereas these studies use GPA and MCAT score as predictive measures of medical school performance, this study proposes to investigate the question of what the most effective and accessible means are for preparing for the MCAT by examining student responses to a variety of free or low-cost sources. By analyzing the pre- and post-tests given to the participants before and after they had received MCAT-based information through one of the four study methods, conclusions can be drawn to understand which method yields the most success. Using a null hypothesis, we hypothesized there is no statistically significant positive effect on MCAT performance using any of the proposed methods on MCAT preparation in comparison to the control.

METHODS

Study site and population

Recruitment for student participants included freshmen through juniors at Olivet Nazarene University. The original sample size was fifty students, with ten participants in each of the five groups. After the last of the data was collected, ten students were omitted for non-compliance with the treatment or post-test expectations. The students were randomized into groups based on pre-

test average so that the average was similar for each group to account for good test-taking skills and difference in academic level. This was done using a complex sort function where the standard deviation between the group averages was less than one. Students involved in the study were required to have taken a minimum of one semester equivalent to a college-level science course. Any student who had taken biochemistry was not allowed to participate in the study, as the topic for the experiment was biochemistry related. To encourage student participation, each student from Groups 2-5 received a \$10 gift card, whereas students in the control group received a \$5 gift card.

Experimental set up

An experiment using five groups of students was used to test the hypothesis as summarized in Table 1. Each group took a pre- and post-test using a set of MCAT-style biochemistry questions. The pre- and post-exams had identical questions; each student took the same exam before and after treatment, and participants were given ninety seconds per question according to the approximate time allotted for each question on the MCAT (Association of American Medical Colleges, 2021). The specific topic within the subject of biochemistry was Michaelis-Menten enzyme kinetics. The students in the control group only took the pre- and post-tests without any additional instruction or reading. The second group was given an assigned textbook reading from an MCAT preparatory book on Michaelis-Menten kinetics between the pre- and post-tests to determine how topic-related readings increase test scores. The third group was given the same reading in addition to a memorization exercise in the form of a Quizlet, which recycles questions answered incorrectly, to complete for about thirty minutes in between the pre- and post-tests to assess the advantages of memorizing information (Rawson & Dunlosky, 2011). A fourth group was given the same reading and memorization task as the previous group but also utilized test-enhanced learning by taking a separate set of biochemistry practice questions and receiving feedback in the form of correct answers with explanations (Roediger & Karpicke, 2006). The final group integrated a combination of the reading, memorization task, and test-enhanced learning exercise into a student-instructor environment (Roediger & Butler, 2011; Steed and Kadavakollu, 2019). For this group, a one-hour lecture on the chosen topic was taught to the students by a professor in the Biological Sciences Department to determine the benefits of an instructor-led course (McCabe, 2010). Throughout a period of four weeks, the initial pre-test phase, treatment phase, and post-test phase were completed. Weeks zero and one included the pre-test phase; the treatment and post-test phases extended throughout weeks three and four.

Table 1: Prescribed regimen for the five experimental groups

Note that all students took the pre- and post-tests, which were identical. The differences between pre- and post-test scores for each group were analyzed in search for the study strategy that yields the greatest improvement in scores.

	N	Pre-Test	Reading Assignment	Memorization Drill	Practice Test With Feedback	Lecture by Instructor	Post-Test
Group 1	9	X					X
Group 2	8	X	X				X
Group 3	9	X	X	X			X
Group 4	6	X	X	X	X		X
Group 5	8	X	X	X	X	X	X

Statistical analysis

To analyze the results, participants' pre- and post-test scores were compared using a paired t-test to determine the significance of each post-test average in comparison to the pre-test average for each individual group. Since five treatments were conducted with a post-exam for each, a Bonferroni correction was employed in order to reduce the occurrence of false positives; therefore, significance was noted when $p < 0.01$ (Girotti et. al). The hypothesis was rejected or accepted based on the p-value for each group.

RESULTS

The data from Figure 1 shows that the pre- and post-test average for Group 1 (control group) were only 0.74% different, which indicates the students were not exposed to information on the biochemistry topic between the pre- and post-test phase. Furthermore, the students' averages are what would be expected if they were to guess on each question, as they are close to 25%. Based on the data for Group 2, students' averages after the reading text treatment were seen to improve. The difference between the two was about 9.7% after reading the given text and immediately taking the post-test. Though the average did increase, the improvement was not statistically significant ($p > 0.05$).

The data obtained from Figure 1 concerning Group 3 was contrary to the expected results of the memorization task treatment. Instead of showing improvement, the post-test average decreased by about 2.4% even with a repetition of information. This was not seen for any of the other treatments. Despite the decrease in average from pre- to post-test, the change was not statistically significant. Like the reading text group, the test-enhanced drill (Group 4) did show an improvement by about 7.8%, which was similar to the amount of improvement seen in the reading text group. Though the treatment did seem to improve the overall scores, the increase was not statistically significant. The data for Group 5 shows a significant improvement in score from the instructor-led course. Students improved by about 47.5%, more than tripling their score average from pre- to post-test. Compared to the other treatments, the instructor-led course was the only treatment to have achieved statistical significance.

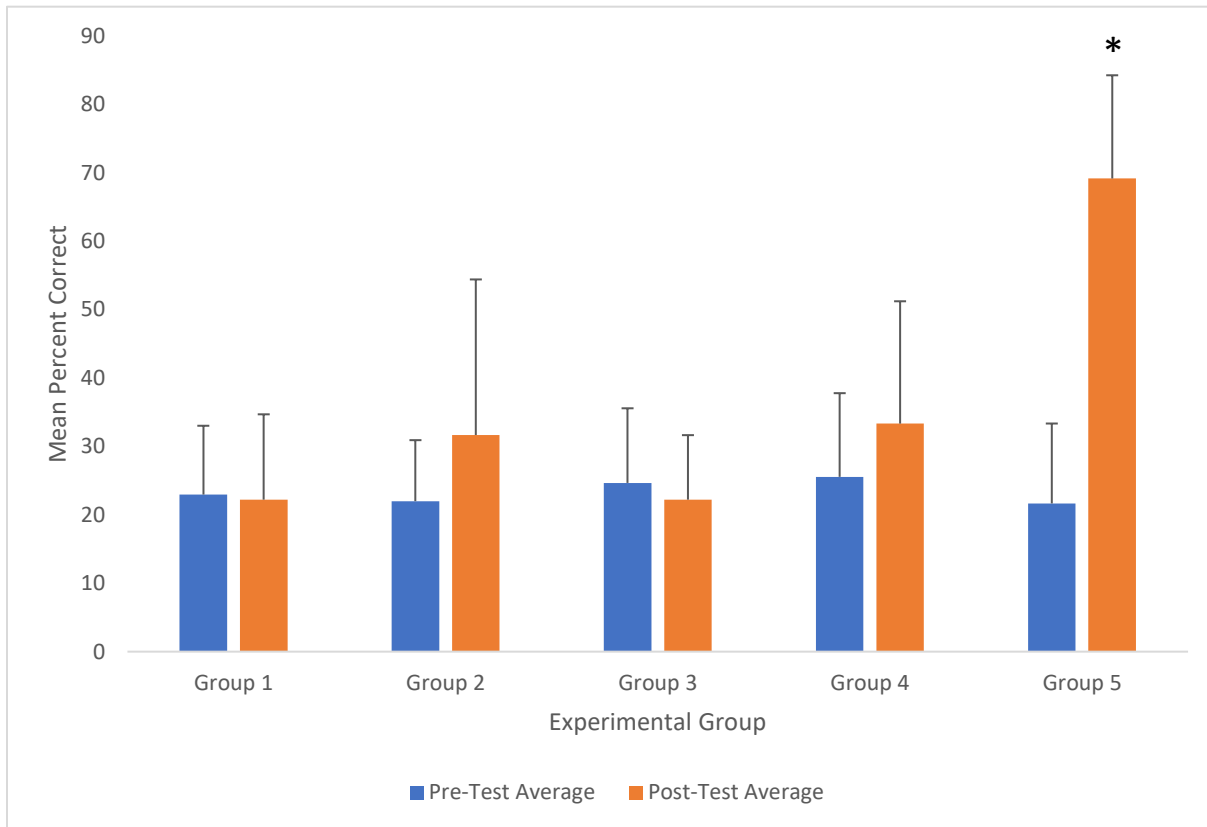


Figure 1: Comparison of pre- and post-exam scores for each treatment

Figure 1 displays a comparison of the pre- and post- test averages for each group including error bars. The error bars indicate the variation of scores within the groups as a range. A star denotes a significant increase in average in comparison to the average percent correct between pre- and post-test average.

Based on the data shown in Table 2, the only treatment group found to have statistical significance was the instructor-led course with a p -value of 5.67×10^{-4} , which also remained under the Bonferroni correction value 0.01, proving that the value is still significant under these conditions. The other treatments showed a p -value far over the 0.05 designation, indicating they did not show statistically significant improvement.

Table 2: P -values for each experimental group

The table below contains the determined p -value for each group in comparison of the post-test average to the pre-test average. A star denotes significance.

Experimental Group	p-value
Control	0.88
Reading Text	0.22
Memorization Task	0.64
Test-Enhanced Drill	0.12
Instructor-Led Course	$5.67E^{-05}$ *

DISCUSSION

Throughout this study, MCAT performance based on various strategies was assessed to understand the benefit to exam average when using a progression of information format. By utilizing commonly used and researched study methods, the intention of the study was to find methods that would increase the overall average on a curated post-exam that could translate to overall MCAT performance. The null hypothesis states that none of the methods will result in a statistically significant increase in the post-exam average, with the purpose to negate the hypothesis with one or more of the proposed methods.

According to Table 2, the null hypothesis is supported for the first four groups, indicating that there is no statistically significant positive effect on the average post-test score using the reading text method, memorization task method, or the test-enhanced drill method. Despite an increase in average from the pre-test exam to the post-test exam for the reading-text method seen in Figure 2, Group 2, the p-value was still above 0.05. Similar to the reading text group, the test-enhanced learning method did result in an overall increase in average by about 7.8% (Figure 1 Group 4), yet this is not statistically significant. As shown in Figure 1, Group 3, the memorization task group shows a decreased average from pre-test to post-test, which is contrary to previous findings by Karpicke et al. 2009 and Rawson & Dunslosky 2011. These studies found that recalling strategies (memorization tasks) are effective in higher level education, and the results seen for the memorization task indicate that this study method was not effective for the exam created for this study as the exam average decreased after treatment. This could be a result from the students only completing the memorization task once instead of multiple times in various settings. Furthermore, the memorization task was secondary exposure to the material, as the participants also received the reading before completing the memorization task in which it is assumed that the average would have increased from the reading text group. The resulting lower average for this group could indicate that recall tasks are not ideal for the MCAT because the exam has a higher proportion of application questions instead of information recall questions. A more directed study to evaluate MCAT recall tasks would be needed to further investigate these findings.

In Figure 1, Group 5 represents the instructor-led course data, and this is the only method used within the study to have rejected the null-hypothesis. The p-value of 0.0000567 seen in Table 2 is below the Bonferroni correction value ($p < 0.01$), indicating that the instructor-led course does have a statistically significant overall positive effect on the post-score average. This aligns with research from Jones (1986) and McCabe (2010) that claim that instructor-led courses are effective in improving student test scores, especially for the MCAT in which Jones (1986) saw a 5-point increase in MCAT scores based on the coaching effect. The instructor-led course seems to yield a significant increase in overall performance, as the pre-test average was 21.66667% with the post-test average rising to 69.16667%. The significant increase in student performance for this group could be due to a variety of factors based on speculation. One major benefit of an instructor-led course is that the professor can adequately explain information to allow students to fully grasp the concept and ask questions for clarity (Kennette & Redd, 2015). The self-study methods exemplified by the reading group, memorization task group, and test-enhanced learning group are devoid of this opportunity for deeper comprehension. Furthermore, Kennette and Redd (2015) note that a sense of presence, described as a sense of being together, can be influential on student engagement and is often not present when an instructor is absent. Based on the apparent success

of the instructor-led course group, Olivet Nazarene University has received a grant from a generous donor which provides the funding and materials for the course beginning in Spring of 2023.

In comparison to the other experimental methods, the instructor-led course is the only one proven to significantly increase the average test score between the pre- and post-scores. Though the research shows miniscule increase in overall average for the reading text, the test-enhanced learning, and the instructor-led course, the instructor-led course data is the only to yield a significant increase. Furthermore, because of the progressive increase in exposure to the information with each experimental group, the averages were expected to increase incrementally from the reading group to the memorization task and so on. This is not seen for the post-test averages as the reading group post-test average was 31.67%, the memorization task average was 22.22%, and the test-enhanced learning average was 33.333%.

Overall, the study supports the efficacy of instructor-led courses as a beneficial means to prepare for a standardized exam but leads to questions about the other study methods. Further research could investigate using recall tasks for MCAT-based material. Though this variable could not be addressed through the present study because of time constraints and student population, future research could uncover solutions to allowing students equal access to study materials despite the diverse backgrounds of medical school applicants. Most schools do not offer MCAT preparation courses. Undergraduate pre-medical programs with low MCAT scores could potentially incorporate a class which not only may improve the MCAT score average for the students, but also recruit more students to their pre-med programs. A study analyzing socioeconomic disadvantage showed that those at a larger disadvantage yielded lower test scores on the standardized U.S. Medical Licensing Examination (USMLE) (Jerant et al., 2019). This research was performed using a different standardized test, yet the results can be applied to the MCAT as well, since those with higher socioeconomic advantage usually can afford materials, tutoring, and other beneficial services. Because of evident differences in scoring, the test bias within the exam itself was investigated, in which the test bias theory for this particular exam was rejected. Davis et al. (2013) concluded that despite test score differences between racial minority and majority students, the general composition and information encompassed on the MCAT did not pose a barrier for minority students. If colleges were to offer instructor led MCAT courses with the same materials provided for students of all socioeconomic backgrounds, further research assessing the socioeconomic and ethnic background in relation to student performance could answer questions concerning the variance in performance based on socioeconomic status.

Though the study was directed with utmost concern for any confounding variables, limitations still exist. A prominent limitation to the study included a time constraint on data collection. An educational study involving an evaluation of information retention would usually take place over the course of months to years. This study was restricted to only four weeks where only one treatment session was given. The lack of consistent increase in post-test average could be a result of the time constraints of the study. Moreover, student motivation towards the study may have been inconsistent as well as their current grade point average, so there could be some variance in the amount of material retained in each group because not all participants had the same level of investment towards the study. A large majority of the participants were nursing majors or freshman students, which may inaccurately represent the type of students who typically take the MCAT. Furthermore, students could not be prevented from receiving any exposure to material that was

related to the chosen biochemistry topic between the pre- and post-test phase. The students were asked to refrain from researching questions they were asked throughout the exam phases but were not monitored to ensure no exposure to the biochemistry topic occurred. The most prominent limitation is likely that the sample size did not exceed ten individuals for each group, which decreases the power of the study. Only fifty students total completed the pre- and post-test phases according to the parameters established. Further studies to establish a larger sample size, longer treatment time, and more consistent student population would support and strengthen the results established throughout this research.

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APPENDIX A

INFORMED CONSENT DOCUMENT FOR IRB APPLICATION

Project Title: Identifying the optimal pedagogy for preparing undergraduates for the MCAT exam

Principal Investigators: Dr. Ryan Himes and Alyssa Black

You are being asked to participate in a research project conducted through Olivet Nazarene University. The University requires that you give your signed agreement to participate in this project.

The investigators will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask them any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researchers any questions you may have.

If you then decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

1. Nature and Purpose of the Project:

The purpose of “Identifying the optimal pedagogy for preparing undergraduates for the MCAT exam” is to investigate the best preparation strategies for the Medical College Admission Test (MCAT).

2. Explanation of Procedures:

An experiment using five groups of students will help us to determine the most effective study strategy for the MCAT exam. Each group will take a pre- and post-test using a set of MCAT style biochemistry questions. Participants will be given ninety seconds per question according to the approximate time allotted for each question on the MCAT. The students in the control group will only take the pre- and post-tests without any instruction or reading. A second group will be given an assigned textbook reading from an MCAT preparatory book between taking the pre- and post-tests to determine how beneficial reading is to the test score. The third group will be given the same reading in addition to a memorization exercise to complete for one hour in between the pre- and post-tests to assess the advantages of memorizing information. A fourth group will be given the same reading and memorization task as the previous group but will also utilize test-enhanced learning by taking a separate set of biochemistry practice questions and receiving feedback. The final group will integrate the reading, memorization task, and test-enhanced learning exercise into a student-instructor environment. For this group, a one-hour lecture on the decided topic will be taught to the students by an instructor to determine the benefits of an instructor-led course.

Students participating in the study must have a minimum of one semester of college level science course but have not taken biochemistry.

3. Discomfort and Risks:

Participants will be required to make some time commitment between thirty minutes to three hours total. There are no evident risks to the participant but if time commitment or test anxiety are a concern, participants should withdraw from the study.

4. Benefits:

Students who are interested in taking the MCAT or other graduate-entry exam may benefit from the results of this study. Determining the best study strategy for this standardized exam may help students better prepare for any other standardized post-undergraduate assessment. Those who participate for more than 30 minutes will also receive a \$10 gift card as incentive for their time commitment.

5. Confidentiality:

Any explicit identification such as names or student ID number will not be recorded. Any information received from the study will remain anonymous.

6. Refusal/Withdrawal:

Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

Signature of Participant

Date

Witness

Date

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE OLIVET NAZARENE UNIVERSITY INSTITUTIONAL REVIEW BOARD

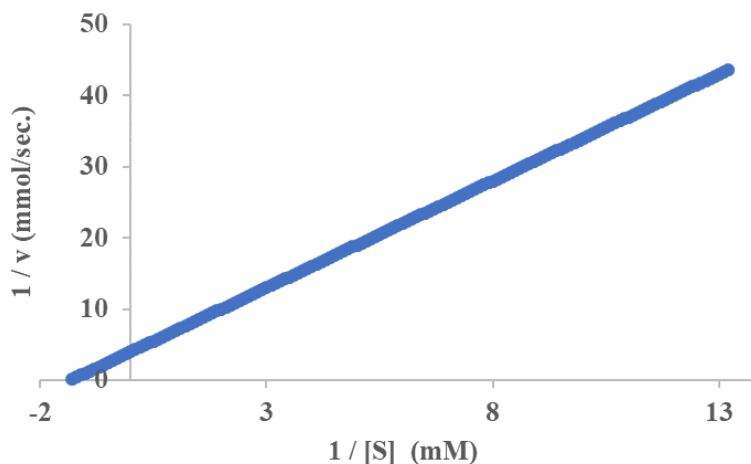
APPENDIX B
PRE- AND POST-TEST QUESTIONS

Name _____

For the following questions, please circle the correct answer. You have 23 minutes to complete this quiz.

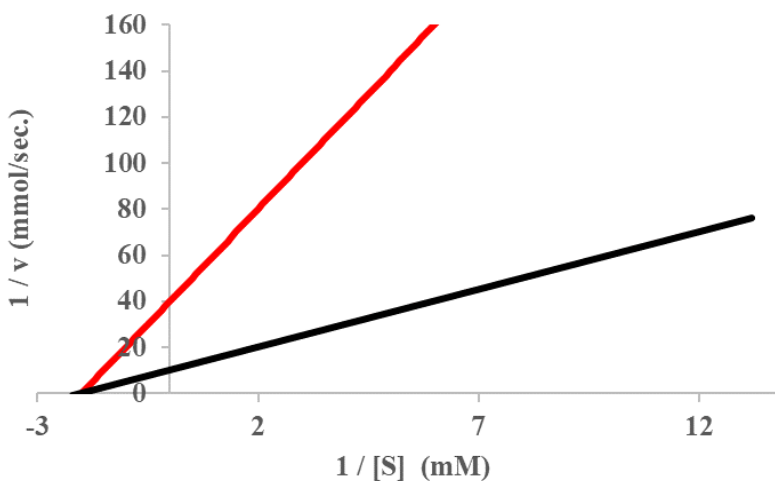
1. Which of the following is the correct equation for deriving the K_m from a Lineweaver-Burk plot, such as the one shown below?

- A. $K_m = 1 / \text{slope}$
- B. $K_m = -1 / \text{x-intercept}$
- C. $K_m = \text{slope} * \text{y-intercept}$
- D. $K_m = -1 * \text{x-intercept} / \text{slope}$



2. Based on the following graph, what type of inhibitor is represented by the red line?

- A. mixed
- B. noncompetitive
- C. uncompetitive
- D. competitive



3. If an enzyme has a low catalytic efficiency, you would expect it to have which of the following characteristics?

- A. Low k_{cat} and high K_m

- B. Low k_{cat} and low K_m
- C. High k_{cat} and low K_m
- D. High k_{cat} and high K_m

4. An enzyme is operating close to its maximal rate. Which of the following is most likely true of [S] and [ES]?

- A. [S] is near zero, and [ES] is high
- B. Both [S] and [ES] are near zero
- C. [S] is high, and [ES] is near zero
- D. Both [S] and [ES] are high

5. If the reaction velocity of an enzyme is at half of its V_{max} when [S] = 14 mM, what is the K_m for this enzyme?

- A. $K_m = 21$ mM
- B. $K_m = 28$ mM
- C. $K_m = 14$ mM
- D. $K_m = 7$ mM

6. Which of the following best describes a competitive inhibitor of an enzyme?

- A. Binds irreversibly to the active site of the enzyme
- B. Binds reversibly to the active site of the enzyme
- C. Binds irreversibly to an allosteric site on the enzyme
- D. Binds reversibly to an allosteric site on the enzyme

7. For a given reaction catalyzed by an enzyme, what would be the effect of decreasing [Enzyme]? Assume that the reaction is allowed to reach equilibrium.

- A. The reaction rate would decrease
- B. The total amount of product formed would decrease
- C. Both the reaction rate and the amount of product formed would decrease
- D. Neither the reaction rate and the amount of product formed would decrease

8. The effect of a noncompetitive inhibitor on an enzyme is to _____.

- A. Raise V_{max} and K_m
- B. Lower V_{max} and K_m
- C. Lower V_{max} only
- D. Raise K_m only

9. The K_m of enzyme A is 12 mM, while the K_m of enzyme B is 20 mM. Which of the following is true?

- A. Enzyme A has lower affinity for its substrate
- B. Enzyme B has lower affinity for its substrate
- C. Enzyme B binds to a different substrate than enzyme A
- D. There is not enough information given to make a comparison between the enzymes.

10. A particular enzyme has a K_m value of 6.0 mM and a V_{max} of 30 mmol/sec. If the substrate concentration is 600 mM, the rate of reaction is most likely to be _____.

- A. 15 mmol/sec.
- B. 29 mmol/sec.
- C. 58 mmol/sec.
- D. 180 mmol/sec.

11. Which of the following has the largest impact on the specificity of an enzyme?

- A. The K_m value
- B. The shape of the active site
- C. The k_{cat} value
- D. The presence of a competitive inhibitor

12. The optimal temperature for a given chemical reaction with an enzyme catalyst will generally be _____ the optimal temperature for the same reaction without an enzyme.

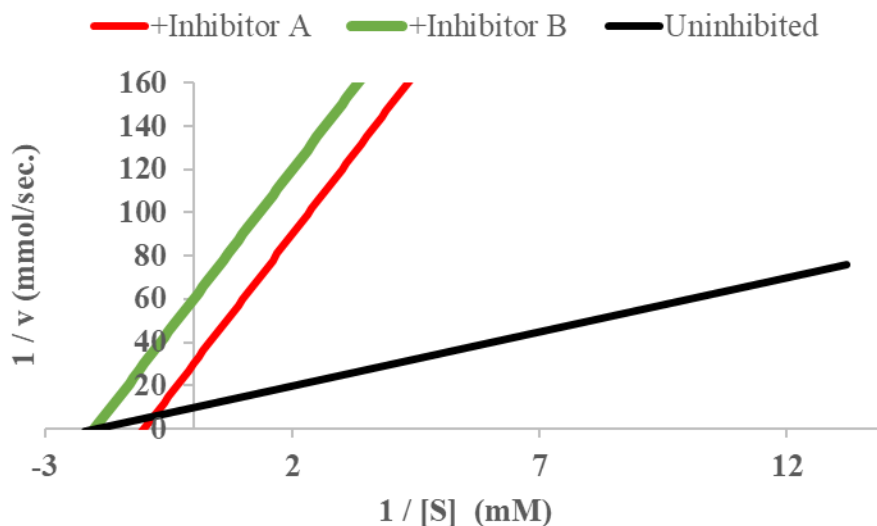
- A. equal to
- B. greater than
- C. lower than
- D. Not enough information is provided to make a comparison.

13. The reaction rate for a chemical reaction catalyzed by an enzyme is measured for a range of substrate concentrations, shown in the table at right. What is the approximate K_m for this enzyme?

- A. 40 mM
- B. 20 mM
- C. 4 mM
- D. 2 mM

[S] (mM)	Reaction Rate (mmol/min.)
0.04	1
0.2	5
0.4	12
2	40
4	56
20	69
40	75
200	78
400	79

14. The following graph depicts reaction rates of an enzyme as a function of substrate concentration, with and without two inhibitors A and B.



Which of the following can be said of the inhibitors, based on the data?

- A. Inhibitor A decreased the affinity of the enzyme for its substrate more than Inhibitor B.
- B. Both inhibitors had an equal effect on the affinity of the enzyme for its substrate.
- C. Inhibitor A decreased the V_{max} of the enzyme more than Inhibitor B.
- D. Both inhibitors are competitive inhibitors of the enzyme.

15. What is the effect of an enzyme on the ΔG° value for a chemical reaction?

- A. The enzyme causes the ΔG° value to increase.
- B. The enzyme changes the ΔG° value to zero.
- C. The presence of an enzyme does not affect the ΔG° value.
- D. The enzyme causes the ΔG° value to decrease.