

The short-term effects of peer tutoring in first-year biology labs on students with
and without ADHD

by
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A thesis submitted to the Department of Biological Sciences, University of
Manitoba,

in partial fulfillment of the requirements for the course

BIOL 4100 (Honours Thesis)

for the degree of

Bachelor of Science (Honours)

©March, 2025

Abstract

Peer tutoring is an active learning strategy that has been implemented in many university-level courses. However, many studies that examine the effects of peer tutoring focus solely on the long-term impacts of peer tutoring on learning outcomes and student perceptions, without considering how peer tutoring may affect students with learning differences, such as attention-deficit/hyperactivity disorder (ADHD). Therefore, this study considers the short-term effects of peer tutoring on learning outcomes and perceptions related to understanding metabolic experiments and the ability to focus in students with different relationships with ADHD. Data was collected from students in BIOL 1020 labs at the University of Manitoba during the Fall 2024 semester through an experiment lab, peer tutoring lab, final lab exam, and demographic survey. The main results of this study revealed that peer tutoring had no significant effect on the learning outcomes of students who have different relationships with ADHD. However, peer tutoring did have a significant positive effect on all students' perceived understanding of metabolic concepts, regardless of their relationship with ADHD. Peer tutoring also had no significant impact on students' perceived ability to focus, regardless of their relationship with ADHD. The findings of this study not only provide useful information to educators who may want to implement peer tutoring in their labs, but also demonstrate how peer tutoring affects all students the same, and can therefore be considered an inclusive active learning strategy for students, regardless of their relationship with ADHD.

Acknowledgements

I would like to thank my Honours thesis advisor, Dr. Cassandra Debets, for her assistance throughout the duration of my research study. I would also like to thank my wonderful committee members, Dr. Jane Waterman and Dr. Kevin Scott, for their helpful advice and encouragement. Finally, I wish to thank Dr. Jim Roth and Dr. Levi Newediuk for all the help and guidance they provided with regard to the statistical analysis of the data collected in this research.

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Introduction/Background

The Social Theory of Learning, which hypothesizes that effective and fulfilling learning takes place through interacting with those around you, has provided the framework for the development of many active learning strategies across different disciplines (Bandura 1977; Griffin and Griffin 1998; Wenger 2009; Bailey et al. 2018). Peer tutoring, which is an active learning strategy that utilizes the Social Theory of Learning, encourages students to go beyond just listening to a lecture and taking notes, and instead work with the material in a different, more engaging and educationally enriching way (Bandura 1977; Pigott et al. 1986; Riggio et al. 1991; Griffin and Griffin 1998; Wenger 2009; Vargas 2013, as cited in Verdun et al. 2021; Bailey et al. 2018).

There are multiple definitions of peer tutoring, but the definition I will use is that peer tutoring involves a pair or small group of students working collaboratively together, where each student participates in an educational activity and takes on two different roles that they switch between; an educator role and a student role (Fantuzzo et al. 1989; Riggio et al. 1991; Vargas 2013, as cited in Verdun et al. 2021; Bailey et al. 2018). In the educator role, students share their knowledge on a topic based on what they have learned through an educational activity or lecture, and attempt to clarify any points of confusion that their group members experience (Fantuzzo et al. 1989; Riggio et al. 1991; Bailey et al. 2018). Those in the student role are responsible for listening to what their peers

teach them and posing questions (Fantuzzo et al. 1989; Riggio et al. 1991; Bailey et al. 2018).

The process of sharing ideas with others and acting as both an educator and student can promote a more relaxed class setting, and the achievement of long-term learning gains by generating new interest in the course material (Fantuzzo et al. 1989; Riggio et al. 1991; Griffin and Griffin 1997; Griffin and Griffin, 1998; Batz et al. 2015; Bailey et al. 2018). Overall, many studies on peer tutoring in science courses have found positive results regarding the effects of peer tutoring on students' grades (i.e. Chrispeels et al. 2014; Batz et al. 2015; Bailey et al. 2018). However, it is important to note that there have been some contradictory results, as studies conducted in education courses (one with graduate students) found that there were no significant learning gains or lowered feelings of unease in university students who had peer tutoring implemented in their lecture courses, when compared to those who did not experience peer tutoring (Griffin and Griffin 1997; Griffin and Griffin 1998).

However, these previous studies had potential limits to our understanding of the applicability and inclusivity of peer tutoring. First, although many of these studies provide demographic information on gender, most fail to question the breakdown of other demographics (i.e. Griffin and Griffin 1997; Griffin and Griffin 1998; Bailey et al. 2018). One specific demographic that seemingly none of these studies considered, is whether the university students partaking in the study have attention-deficit/hyperactivity disorder (ADHD) (Fantuzzo et al. 1989; Riggio et al. 1991; Griffin and Griffin 1997; Griffin and Griffin 1998; Batz et al. 2015; Bailey et

al. 2018). Upwards of one in every six first-year students have been diagnosed with ADHD worldwide, and one in every fourteen young adults have been diagnosed with ADHD in Manitoba (Yallop et al. 2015; Mak et al. 2022). These statistics suggest that there may be a large proportion of both international and domestic university students in biological sciences who have ADHD (Yallop et al. 2015; Gin et al. 2020; Mak et al. 2022; Pfeifer et al. 2023). Additionally, studies that did consider how active learning strategies may affect students with ADHD have expressed concerns that active learning strategies (although having benefits) may negatively impact students with ADHD, when they require working with others (Heiligenstein et al. 1999; DuPaul et al. 2009; Gin et al. 2020; Pfeifer et al. 2023). Working with other students is a major component of peer tutoring (Fantuzzo et al. 1989; Riggio et al. 1991; Bailey et al. 2018). Therefore, given the suggested large proportion of students that experience ADHD at the University of Manitoba, considering how active learning strategies, including peer tutoring, affect students with ADHD is worth researching further.

Many of these peer tutoring studies work with samples of students from disciplines other than biology (such as psychology and education) and/or in lecture settings rather than lab settings (i.e. Fantuzzo et al. 1989; Griffin and Griffin 1997; Griffin and Griffin 1998; Bailey et al. 2018). Additionally, it also appears that most studies on peer tutoring focus on long-term learning gains, but do not consider how the learning outcomes of students are affected in the short-term (such as between the start and end of a class) (Fantuzzo et al. 1989; Riggio et al. 1991; Chrispeels et al. 2014; Bailey et al. 2018). Chrispeels et al. (2014)

seemed to include these aspects in their study, but considered peer teaching students in different grade levels instead of peer tutoring students in the same class, and still failed to consider those with ADHD in their research.

Expanding on these concerns, my proposed study aims to better understand how active learning methods based on the Social Theory of Learning, specifically peer tutoring, influence the education of students with ADHD in the short term, in an introductory biology laboratory setting. Specifically, I aim to address how the implementation of peer tutoring in introductory biology labs affects learning outcomes and perceptions of undergraduate biology students with different relationships with ADHD. The four different relationships with ADHD I considered for this study are:

- 1) those who have been diagnosed with ADHD but are not taking medication for their symptoms;
- 2) those who have been diagnosed with ADHD and are taking medication for their symptoms;
- 3) those who are undiagnosed but experience symptoms of ADHD; and
- 4) those who are undiagnosed and experience no symptoms of ADHD.

It is also important to include students who have not been diagnosed with ADHD but experience symptoms. The lack of inclusion of adults who have not been officially diagnosed with ADHD has been considered a problem point in other studies (Ginsberg et al. 2014; Yallop et al. 2015). This demographic may provide insight as to how peer tutoring affects students who may have difficulty maintaining focus in class, in addition to students with ADHD who have not

received an official diagnosis, as receiving a diagnosis can be challenging to achieve in adulthood (Faraone et al. 2006; Ginsberg et al. 2014). Additionally, it is important to consider the difference between those with ADHD who are taking medication to help regulate/reduce their symptoms and those who are not, as medications could affect their ability to learn in class effectively, and thus, potentially their response to peer tutoring (Lu et al. 2017; Jangmo et al. 2019).

I hypothesized that the active learning method of peer tutoring would affect short-term learning gains and student perceptions in first-year biology labs, both in students with and without ADHD. I predicted peer tutoring would increase short-term learning gains in students without ADHD and students with ADHD who are taking medication for their ADHD compared to a more traditional lab, but would decrease short-term learning gains in students diagnosed with ADHD and undiagnosed students who experience symptoms of ADHD. I also anticipated that peer tutoring would affect short-term student perceptions relating to feelings of understanding biology concepts and the ability to focus in students with and without ADHD. I predicted peer tutoring would result in improved perceptions of understanding and ability to focus in students without ADHD and students with ADHD who are taking medication for their ADHD, but would result in more negative perceptions in students diagnosed with ADHD and undiagnosed students who experience symptoms of ADHD.

Methods

For this study, I used a repeated measures design, collecting data from the same cohort of students throughout the semester. I collected learning gain and perception data during the fourth and fifth labs in the introductory biology lab for the course titled “Biology 1: Principles and Themes” (BIOL 1020) during the Fall 2024 semester at the University of Manitoba, which has over 1000 students enrolled across ten lab sections. I also collected learning gain data during the final lab exam, as well as perception data and demographic information during the demographic survey, both of which students completed at the end of the term in December. These demographic questions are commonly collected in biology education research projects, as there are known achievement gaps found in certain demographics that many studies consider or work towards improving in their research, which is especially important in my study sample, as the University of Manitoba is a highly diverse institution (i.e. Theobald et al. 2020; Farrar et al. 2023; University of Manitoba 2024). The demographics survey also allowed us to identify the students into the four groups outlined earlier based on what they consider their relationship with ADHD to be.

Photosynthesis and Cellular Respiration Experiment Lab

During Lab 4, students were assigned by a teaching assistant (TA) to complete either a photosynthesis or cellular respiration experiment individually. The TAs were encouraged to assign the experiments by telling students sitting on one side of the lab table to complete one experiment, and those sitting across

from them to complete the other. The photosynthesis experiment consisted of students placing spinach leaves in four solutions, which had different carbon dioxide and light treatments, and measuring how many leaves were floating due to the production of oxygen (as a proxy for photosynthesis) at specific times throughout the lab. The cellular respiration experiment consisted of students adding yeast to four different sugar solutions and measuring the amount of carbon dioxide produced and trapped in a fly tube, at specific intervals throughout the lab. Students would then calculate the average photosynthesis or cellular respiration rates. During the lab, students were required to follow the instructions provided in experimental protocol documents to complete their assigned experiment. Students were encouraged to read both experimental protocols ahead of time, as they were informed they would be assigned to one of the two experiments, but they were not aware of which experiment they would be completing until the beginning of their lab. The topics of photosynthesis and cellular respiration were chosen as they are both taught at around the same point in the term, and the data from these two experiments can be presented similarly.

After the experiments were completed, students were encouraged to complete a worksheet in groups of three to four students who had completed the same experiment, which outlined some of the main takeaways and encouraged students to think about how they would present the data from their experiments. Students in groups of two were permitted if they were unable to form a group of three or four. The worksheets consisted of questions relating to how to graph the data from the experiment, as well as what the inputs and outputs were in the

biological process studied (see Appendix A). Effective graphing skills were an ongoing topic addressed in most of the labs throughout the course, and students already had some background knowledge on how to create them. However, the application of graphs to these specific experiments was new to the students. The worksheets were graded for completeness, not correctness, and students were made aware of this grading plan beforehand. Students were informed that they would be using this worksheet in Lab 5 to assist them in peer tutoring the students who completed the alternative experiment.

Peer Tutoring Lab

During Lab 5, students received their worksheets back from Lab 4 and then completed the peer tutoring activity. First, students who completed the photosynthesis experiment typically worked together in groups of three to four (usually in the same groups in which they completed the worksheet from Lab 4) to peer teach their experiment to a group of students who had completed the cellular respiration experiment. Students were allowed to use their worksheets as a guide for reminders of what they should be teaching to the other group, and an additional non-graded worksheet was provided to help them take notes on what they were learning. Students who had completed the cellular respiration experiment and who were listening to what those who had completed the photosynthesis experiment were peer tutoring, were encouraged to ask questions (Bailey et al. 2018). Those who were peer tutoring were encouraged to answer these questions to the best of their ability (Bailey et al. 2018). After the groups had completed this process, they would switch, and the process would repeat, so

the groups who completed the cellular respiration experiment would peer tutor the groups who had completed the photosynthesis experiment. The process of switching between informing/answering questions and listening/asking questions made up the peer tutoring activity of this lab (Fantuzzo et al. 1989; Riggio et al. 1991; Bailey et al. 2018).

Learning Gain Assessments

Students were administered concept-check assessments through iClicker during lab at the beginning of Lab 4 and the beginning and end of Lab 5. Other iClicker questions were asked throughout the course and all were worth 2.5% of the course grade. The questions asked in labs 4 and 5 consisted of four multiple-choice questions, two related to the cellular respiration experiment and two related to the photosynthesis experiment. These questions were all similar and comparable in nature and concepts, as half of the questions in each iClicker related to graphing the data from the experiments, and half were related to the biological processes the experiments were focused on (see Appendix B). Additionally, students answered these questions independently and silently. Students did not receive immediate feedback on these questions. Instead, the questions were graded after the two labs considered in this study were completed, and the correct answers were provided to the students to allow for a learning opportunity (Lantz and Stawiski 2014).

Taking the difference in the proportion of correct answers for the iClicker questions asked at the beginning of lab 4 and the beginning of lab 5 would represent the short-term learning of the hands-on experiments, a more traditional

activity in biology labs. The difference in the proportions of correct answers at the beginning of lab 5 and the end of lab 5 would represent the short-term learning outcomes due to peer tutoring. Therefore, in comparing the learning outcomes of the experiment lab and the peer tutoring lab, I determined whether peer tutoring is more effective in improving the learning outcomes of students with different relationships with ADHD, compared to a more traditional lab.

Perception Questions

The perception questions were administered to students through iClicker during lab at the beginning and end of Lab 5. Students were asked to answer these questions individually and silently to help minimize the influence of their peers, and responses were not shown to the class. Two multiple-choice perception questions were provided during each of these iClicker sessions (see Appendix B). Students received a participation grade that contributed to their overall iClicker grade in the class as an incentive to answer the questions. The responses collected during Lab 5 were used to determine short-term changes in perceptions that have occurred due to peer tutoring, as the responses collected at the beginning of the lab will provide information on students' perceptions before peer tutoring (and after completing the experiments), while the responses collected at the end of the lab will provide information on how students' perceptions changed after peer tutoring. No perception questions were asked in Lab 4, as we are primarily concerned about how student perceptions change due to peer tutoring.

Final Lab Exam

The final lab exam was worth 7.5% of students' grades and occurred approximately eight weeks after the peer tutoring lab. Within the final lab exam, there were six concept questions relating to the material covered in the experiment lab and the peer tutoring lab (see Appendix C). Three of these questions related to the photosynthesis experiment and three to the cellular respiration experiment. Since this exam was a two-stage exam, where students completed the exam individually first and then a second time in groups of three to five students, I only considered the data collected from the exams completed individually, as in this study, we are concerned about how peer tutoring affects individual students with different relationships with ADHD.

Demographic Survey

A demographic survey was sent out to students through UM Learn (the course's online software) at the end of the semester, approximately seven weeks after the peer tutoring lab had occurred. The survey was a mandatory course component worth a small portion (1%) of their final grades. Student responses to all questions were anonymized. The demographic survey consisted of nine multiple-choice questions relating to students' background, and two multiple-choice questions that provided information on the students' relationships with ADHD, and whether they are taking medication for their ADHD (see Appendix D). Students selected their relationship with ADHD themselves. The demographic

survey also consisted of ten Likert-style perception questions and three open-ended perception questions (see Appendix D).

Data Organization and Statistical Analyses

After removing students from the dataset who did not respond to at least one of the questions or who chose to respond with “prefer not to answer” on the demographics survey, my final sample size was 545 students. I combined the students into three groups for student background based on their responses to whether they considered themselves Indigenous and/or international students on the demographics survey. These groups were Canadian Non-Indigenous, Canadian Indigenous, and international students. Overall, a proportion of 79.8%, 8.3%, and 11.9% of students were included in these groups, respectively (Table 1). When correlating demographic data to the perception data relating to perceived ability to focus, I removed students who answered with a “C” to the statement “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention”, as “C” could be considered a neutral response. Removing students who answered “C” resulted in a dataset consisting of a sample size of 264 students (Table 2). I accounted for the non-independence of the data points by including student ID as a random-effect variable in all regression models. For all statistical analyses, I considered significance when $p < 0.05$.

To determine if peer tutoring affects the learning outcomes of all students and students who have different relationships with ADHD, I ran multiple paired t-tests to determine if there were any significant differences in the changes in the

proportion of correct iClicker questions as a result of the experiment lab and the peer tutoring lab. For data that were not normally distributed, I ran Wilcoxon signed rank tests instead of paired t-tests. I also ran mixed-effects linear regression models using a response variable of the difference in the proportion of correct answers between iClicker sessions and used AIC to determine the best model (Table 3). There was no multicollinearity between the predictor variables considered in possible models (Table 4).

To determine if peer tutoring affected students' perceived understanding of metabolic experiments in students who have different relationships with ADHD, I sorted the four possible responses to the statement "I find it difficult to understand the concepts of metabolic experiments in the lab" ("strongly disagree", "disagree", "agree", and "strongly agree"), into binary data, by grouping "strongly disagree" and "disagree" responses into "disagree to some extent" and grouping "agree" and "strongly agree" responses into "agree to some extent". With the data sorted into a binary predictor variable, I ran multiple mixed-effects logistic regression models and used AIC to determine the best model (Table 5). No multicollinearity was found between any predictor variables considered in the possible models (Table 6). I grouped students with ADHD into a single category consisting of those who take medication for their ADHD and those who do not, and included an optimizer in running the code and increased the number of iterations of the model using the equation to assess the data to ensure model convergence.

I used a similar approach to see if peer tutoring affected students' perceived ability to focus in students with different relationships with ADHD, but

used the smaller dataset with a sample size of 264 students. I combined students who answered “A” or “B” to the perception question “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” into one category, and considered this category to be “have difficulty focusing to some extent”. I also combined student responses of “D” and “E”, creating a second category that I considered “can focus to some extent”. Reorganizing the data in this way allowed me to treat the response variable as binary, and therefore, I was able to run a mixed-effects logistic regression model. All variables in the model had no multicollinearity (Table 7). I combined students with ADHD into one category and applied an optimizer to achieve model convergence, as this data is more complex. The only model I was able to achieve convergence on was the model that included the interaction between lab type and relationship with ADHD as a predictor variable. However, the lack of possible models is not of major concern, given that the central hypothesis of this study is only concerned with the effects of peer tutoring on students with different relationships with ADHD.

Results

Learning Outcomes

I found no significant difference between the differences in proportion of correct answers in the experiment lab and the peer tutoring lab when considering all students ($t_{544} = -1.43$, $p = 0.15$) (Figure 1). There was also no significant difference in the change in proportion of correct answers in students with no

ADHD and no symptoms of ADHD as a result of the experiment lab and the peer tutoring lab ($t_{359} = -0.86$, $p = 0.39$) (Figure 2). There was no significant difference in the change in proportion of correct answers in students with no ADHD but who experience symptoms of ADHD as a result of the experiment lab and the peer tutoring lab ($t_{155} = -0.82$, $p = 0.417$) (Figure 2). Similarly, there was no significant difference in the change in proportion of correct answers of students with diagnosed ADHD as a result of the experiment lab and the peer tutoring lab, in both students who are medicated for their symptoms ($W = 41$, $p = 0.78$) and not medicated for their symptoms ($W = 4.5$, $p = 0.25$) (Figure 2).

In running my mixed-effect linear regression models, the model that contained the fixed-effect variables of lab type and ADHD was the best-fitting model according to AIC (AIC = 558.69) (Table 3). However, given that this model did not contain an interaction variable between lab type and ADHD, I used the next best fitting model according to AIC (AIC = 572.39), which included this interaction as its only fixed-effect variable for further analysis (Table 3). This model supported the interaction between ADHD and lab type was insignificant ($\chi^2 = 1.83$, $df = 3$, $p = 0.61$) (Figure 2). Additionally, the variables of ADHD ($\chi^2 = 0.57$, $df = 3$, $p = 0.90$) and lab type ($\chi^2 = 2.97$, $df = 1$, $p = 0.09$) separately also had no significant effect on the change in scores in iClickers.

Student Perceptions

A summary of student responses to the perception question “I find it difficult to understand the concepts of metabolic experiments in the lab” before grouping the data into binary responses for all students and groups of students

with different relationships with ADHD can be found in Figures 3 and 4, respectively.

In the mixed-effects logistic regression models used to test the effects of peer tutoring on the perceived understanding of metabolic experiments in students with different relationships with ADHD, the best fit AIC was the model containing the fixed effect variables of lab type and ADHD (AIC = 1182.36) (Table 5). However, given that my main question of interest is looking into the effects of peer tutoring on students with different relationships with ADHD, I decided to use the model containing the fixed effect variables of an interaction between lab type and ADHD, English as a second language, first-generation student, and planning to major in biology for further analysis, as it included the important interaction term of the type of lab and ADHD, and still had a good fit according to AIC (AIC = 1182.67) (Table 5). The interaction between peer tutoring and the student's relationship with ADHD did not have a significant effect on the probability that a student agreed to some extent with the statement, "I find it difficult to understand the concepts of metabolic experiments in the lab" ($\chi^2 = 3.40$, $df = 2$, $p = 0.18$) (Figure 5). Additionally, a student's relationship with ADHD had no significant effect on the probability that a student agrees to some extent with the above statement ($\chi^2 = 3.77$, $df = 2$, $p = 0.15$) (Figure 5). However, peer tutoring significantly affected the probability that a student, in general, agreed to some extent with the above statement ($\chi^2 = 26.04$, $df = 1$, $p < 0.0001$) (Figure 6). The standardized odds ratios showed that before peer tutoring, students were 6.54 times as likely to agree to some extent with the statement "I find it difficult to

understand the concepts of metabolic experiments in the lab” in comparison to after peer tutoring (Figure 6). The other fixed-effects predictor variables in this model, including whether the student is a first-generation student ($\chi^2 = 1.76$, $df = 1$, $p = 0.18$), whether the student considers English to be a second language ($\chi^2 = 0.90$, $df = 1$, $p = 0.34$), and whether the student plans to major in biology ($\chi^2 = 3.30$, $df = 1$, $p = 0.07$), did not affect student perceptions relating to their understanding of metabolic experiments.

A summary of student responses to the perception question “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” before grouping the data into binary responses for all students and groups of students with different relationships with ADHD can be found in Figures 7 and 8, respectively.

In running the second mixed-effects logistic regression model, I was able to determine that the interaction between peer tutoring and the student’s relationship with ADHD also does not have a significant effect on the probability a student perceives they can focus to some extent during the activity outlined ($\chi^2 = 2.25$, $df = 2$, $p = 0.32$) (Figure 9). Additionally, a student’s relationship with ADHD had no significant effect on the probability that a student feels they can focus during the outlined activity to some extent ($\chi^2 = 0.27$, $df = 2$, $p = 0.87$) (Figure 9). Peer tutoring, when considering all students, also had no significant effect on the probability that a student feels they can focus during the outlined activity to some extent ($\chi^2 = 0.07$, $df = 1$, $p = 0.80$) (Figure 10).

Discussion

Learning Outcomes

There was no significant difference in the proportion of correct iClicker answers from before and after each lab, between the experiment lab and peer tutoring lab for all students, regardless of their relationship with ADHD. These results did not support my hypothesis, as peer tutoring was predicted to increase short-term learning outcomes in students without ADHD and students with ADHD who are taking medication for their symptoms, but decrease short-term learning outcomes in students diagnosed with ADHD and undiagnosed students who experience symptoms of ADHD.

Although my results do not align with much of the literature, as many previous studies have found that peer tutoring increases understanding of concepts in all students (i.e. Fantuzzo et al. 1989; Batz et al. 2015; Bailey et al. 2018), my results do seem to align with the findings of the study conducted by Griffin and Griffin (1997), and Griffin and Griffin (1998). Although these two studies implemented peer tutoring in different subject areas than my study and did not consider the effects on students with learning differences, both found that peer tutoring had no significant effect on learning outcomes. However, the two studies shared some similarities with my study, as one collected data from undergraduate students and the other from an introductory course (Griffin and Griffin 1997; Griffin and Griffin 1998). It is also important to note that most of the other peer tutoring studies have mainly considered the effects of peer tutoring for all students, rather than comparing results across students with different

relationships with ADHD, and focused more on long-term learning outcome data, rather than short-term learning outcomes (i.e. Fantuzzo et al. 1989; Batz et al. 2015; Bailey et al. 2018). These differences in studies may contribute to why I am seeing differences in my results.

Additionally, the results of my study indicate that peer tutoring has the same effect on short-term learning outcomes in students with different relationships with ADHD. One possible reason for these results could be that peer tutoring may be considered a highly structured activity (Freeman et al. 2011; Haak et al. 2011; Eddy and Hogan 2014; Beck and Roosa 2020). High structure learning settings have been found to improve learning outcomes more in students facing barriers and who have lower grades in introductory biology courses, and have even reduced failure rates in these courses by over 10% (Freeman et al. 2011; Haak et al. 2011; Eddy and Hogan 2014; Beck and Roosa 2020). Although these studies did not explicitly mention peer tutoring as an example of a high-structure active learning strategy, based on the summary of Beck and Roosa (2020) and the description of Freeman et al. (2011), the peer tutoring lab implemented in my study did consist of some of the important elements of a high structured course. For example, the peer tutoring component involved obtaining and sharing new skills through experiments and teaching, and during that process, thinking critically about the experiments and compiling information using a worksheet to effectively teach others, which further supports this idea (Freeman et al. 2011; Beck and Roosa 2020). Given that students with ADHD can also experience lower course grades in university courses, we could find that the

highly structured nature of peer tutoring may also increase learning outcomes for students with ADHD and symptoms of ADHD (Heiligenstein et al. 1999; DuPaul et al. 2009; Haak et al. 2011; Beck and Roosa 2020). The highly structured components of peer tutoring may contribute to the finding that there is no significant difference in the results of peer tutoring between students with different relationships with ADHD (Heiligenstein et al. 1999; DuPaul et al. 2009; Haak et al. 2011; Beck and Roosa 2020). Therefore, considering the breakdown of the structure level of peer tutoring and its effects on students with different relationships with ADHD may be an area to explore further in future research (Freeman et al. 2011; Haak et al. 2011; Eddy and Hogan 2014; Beck and Roosa 2020).

Student Perceptions

The results of my study partially aligned with my predictions regarding the effects of peer tutoring on student perceptions in students with different relationships with ADHD. Overall, student perceptions of their understanding of metabolic experiments were significantly affected by peer tutoring, but students with different relationships with ADHD were affected the same. Peer tutoring increased the probability of students feeling as though they understood the concepts of the metabolic experiments. I did anticipate seeing these results in students with no diagnosed ADHD and in those who are diagnosed with ADHD and receiving medication for their symptoms. However, I expected to see an opposite pattern in students who experience symptoms of ADHD and those who are diagnosed with ADHD but who are not taking medication for their symptoms.

Additionally, student perceptions of their ability to focus during the labs and peer tutoring were not significantly affected by peer tutoring in all students, regardless of how they identify with ADHD. The majority of students in each group, based on their relationship with ADHD, felt they could focus during the labs and during peer tutoring, both before and after peer tutoring. However, I had predicted peer tutoring would significantly improve students' perceived ability to focus in students with no diagnosed ADHD and in those who are diagnosed with ADHD and receiving medication for their ADHD symptoms. I expected to find a significant reduction in students' perceived ability to focus as a result of peer tutoring in students not diagnosed with ADHD but who experience symptoms of ADHD, and students who are diagnosed with ADHD but who are not taking medication for their symptoms.

The peer tutoring studies by Griffin and Griffin (1997) and Fantuzzo et al. (1989) provide comparable results to some of the results outlined in my study, as they found that peer tutoring significantly improved student perceptions of how well they understood the material they peer tutored. When considering how student perceptions were influenced by peer tutoring in students with different relationships with ADHD, the results of my study seem to contradict results found in other studies that indicate that working in small groups can have negative implications for students with ADHD (Gin et al. 2020; Pfeifer et al. 2023). These studies primarily focused on perceptions of students or those who work with students with disabilities and learning differences, and differ from my study in that

they obtained their data by asking open-ended questions in interviews, rather than Likert-style questions (Gin et al. 2020; Pfeifer et al. 2023).

One possible reason that may have resulted in all students experiencing the same effect of peer tutoring on their perceptions of understanding and ability to focus, regardless of their relationship with ADHD, could be that the groups of students who taught together were typically students who had worked with each other throughout the semester. Working with familiar peers has been shown to significantly impact the comfort and willingness to work in a group, as well as course grades, in biology courses (Premo et al. 2022; Connell et al. 2023). Therefore, given that one of the challenges faced by students with ADHD is group work due to the concern of having a negative experience or being poorly evaluated by others, working with familiar lab members may have helped to alleviate some of these concerns, and allow students who may face these barriers to focus more on the material they are teaching and learning from others (Gin et al. 2020; Premo et al. 2022; Connell et al. 2023; Pfeifer et al. 2023). This idea is worth exploring further in future studies, and can be achieved by exploring the open-ended perception question responses collected from the demographic survey.

Implications of Study and Conclusions

Regardless of many of the results of my study being unexpected, the results suggest a few valuable pieces of information. First, the findings of this study reveal that peer tutoring has the same effect on students, regardless of their relationship with ADHD, in terms of both learning outcomes and student

perceptions. Other studies have suggested that many active learning strategies may negatively affect students with ADHD, despite being considered as a positive teaching method in studies that fail to consider this demographic in their research, making the finding of my study important to consider (Fantuzzo et al. 1989; Chrispeels et al. 2014; Bailey et al. 2018; Gin et al. 2020; Pfeifer et al. 2023). The results of my study suggest that peer tutoring can be implemented into introductory biology labs with a diverse student body, without negatively impacting students with learning differences such as ADHD, and therefore, may serve as an accommodating active learning strategy instructors can implement into their courses.

The results also reveal that in a biology lab setting, peer tutoring may not be as effective as it is in biology lecture settings of previous studies, or for learning different introductory biology topics than those studied previously (i.e. Batz et al. 2015; Bailey et al. 2018). The peer tutoring lab produced the same change in iClicker scores as the experiment lab, which suggests that completing an experiment in a lab individually may be just as effective as learning about the experiment from other students. Peer tutoring may be useful in courses where there are time, cost, or resource constraints which prevent instructors from implementing specific experiments that could add value to students' education. My findings suggest that instructors could break groups up to have multiple different experiments running in a single lab, and students who did not complete some experiments would still demonstrate the same learning outcomes by having the experiment taught to them by their peers.

However, some aspects of this study can still be improved. Although I collected data on both short-term and long-term learning outcomes and perceptions in students with different relationships with ADHD, due to the time constraints of this project, only short-term data could be analyzed. Given that many of the other peer tutoring studies focused on long-term effects (i.e. Fantuzzo et al. 1989; Riggio et al. 1991; Chrispeels et al. 2017; Bailey et al. 2018), I may see different and significant results between students with different relationships with ADHD if I consider how peer tutoring affects learning outcomes and perceptions in the long-term, and consider if peer tutoring can affect retention in these demographics. Since the final lab exam occurred approximately eight weeks after the peer tutoring lab, future studies could compare the data collected during the peer tutoring lab to the data collected during the final lab exam to gain insight as to the long-term effects of peer tutoring on learning outcomes and retention in students with different relationships with ADHD. Additionally, since the perception questions on the demographic survey were asked approximately seven weeks after the peer tutoring lab occurred, future studies could compare the perception data collected during the peer tutoring lab to the data collected during the demographic survey, to gain insight about the long-term changes in student perceptions due to peer tutoring in students with different relationships with ADHD.

An additional area of my study that could be improved upon is refining the perception question relating to the ability to focus. I modified this perception question from Hlas et al. (2019), but in processing the data for this question, I

found that the categories were not clearly defined and could be interpreted differently by different students. If provided with more time in a future study, it would be ideal to phrase this question as a Likert-style response with clear groupings, so that the results from this question are more straightforward to distinguish, and test the question prior to data collection to ensure it is effective, by following a similar method to that outlined by Artino et al. (2014).

Finally, due to time restraints, I was not able to use ordinal logistic regressions as a way of analyzing the perception data. Using ordinal regression models would allow me to observe if there were any changes in the probability of students answering in more than just two categories, and allow me to analyze the perception data in more detail.

Overall, given that no significant differences in learning outcomes occurred between the experiment lab and the peer tutoring lab in all students, regardless of how they identify with ADHD, peer tutoring may not be effective in biology labs, but could serve as a substitution for traditional metabolic experiments. We know from the perception data results that using peer tutoring as a substitution for traditional experiments could also provide an added benefit of improving student perceptions of their understanding of these experiments. The findings of this study also suggest that active learning strategies, such as peer tutoring, in different environments and on students with different relationships with ADHD, may not negatively impact students with ADHD. Since the findings of this study indicate that peer tutoring has the same effect on students with different relationships with ADHD in terms of learning outcomes, and perceptions relating

to understanding and ability to focus, peer tutoring could be considered an inclusive choice to implement into introductory biology labs.

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Tables

Table 1. Demographic breakdown of data collected from students in BIOL 1020 labs during the Fall 2024 term, which was used for learning outcome and perception data relating to student understanding (n = 545).

Predictor Variable	Number of Students	Proportion (%)
<i>Relationship with ADHD</i>		
No ADHD, No Symptoms	360	66.1
No ADHD, Has Symptoms	156	28.6
ADHD, Medicated	17	3.1
ADHD, Non-Medicated	12	2.2
<i>Background</i>		
Canadian Non-Indigenous	435	79.8
Canadian Indigenous	45	8.3
International	65	11.9
<i>Gender</i>		
Male	168	30.8
Female	371	68.1
Other	6	1.1
<i>First-Generation Student</i>		
Yes	90	16.5
No	455	83.5
<i>English Second-Language</i>		
Yes	163	29.9
No	382	70.1
<i>Year of Degree</i>		
1st Year	409	75.0
2nd Year	91	16.7
3rd Year	32	5.9
4th Year or More	13	2.4
<i>Planning to Major in Biology</i>		
Yes	204	37.4
No	341	62.6

Table 2. Demographic breakdown of data collected from students in BIOL 1020 labs during the Fall 2024 term, which was used for perception data relating to the ability to focus (n = 264).

Predictor Variable	Number of Students	Proportion (%)
<i>Relationship with ADHD</i>		
No ADHD, No Symptoms	184	69.7
No ADHD, Has Symptoms	63	23.9
ADHD, Medicated	11	4.2
ADHD, Non-Medicated	6	2.3
<i>Background</i>		
Canadian Non-Indigenous	207	78.4
Canadian Indigenous	28	10.6
International	29	11.0
<i>Gender</i>		
Male	73	27.7
Female	187	70.8
Other	4	1.5
<i>First-Generation Student</i>		
Yes	41	15.5
No	223	84.5
<i>English Second-Language</i>		
Yes	86	32.6
No	178	67.4
<i>Year of Degree</i>		
1st Year	197	74.6
2nd Year	44	16.7
3rd Year	16	6.1
4th Year or More	7	2.7
<i>Planning to Major in Biology</i>		
Yes	112	42.4
No	152	57.6

Table 3. Proposed models that examined the effects of peer tutoring on the learning outcomes of those with different relationships with ADHD, as well as the effects of different variables, and their corresponding AIC, Δ AIC, and log-likelihood values.

Model	AIC	Δ AIC	Log-Likelihood
ScoreDifference ~ LabType + ADHD + (1 studentID)	558.69	0.00	-272.29
ScoreDifference ~ LabType* ADHD + (1 studentID)	572.39	13.70	-276.09
ScoreDifference ~ LabType* ADHD + EnglishSecondLanguage + (1 studentID)	577.36	18.67	-277.56
ScoreDifference ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + (1 studentID)	584.51	25.82	-280.11
ScoreDifference ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + PlanBioMajor + (1 studentID)	592.45	33.76	-283.05
ScoreDifference ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + PlanBioMajor + Gender + (1 studentID)	605.31	46.63	-287.43
ScoreDifference ~ LabType* ADHD + FirstGeneration + Background + DegreeYear + (1 studentID)	612.60	53.92	-290.05
ScoreDifference ~ LabType* ADHD + FirstGeneration + Background + Gender + EnglishSecondLanguage + PlanBioMajor + (1 studentID)	619.39	60.71	-292.41
ScoreDifference ~ LabType* ADHD + FirstGeneration + Background + Gender + EnglishSecondLanguage + PlanBioMajor + DegreeYear + (1 studentID)	638.96	80.28	-299.09

Table 4. Generalized Variance Inflation Factor (GVIF) values for the predictor variables used in proposed models that examined the effects of peer tutoring on the learning outcomes of those with different relationships with ADHD. Values under 2.5 indicate that there is no multicollinearity with other variables.

Predictor Variable	GVIF Value
Lab Type	1.00
Relationship with ADHD	1.10
Gender	1.07
Background	1.31
English Second-Language	1.16
First-Generation Student	1.03
Year of Degree	1.31
Planning to Major in Biology	1.05

Table 5. Proposed models that examined the effects of peer tutoring on the perceptions relating to understanding of those with different relationships with ADHD, as well as the effects of different variables, and their corresponding AIC, Δ AIC, and log-likelihood values.

Model	AIC	ΔAIC	Log-Likelihood
UnderstandingQ ~ LabType + ADHD + (1 studentID)	1182.36	0.00	-586.15
UnderstandingQ ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + PlanBioMajor + (1 studentID)	1182.67	0.31	-581.23
UnderstandingQ ~ LabType* ADHD + (1 studentID)	1182.89	0.53	-584.39
UnderstandingQ ~ LabType* ADHD + EnglishSecondLanguage + (1 studentID)	1183.89	1.54	-583.88
UnderstandingQ ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + (1 studentID)	1184.07	1.71	-582.95
UnderstandingQ ~ LabType* ADHD + EnglishSecondLanguage + FirstGeneration + PlanBioMajor + Gender + (1 studentID)	1185.53	2.97	-580.52
UnderstandingQ ~ LabType* ADHD + FirstGeneration + Background + Gender + EnglishSecondLanguage + PlanBioMajor + (1 studentID)	1188.60	6.24	-580.11
UnderstandingQ ~ LabType* ADHD + FirstGeneration + Background + DegreeYear + (1 studentID)	1192.62	10.26	-583.14
UnderstandingQ ~ LabType* ADHD + FirstGeneration + Background + Gender + EnglishSecondLanguage + PlanBioMajor + DegreeYear + (1 studentID)	1194.45	12.09	-579.94

Table 6. Generalized Variance Inflation Factor (GVIF) values for the predictor variables used in proposed models which look at the effects of peer tutoring on the probability of agreeing with the statement “I find it difficult to understand the concepts of metabolic experiments in the lab” of those with different relationships with ADHD. Values under 2.5 indicate that there is no multicollinearity with other variables.

Predictor Variable	GVIF Value
Peer Tutoring	1.02
Relationship with ADHD	1.07
Gender	1.07
Background	1.33
English Second-Language	1.17
First-Generation Student	1.03
Year of Degree	1.31
Planning to Major in Biology	1.05

Table 7. Generalized Variance Inflation Factor (GVIF) values for the predictor variables used in a model that examined the effects of peer tutoring on the perceptions relating to the ability to focus of students with different relationships with ADHD. Values under 2.5 indicate that there is no multicollinearity with other variables.

Predictor Variable	GVIF Value
Peer Tutoring	1.00
Relationship with ADHD	1.00

Figures

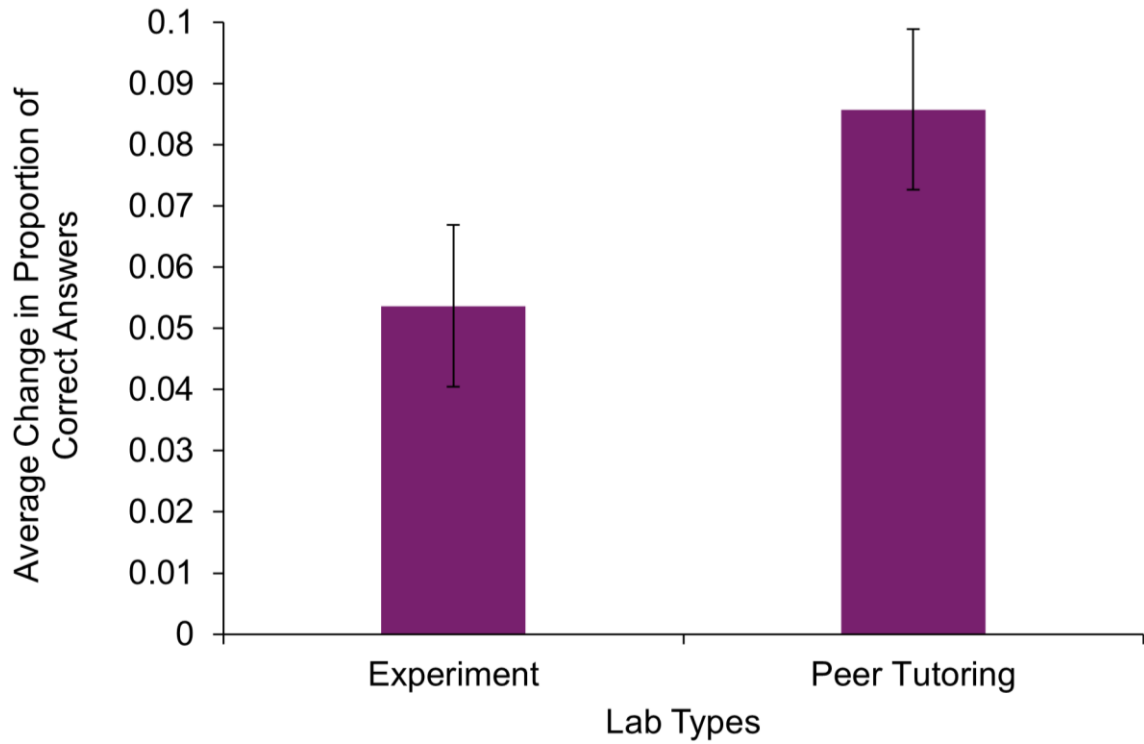


Figure 1. Average change in proportion of correct iClicker answers for the experiment lab and peer tutoring lab for all students ($n = 545$). Error bars represent the standard error of the mean.

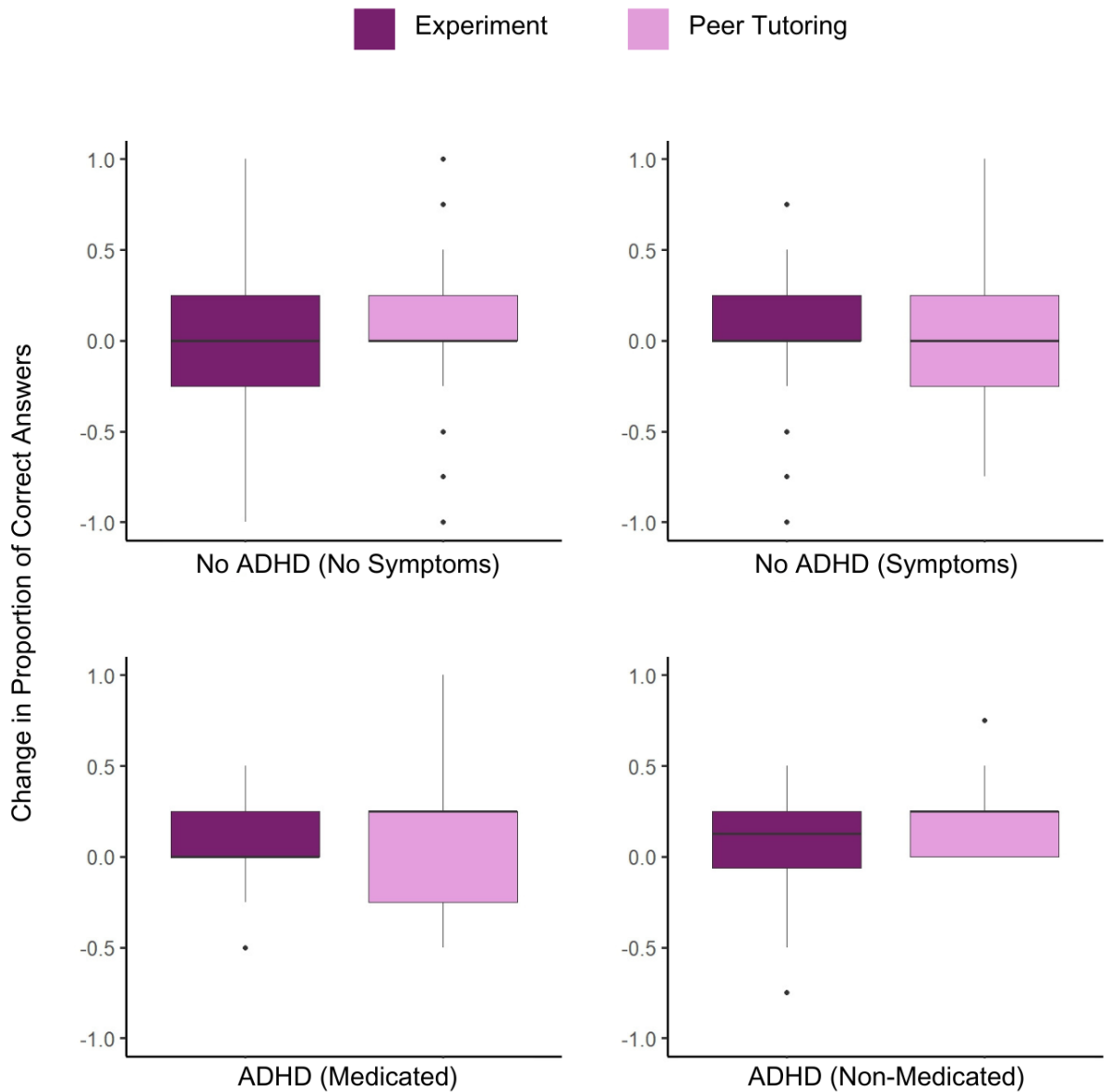


Figure 2. Change in the proportion of correct iClicker answers for the experiment lab (dark purple) and peer tutoring lab (light purple) for students with no ADHD and no symptoms of ADHD ($n = 360$), no ADHD but symptoms of ADHD ($n = 156$), ADHD and medicated for their ADHD ($n = 17$), and ADHD and not medicated for their ADHD ($n = 12$).

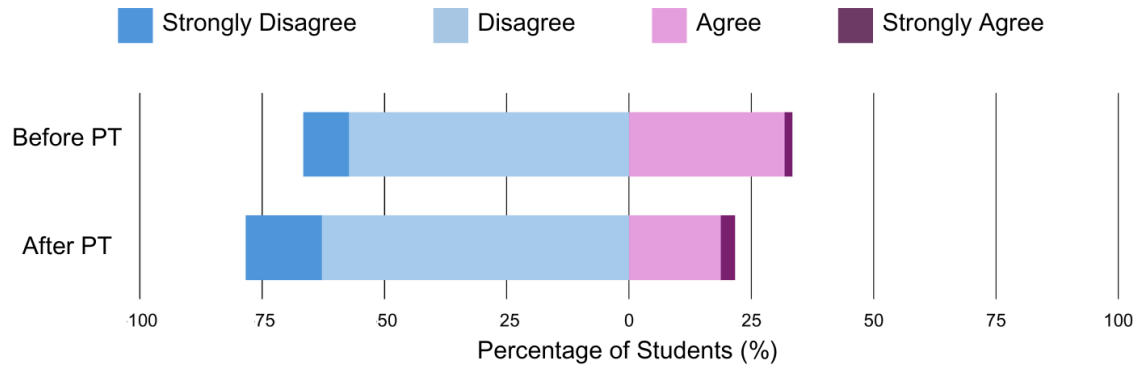


Figure 3. All students (n = 545) responses to the statement “I find it difficult to understand the concepts of metabolic experiments in the lab” before and after peer tutoring (PT), where dark blue bars represent the percentage of students who strongly disagree with the statement, light blue bars represent the percentage of students who disagree with the statement, light purple bars represent the percentage of students who agree with the statement, and dark purple bars represent the percentage of students who strongly agree with the statement.

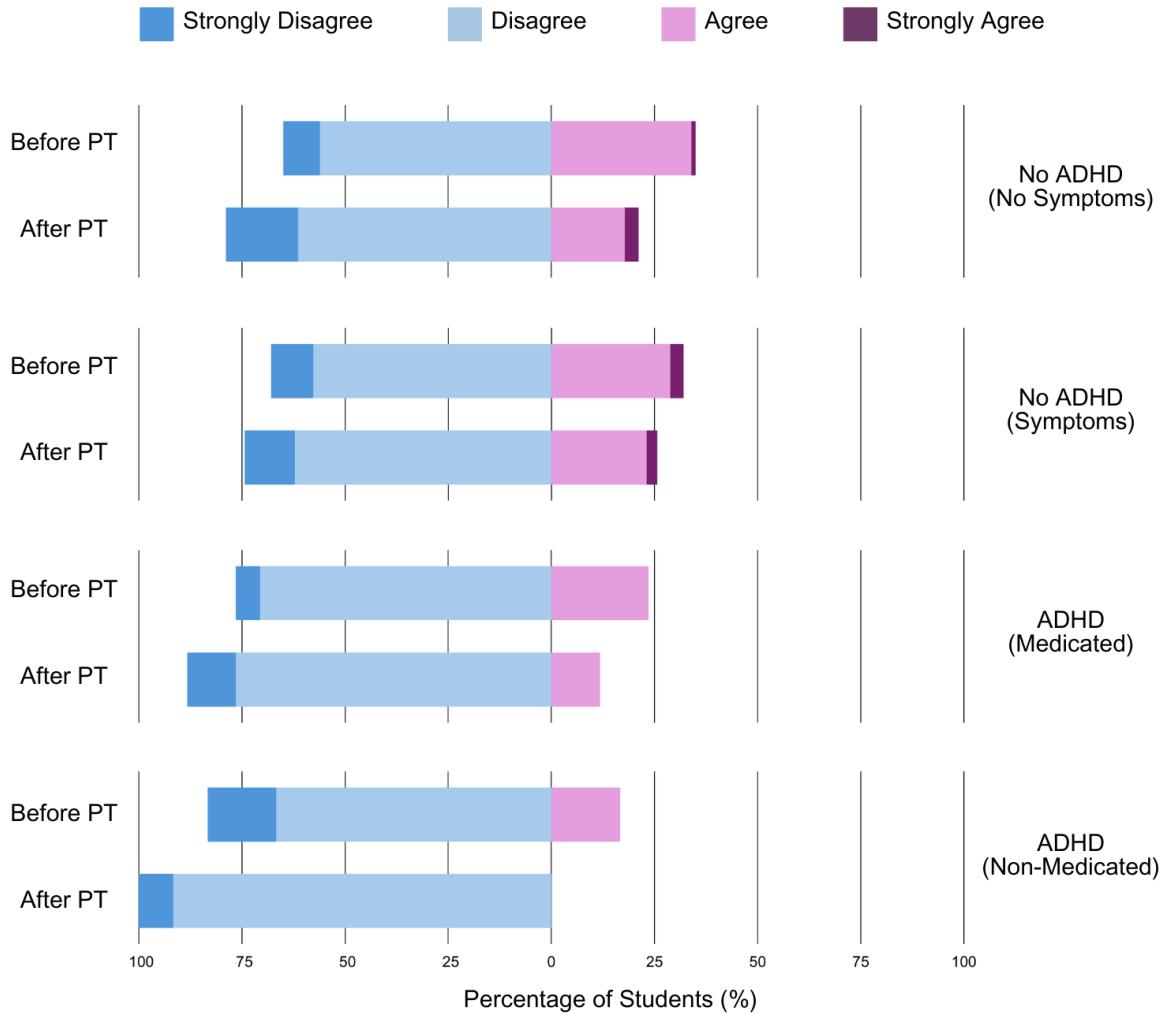


Figure 4. Student responses to the statement “I find it difficult to understand the concepts of metabolic experiments in the lab” before and after peer tutoring (PT), where dark blue bars represent the percentage of students who strongly disagree with the statement, light blue bars represent the percentage of students who disagree with the statement, light purple bars represent the percentage of students who agree with the statement, and dark purple bars represent the percentage of students who strongly agree with the statement. Data from students with no ADHD (n = 360), students with no ADHD but who have symptoms of ADHD (n = 156), students with ADHD and who are medicated for their ADHD (n = 12), and students with ADHD who are not medicated for their ADHD (n = 17).

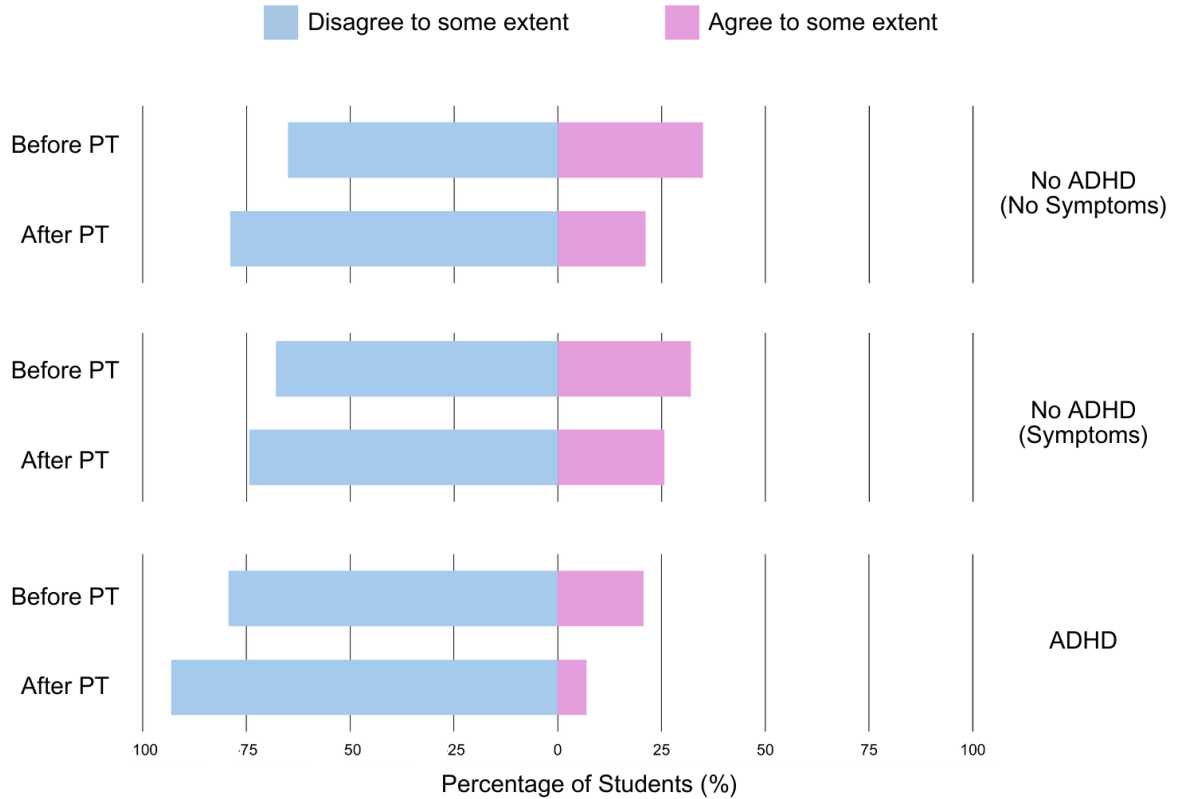


Figure 5. Student responses to the statement "I find it difficult to understand the concepts of metabolic experiments in the lab" before and after peer tutoring (PT), where blue bars represent the percentage of students who disagree with the statement to some extent, and purple bars represent the percentage of students who agree with the statement to some extent. Data from students with no ADHD ($n = 360$), students with no ADHD but who have symptoms of ADHD ($n = 156$), and students with ADHD ($n = 29$).

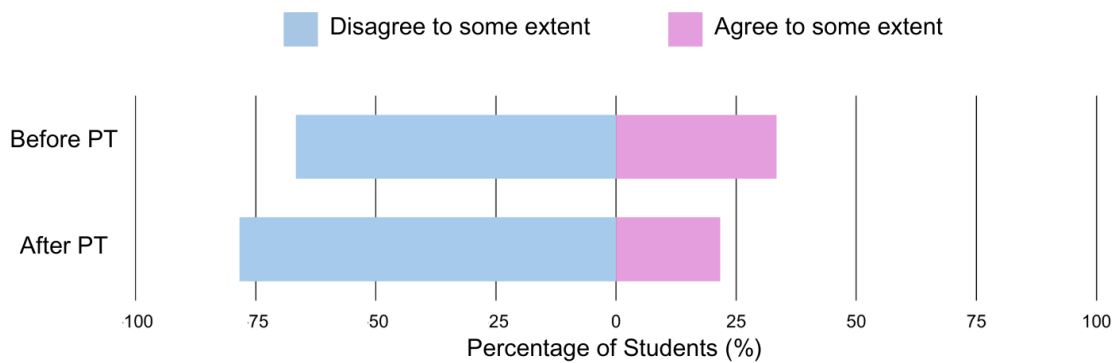


Figure 6. All students ($n = 545$) responses to the statement "I find it difficult to understand the concepts of metabolic experiments in the lab" before and after peer tutoring (PT), where blue bars represent the percentage of students who disagree with the statement to some extent, and purple bars represent the percentage of students who agree with the statement to some extent.

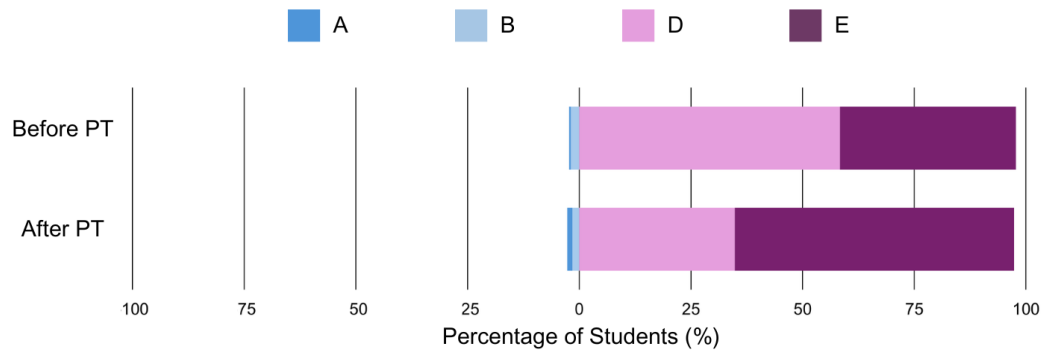


Figure 7. All students (n = 264) responses to the statement “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” before and after peer tutoring (PT), where dark blue bars represent percentage of students who answered A, light blue bars represent percentage of students who answered B, light purple bars represent percentage of students who answered D, and dark purple bars represent percentage of students who answered E.

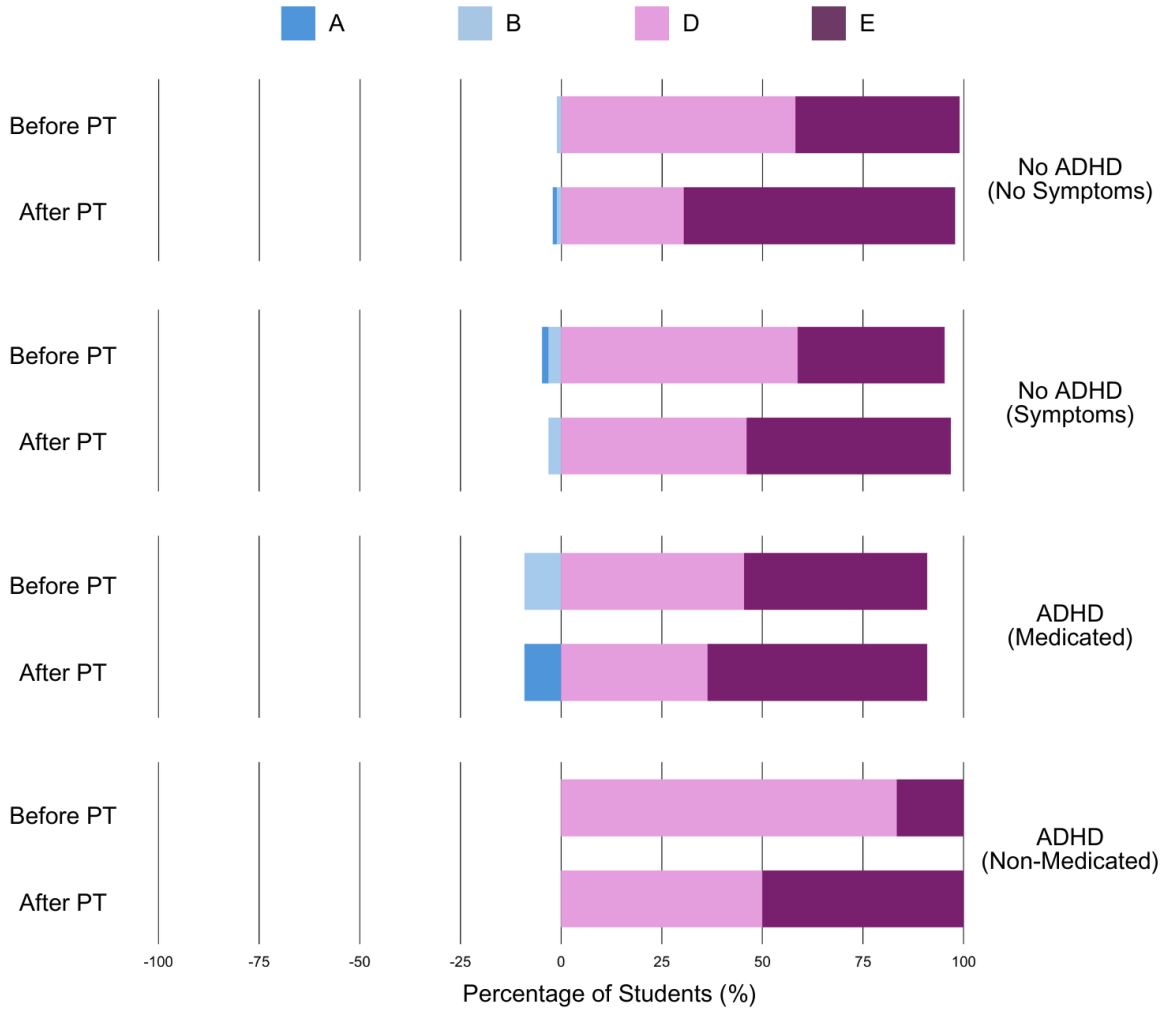


Figure 8. Student responses to the statement “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” before and after peer tutoring (PT), where dark blue bars represent percentage of students who answered A, light blue bars represent percentage of students who answered B, light purple bars represent percentage of students who answered D, and dark purple bars represent percentage of students who answered E. a is data for students with no ADHD ($n = 184$), b is data for students with no ADHD but who have symptoms of ADHD ($n = 63$), c is data for students with ADHD ($n = 63$) and who are medicated for their ADHD ($n = 11$), and d is data for students with ADHD who are not medicated for their ADHD ($n = 6$).

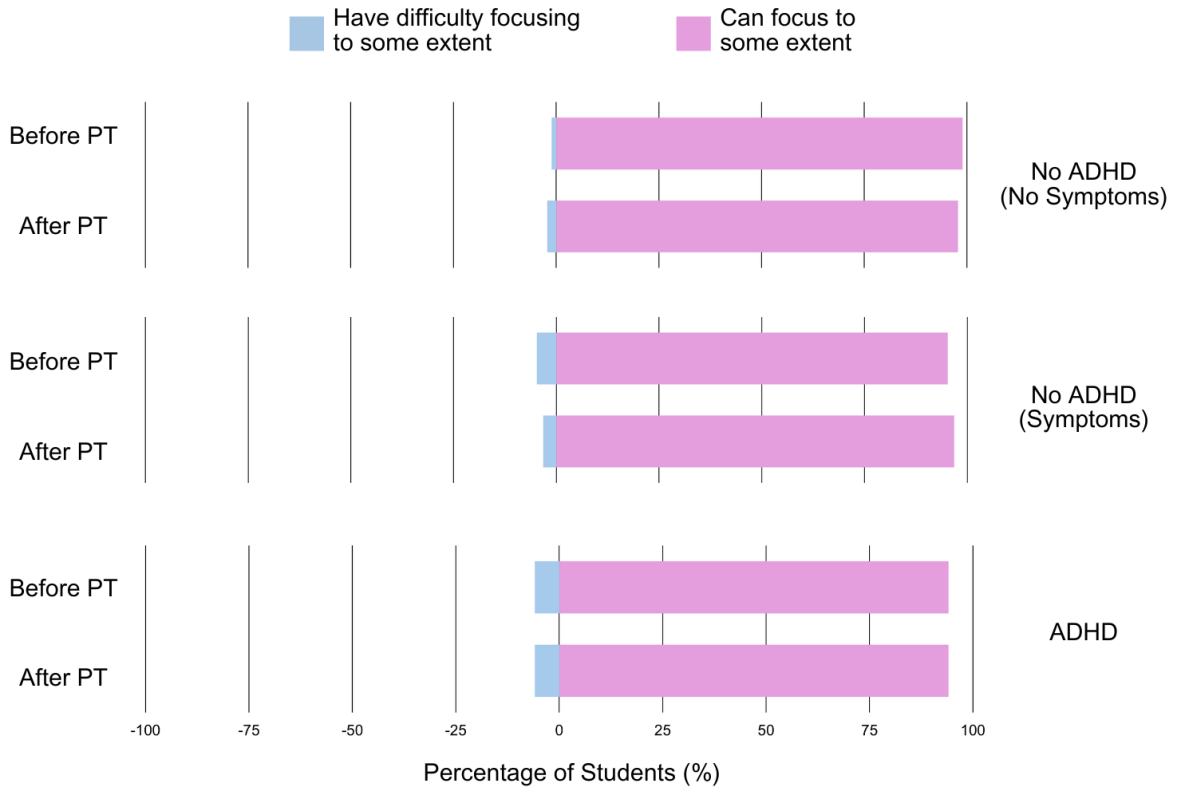


Figure 9. Student responses to the statement “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” before and after peer tutoring (PT), where light blue bars represent percentage of students who have some difficulty focusing to some extent, and light purple bars represent percentage of students who can focus to some extent. Data is from students with no ADHD (n = 184), students with no ADHD but who have symptoms of ADHD (n = 63), and students with ADHD (n = 17).

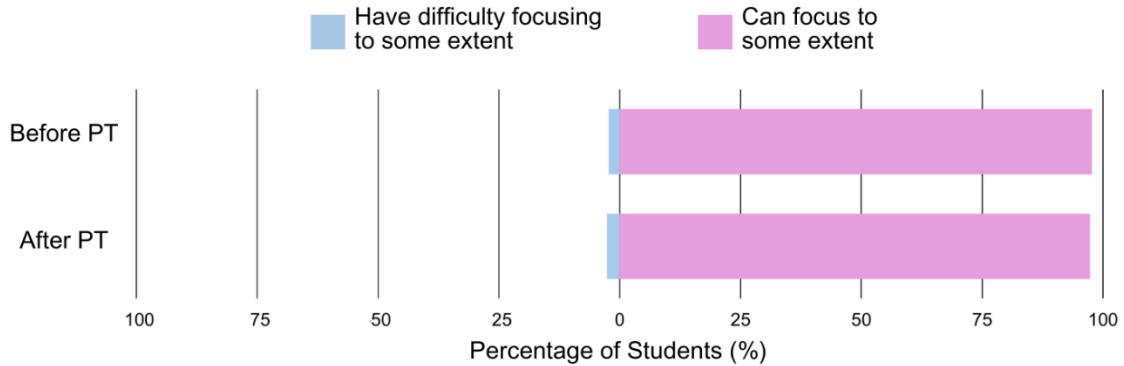


Figure 10. All students (n = 264) responses to the statement “Rate yourself on paying attention during labs/peer tutoring on a scale between A-E where A is not paying attention and E is paying complete attention” before and after peer tutoring (PT), where light blue bars represent percentage of students who have some difficulty focusing to some extent, and light purple bars represent percentage of students who can focus to some extent.

Appendix A - Worksheets

Cell Respiration Experiment Worksheet

Lab 4 Cell Respiration Experiment

Be sure to complete both sides of this worksheet!

Names of Group members (ENSURE EVERYONE'S NAME IS LISTED):

Question 1: Describe the role of each tube in the experiment. Are any of the tubes controls? How do you know?

Question 2: What are the dependent variables in the experiment? What are the independent variables in this experiment?

Question 3: What other outputs of Cell Respiration could we measure (if we had the proper equipment) to determine respiration rate?

Question 4: What are all the inputs and requirements for Cell Respiration? (specifically in Eukaryotes)

Question 5: What are the processes of cell respiration that are taking place in the tube as the yeast cells break down the sugars.

Replicate	Respiration Rate (mL/minute)			
	Glucose	Sucrose	Lactose	Lactose & Lactase
1				
2				
3				
4				
AVERAGE Respiration Rate (mL/minute)				

What kind of graph would you make to display the average difference of the four different sugar solutions?

SKETCH (using pen/paper below) a Graph of your groups average data below:

What do the results indicate? Which was the highest? Which was the lowest? Be prepared to explain why during the NEXT lab period.

Photosynthesis Experiment Worksheet

Lab 4 Photosynthesis Experiment

Be sure to complete both sides of this worksheet!

Names of Group members (ENSURE EVERYONE'S NAME IS LISTED):

Question 1: Describe the role of each tube in the experiment. Are any of the tubes controls? How do you know?

Question 2: What are the dependent variables in the experiment? What are the independent variables in this experiment?

Question 3: What other outputs of photosynthesis could we measure (if we had the proper equipment) to determine respiration rate?

Question 4: What other independent variables (not accounted for in this experiment) could influence photosynthetic rate, hint remember that a single enzyme catalyzes the reactions in the Calvin Cycle?

Question 5: What are the processes of photosynthesis that are taking place in the tube as the spinach leaves float? Try to be descriptive.

Replicate	Photosynthetic Rate (Proportion of leaves floating/ time)			
	Tube 1	Tube 2	Tube 3	Tube 4
1				
2				
3				
4				
AVERAGE photosynthetic Rate				

What kind of graph would you make to display the average difference of the four different treatments?

SKETCH (using pen/paper below) a Graph of your groups average data below:

What do the results indicate? Which was the highest? Which was the lowest? Be prepared to explain why during the NEXT lab period.

Appendix B – iClicker Questions

Concept Questions

Lab 4 (Experiments Lab) - Beginning of lab

Question 1: Which of the following are products of cellular respiration?

- a) Carbon dioxide and oxygen
- b) Carbon dioxide and energy (ATP)
- c) Oxygen and glucose
- d) Oxygen and water
- e) Oxygen and energy (ATP)

Question 2: Which of the following are products of photosynthesis?

- a) Carbon dioxide and light
- b) Carbon dioxide and glucose
- c) Oxygen and glucose
- d) Oxygen and light
- e) Carbon dioxide and water

Question 3: What is/are the independent variable(s) in our photosynthesis experiment? *Choose single best answer*

- a) Photosynthetic rate
- b) Carbon dioxide/light treatments
- c) Carbon dioxide/light treatments AND time
- d) Time
- e) Photosynthetic rate AND time

Question 4: What is/are the independent variable(s) in our cellular respiration experiment? *Choose single best answer*

- a) Sugar solution treatments AND time
- b) Sugar solution treatments
- c) Time
- d) Cellular respiration rates
- e) Cellular respiration rates AND time

Lab 5 (Peer Tutoring Lab) - Beginning of lab

Question 1: Which of the following are inputs of cellular respiration?

- a) Carbon dioxide and oxygen

- b) Carbon dioxide and energy (ATP)
- c) Oxygen and glucose
- d) Oxygen and water
- e) Oxygen and energy (ATP)

Question 2: Which of the following are reactants of photosynthesis?

- a) Carbon dioxide, light, and water
- b) Oxygen, light, and glucose
- c) Oxygen and glucose
- d) Oxygen and light
- e) Carbon dioxide and water

Question 3: What is/are the independent variable(s) in our photosynthesis experiment? *Choose single best answer*

- a) Photosynthetic rate
- b) Carbon dioxide/light treatments
- c) Carbon dioxide/light treatments AND time
- d) Time
- e) Photosynthetic rate AND time

Question 4: What is/are the independent variable(s) in our cellular respiration experiment? *Choose single best answer*

- a) Sugar solution treatments AND time
- b) Sugar solution treatments
- c) Time
- d) Cellular respiration rates
- e) Cellular respiration rates AND time

Lab 5 (Peer Tutoring Lab) - End of lab

Question 1: What type of graph would best represent the photosynthetic rate between the treatments?

- a) Line graph
- b) Bar graph
- c) Scatterplot

Question 2: What type of graph would best represent the respiration rate over time for just glucose?

- a) Line graph
- b) Bar graph

- c) Scatterplot

Question 3: What is/are the independent variable(s) in our photosynthesis experiment? *Choose single best answer*

- a) Photosynthetic rate
- b) Carbon dioxide/light treatments
- c) Carbon dioxide/light treatments AND time
- d) Time
- e) Photosynthetic rate AND time

Question 4: What is/are the independent variable(s) in our cellular respiration experiment? *Choose single best answer*

- a) Sugar solution treatments AND time
- b) Sugar solution treatments
- c) Time
- d) Cellular respiration rates
- e) Cellular respiration rates AND time

Perception Questions

Lab 5 (Peer Tutoring Lab) - Beginning of lab

Question 1: I find it difficult to understand the concepts of metabolic experiments in the lab (Modified from Papanastasiou 2005)

- a) Strongly disagree
- b) Disagree
- c) Agree
- d) Strongly agree

Question 2: Rate yourself on paying attention during labs on a scale between A - E where A is not paying attention and E is paying complete attention (Modified from Hlas et al. 2019)

- a) A
- b) B
- c) C
- d) D
- e) E

Lab 5 (Peer Tutoring Lab) - End of lab

Question 1: Rate yourself on paying attention during peer tutoring on a scale between A - E where A is not paying attention and E is paying complete attention (Modified from Hlas et al. 2019)

- a) A
- b) B
- c) C
- d) D
- e) E

Question 2: I find it difficult to understand the concepts of metabolic experiments in the lab (Modified from Papanastasiou 2005)

- a) Strongly disagree
- b) Disagree
- c) Agree
- d) Strongly agree

Appendix C – Final Lab Test Questions

Question 1: What product of photosynthesis were we measuring with floating leaves in our photosynthesis experiment?

- a) Carbon dioxide
- b) Water
- c) Light
- d) Oxygen
- e) Glucose

Question 2: Which of the following are inputs in photosynthesis reactions?

- a) Carbon dioxide and light
- b) Carbon dioxide and glucose
- c) Oxygen and glucose
- d) Oxygen and light
- e) Oxygen and water

Question 3: What were the independent variable(s) in our photosynthesis experiment?

- a) Carbon dioxide concentrations (treatments)
- b) Time
- c) Carbon dioxide/light treatments
- d) Carbon dioxide/light treatments AND time
- e) Photosynthetic rate AND time

Question 4: What product of cellular respiration were we measuring in our cellular respiration experiment?

- a) Oxygen
- b) Glucose
- c) Carbon dioxide
- d) Water
- e) Light

Question 5: When we graphed the differences between the sugar solutions in the cellular respiration experiment, what is our dependent variable?

- a) Time
- b) Oxygen concentrations
- c) Sugar solution treatments

- d) Yeast concentrations
- e) Cellular respiration rate

Question 6: If we wanted to see how the amount of gas produced during cellular respiration of just a single sugar, e.g. glucose over time, at the time points we collected. What graph would we use?

- a) Scatterplot
- b) Line graph
- c) Bar graph
- d) Pie chart

Appendix D – Demographics Survey Questions

Question 1: What are your preferred pronouns?

- a) She/her
- b) He/his
- c) They/them
- d) Prefer not to say

Question 2: Are you an International student?

- a) Yes
- b) No
- c) Prefer not to say

Question 3: Is English your second language?

- a) Yes
- b) No
- c) Prefer not to answer

Question 4: Do you identify as: (select more than one if applicable) (Statistics Canada 2021)

- a) Caucasian
- b) South Asian
- c) Chinese
- d) Black
- e) Filipino
- f) Arab
- g) Latin American
- h) Southeast Asian
- i) Korean
- j) Japanese
- k) Prefer not to say
- l) Other

Question 5: Do you consider yourself a part of the LGBTQIA2S+ Community?

- a) Yes
- b) No
- c) Prefer not to say

Question 6: Are you a first-generation university student? (The first person in your family to attend post-secondary education)

- a) Yes
- b) No
- c) Prefer not to say

Question 7: What year of this undergraduate degree are you in?

- a) 1st year
- b) 2nd year
- c) 3rd year
- d) 4th year or more
- e) Prefer not to say

Question 8: Are you planning to major in Biology?

- a) Yes
- b) No
- c) Prefer not to say

Question 9: Do you identify as Indigenous?

- a) Yes
- b) No
- c) Prefer not to say

Question 10: How do you identify with ADHD?

- a) I am diagnosed with ADHD
- b) I am not diagnosed with ADHD but experience symptoms of ADHD
- c) I am not diagnosed with ADHD and do not experience symptoms of ADHD
- d) Prefer not to answer

Question 11: If you are diagnosed with ADHD or have ADHD symptoms, are you taking medication for your ADHD and/or ADHD symptoms?

- a) Yes
- b) No
- c) Does not apply
- d) Prefer not to answer

Question 12: The following are questions based on in-lab experiences

	Strongly Disagree	Disagree	Agree	Strongly Agree	Neutral
I am comfortable while participating in lab activities that involve working with others. ¹	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I dislike participating in lab activities that involve working with others. ¹	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The lab with peer tutoring (lab 5) makes me anxious. ²	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The lab without peer tutoring makes me anxious. ²	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I benefited from peer tutoring during lab 5 in the lab. ²	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Peer tutoring provided a more positive relationship among students. ³	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel focused during peer tutoring.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have a difficult time focusing during peer tutoring.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer teaching others	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer having others teach me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

1. Modified from McCroskey 1982 as cited in McCroskey et al. 1985, 2. Modified from Papanastasiou 2005, 3. Modified from Cortright et al. 2005

Question 13: In what ways did peer tutoring support your learning? (Modified from Alvares et al. 2023)

Question 14: In what ways did peer tutoring interfere with your learning? (Modified from Alvares et al. 2023)

Question 15: Please describe your ability to focus in the labs, during peer tutoring. (Modified from Hlas et al. 2019)