

# **Creation, Adoption, and Assessment of a Lab Manual in an Introductory Biology Lab Course**

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## **ABSTRACT**

The use of open education resources (OER) in the Biological Sciences major courses can reduce financial hardships and stress for undergraduate students while improving course passing rates and major retention. Equitable and timely access to course materials can especially improve outcomes for disadvantaged students. Although there exists a large repository of biology-related OER materials, few lab manuals have aligned specifically with the curriculum at SUNY Old Westbury. The goal for this study was to create an OER lab manual specifically for a foundational biology lab course that embeds more hands-on activities and uses mini-course-embedded research experiences (mini-CURE). Student perception to this manual and course grade outcomes were also assessed. The results from this study show that student perception of the OER lab manual is comparable to any purchased lab manual and that the largest benefit to using the new OER lab manual is a reduction in drop-fail-withdraw (DFW) rates. This suggests that access to free and curriculum aligned lab manuals can improve the student passing rate in biology courses.

**Keywords:** Open educational resources, introductory biology lab, mini-CUREs, OER lab manual, disadvantaged students

## Creación, adopción y evaluación de un manual de laboratorio en un curso introductorio de biología

### RESUMEN

El uso de recursos educativos abiertos (REA) en las asignaturas de Ciencias Biológicas puede reducir las dificultades económicas y el estrés de los estudiantes de pregrado, a la vez que mejora las tasas de aprobación y la retención en la carrera. El acceso equitativo y oportuno a los materiales del curso puede mejorar especialmente los resultados de los estudiantes desfavorecidos. Si bien existe un amplio repositorio de materiales REA relacionados con la biología, pocos manuales de laboratorio se han alineado específicamente con el currículo de SUNY Old Westbury. El objetivo de este estudio fue crear un manual de laboratorio REA específico para un curso de laboratorio de biología fundamental que integre más actividades prácticas y utilice experiencias de investigación integradas en minicursos (mini-CURE). También se evaluó la percepción de los estudiantes sobre este manual y las calificaciones del curso. Los resultados de este estudio muestran que la percepción de los estudiantes sobre el manual de laboratorio REA es comparable a la de cualquier manual de laboratorio adquirido y que el mayor beneficio de usar el nuevo manual de laboratorio REA es una reducción en las tasas de abandono, reprobación y abandono (DFW). Esto sugiere que el acceso a manuales de laboratorio gratuitos y alineados con el currículo puede mejorar la tasa de aprobación de los estudiantes en las asignaturas de biología.

**Palabras clave:** Recursos educativos abiertos, laboratorio de biología introductoria, mini-CUREs, manual de laboratorio de REA, estudiantes desfavorecidos

## 生物学入门实验课程中实验手册的创建、采用和评估

### 摘要

在生物科学专业课程中使用开放教育资源(OER)能减轻本科生的经济困难和压力,同时提高课程通过率和专业保留率。公平及时地获取课程资料尤其能改善弱势学生的学习成果。尽管存在大量与生物学相关的OER资料库,但很少有实验手册与纽约州立大学奥尔德韦斯特伯里分校(SUNY Old Westbury)的课程设置相符。本研究的目标是专门为基础生物学

实验课程创建一本OER实验手册，该手册包含更多实践活动，并采用迷你课程嵌入研究体验(mini-CURE)。研究还评估了学生对这本手册的评价和课程成绩。研究结果表明，学生对OER实验手册的评价与任何购买的实验手册相当，并且使用新版OER实验手册的最大好处是降低了退课-挂科率(DFW)。这表明，获取免费且与课程设置相符的实验手册能提高学生的生物学课程通过率。

关键词：开放教育资源，入门生物学实验室，迷你课程嵌入研究体验，OER实验室手册，弱势学生

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## Introduction

The rising textbook costs in STEM education is both a barrier and a burden for students that are trying to achieve a higher education degree. Purchasing textbooks is a source of stress to students that negatively impacts learning outcomes and is a barrier for student retention, particularly from those in disadvantaged groups (Jenkins et al., 2020; Lo et al., 2023; Spica & Biddix, 2021). This is exacerbated for STEM majors, where the cost of science textbooks is higher than average (Krueger, 2020) and are frequently updated to new editions, limiting the cost savings from purchasing a previously owned textbook. Lab manuals in particular need to be developed to align with curriculum for further cost savings to students (Moorberg, 2017).

Studies that surveyed student textbook purchases show that nearly all students do not have their textbook on the first day of class, while approximately half of students do not buy the book at all (Hanson, 2024; Jenkins et al.,

2020). Students who did not purchase a textbook felt that this hurt their class performance (Jenkins et al., 2020; Spica & Biddix, 2021). Additionally, students from disadvantaged backgrounds, such as those who were first to college, financially disadvantaged, or underrepresented minorities, reported significantly higher levels of stress as well as course fail rates in comparison to those that were not disadvantaged (Jenkins et al., 2020; Spica & Biddix, 2021). This suggests that reducing textbook costs, particularly for students from disadvantaged groups, may help to improve student success, especially in STEM fields.

Open educational resources (OER) can alleviate the financial burden of textbook costs for students and provide first day access to course materials. There is substantial evidence that indicates adoption of OER materials to reduce the success gap between white and underrepresented minority students in STEM majors, and has the greatest benefit for financially disadvantaged groups and students of color (Colvard et al., 2018; Marsh, 2022).

Overall, courses that adopt OER materials show improved grades and have decreased drop-fail-withdrawal (DFW) rates (Colvard, 2018; Davidson Squibb et al., 2023; Suriano, 2024). This strongly suggests that the adoption of OER materials can improve student success rates and remove the financial burden for textbook acquisition.

A major hurdle for STEM retention in STEM majors is passing the introductory foundational courses, which is typically a C or better. For many students, STEM degree attainment is highly correlated to their performance in the introductory courses. There is a dramatic decline for students to complete a STEM degree with each additional grade that is below a C in the introductory courses (Hatfield et al., 2022). Moreover, fewer than 20% of Biological Sciences degree holders in the United States are from underrepresented minorities (Meyers et al., 2018), and even fewer first generation students obtain a STEM degree (Bettencourt, 2020). Many of these marginalized students are also financially disadvantaged (Bettencourt, 2020), suggesting that adopting OER materials and providing first-day access could improve access to course materials and subsequently increase passing rates (Feldstein, 2012; Moorberg, 2017).

While there are several OER textbooks in existence for biology lecture courses, fewer OER lab manuals are available or align precisely to the offered curriculum. Currently OER commons has a couple of OER lab manuals could be used for the anatomy and

physiology-based introductory biology course (McKeon S., 2016; “Principles of Biology I and II lab manuals,” 2020). However, the materials and procedures, as well as topics, differ from the resources that are available at our university. Additionally, these lab manuals also lack course-embedded undergraduate research experience (CURE) components. The use of CUREs in the curriculum are recognized for its influence on increasing and retaining interest in STEM fields, retention in science majors, increasing graduation rates, and enhancing persistence in STEM (Drew & Triplett, 2008; Leonetti et al., 2023). Early experience with research, especially in introductory courses, can also positively impact both retention and graduation rates (Leonetti et al., 2023; Rodenbusch et al., 2016). This is particularly true for disadvantaged students (Bradshaw et al., 2023; Estrada et al., 2016), which make up a large proportion of our Biological Sciences major students.

This study was conducted at the State University of New York at Old Westbury (SUNY-OW) in the Biological Sciences department. The goal of this study was to create an OER lab manual for one of the introductory biology courses that is specific to the resources available at the university and aligns with the offered curriculum, as well as embed mini-CUREs. Successful use of this lab manual was measured through student surveys to determine perception of the lab manual in comparison to prior use of purchased lab manuals. Student outcomes from adopting this new OER lab manual were also mea-

sured through grade comparisons and DFW rates. The results suggest that the OER lab manual both reduces financial stress and improves the DFW rates in one introductory biology lab course.

## Methodology

### Overall Study Design

SUNY-OW is a comprehensive, primarily 4-year, undergraduate institution. All assessments were approved and exempt by the Institutional Review Board at SUNY-OW and enrolled students were provided with informed consent to participate in this study. Only students aged 18 or older completed the surveys. Students had the opportunity to opt out of this study at any time. All student scores and survey responses, as well as reported outcomes, have been anonymized to maintain confidentiality.

### Creation of the Lab Manual

The OER lab manual for the Basic Biological Sciences II Lab (BS2411) was written with the current available resources at the institution. Each lab unit includes the following elements:

1. *An introduction to the topic*
2. *Learning objectives (see Table 1 for a summary)*
3. *Hypotheses and a space for students to fill out their answer*
4. *Materials section*
5. *Instructions*
6. *Post-lab questions*

7. *Space with charts, tables, etc., for students to enter their data, answers, and draw any flow charts or insert microscopic images*

The lab manual was made available to students on the first day of class both digitally on the Learning Management System (LMS) and as a printed copy. The manual was published under the Creative Commons License Agreement Attribution 4.0 International License: (<https://creativecommons.org/licenses/by/4.0/>), and it is accessible via SUNY Soar, an online repository for OER works (Poon et al., 2023). **Table 1** shows the content for each unit and the learning objectives for each topic. The topics covered were similar to the purchased lab manual (Biological Investigations Lab Manual by Dolphin and Vleck, McGraw Hill) (Dolphin, 2015). The lab manual will be updated annually as new materials or updated protocols are developed.

Students were also provided with additional OER materials through labxchange (<https://www.labxchange.org>), which is a website that compiles online OER resources for use in education. **Table 2** summarizes the newly implemented experiments for each lab in the OER lab manual in comparison to the purchased lab manual. The protocols were carefully written with supplies and materials that are currently available at SUNY-OW.

| <b>Table 1.</b>                                              | <b>Lab manual content with learning objectives for each topic.</b>                                                                                                                                                                                                                                                                |
|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Topic</b>                                                 | <b>Learning Objective</b>                                                                                                                                                                                                                                                                                                         |
| <b><i>Cellular Respiration</i></b>                           | 1. Examine the process of cellular respiration in yeast and in germinating seeds                                                                                                                                                                                                                                                  |
| <b><i>Photosynthesis</i></b>                                 | 1. Determine the photosynthesis rate of a plant as a function of distance.<br>2. Determine the absorption spectra of photopigments.<br>3. Examine the number of chloroplasts in plant samples.                                                                                                                                    |
| <b><i>Plant Structure</i></b>                                | 1. Examine plant structures and learn about the anatomy and physiology of plants.<br>2. Distinguish the basic cell and tissue types in plants and their function.<br>3. Distinguish the differences in structure between a monocot and a eudicot.                                                                                 |
| <b><i>Plant Reproduction</i></b>                             | 1. Understand the reproductive cycle in an angiosperm.<br>2. Observe the structures of an angiosperm.<br>3. Distinguish characteristics that are common to monocots and eudicots.                                                                                                                                                 |
| <b><i>Populations</i></b>                                    | 1. Estimate population growth using an online simulator.<br>2. Estimate population size of moving organisms in a simulated lab setting.                                                                                                                                                                                           |
| <b><i>Animal Phyla</i></b>                                   | 1. Examine the anatomy and life cycles of three representative animal phyla.<br>2. Examine how embryonic development determines adult form.<br>3. Determine the organizational differences between animals.<br>4. Understanding body symmetry.                                                                                    |
| <b><i>Fetal Pig Dissection</i></b>                           | 1. Examine the anatomical and physiological systems of vertebrates using the fetal pig as the model organism.                                                                                                                                                                                                                     |
| <b><i>Digestive System</i></b>                               | 1. Know the parts and function of the digestive system.                                                                                                                                                                                                                                                                           |
| <b><i>Musculoskeletal, Nervous &amp; Sensory Systems</i></b> | 1. Examine the microanatomical and macroanatomical structure of muscles, neurons, and sensory systems.<br>2. Relate how the structure of cells found in the muscular, nervous, and sensory systems allow an organism to have specific physiological functions.<br>3. Perform self-tests to observe the function of these systems. |
| <b><i>Circulatory System</i></b>                             | 1. Learn the parts of the mammalian heart, the chambers, and the valves.<br>2. Know the direction of blood flow through the circulatory system.<br>3. Understand the difference between the pulmonary and systemic circuits.<br>4. Understand the differences between arteries, veins and capillaries.                            |

|                                                   |                                                                                                                                                                                                                                     |
|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Respiratory System</i></b>                  | <ol style="list-style-type: none"> <li>1. Examine the structures of the respiratory system and how each component contributes to breathing and gas exchange.</li> <li>2. Examine respiratory capacity.</li> </ol>                   |
| <b><i>Excretory &amp; Reproductive System</i></b> | <ol style="list-style-type: none"> <li>1. Examine the renal system.</li> <li>2. Examine the male and female reproductive systems.</li> </ol>                                                                                        |
| <b><i>Plant Project</i></b>                       | <ol style="list-style-type: none"> <li>1. Examine using two different types of seeds how the absence of light effects germination and the growth of plants</li> <li>2. Determine the type of angiosperm you have planted</li> </ol> |
| <b><i>Exercise Physiology Project</i></b>         | <ol style="list-style-type: none"> <li>1. Determine the lung capacity, breathing rate, body temperature and pulse rate of different people and compare this to factors such as age, sex, height and weight.</li> </ol>              |
| <b><i>Animal Biodiversity Show and Tell</i></b>   | <ol style="list-style-type: none"> <li>1. Compare and contrast species within the animal kingdom.</li> </ol>                                                                                                                        |

| <b>Table 2</b>                     | <b>OER lab manual differences from the purchased lab manual</b>                                                                                                                                                                                                                                                                         |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Cellular Respiration</i></b> | <ol style="list-style-type: none"> <li>1. Used CO<sub>2</sub> and O<sub>2</sub> probes from Vernier.</li> <li>2. Use of spectrophotometer to estimate yeast cell number.</li> <li>3. Added pH measurements of yeast cultures.</li> </ol>                                                                                                |
| <b><i>Photosynthesis</i></b>       | <ol style="list-style-type: none"> <li>1. Used CO<sub>2</sub> and O<sub>2</sub> probes from Vernier.</li> <li>2. Used spinach leaves for photosynthesis.</li> <li>3. Ordered aqueous chlorophyll from a vendor for absorbance measurement.</li> <li>4. Used orange dye in water for carotenoid absorbance measurement.</li> </ol>       |
| <b><i>Plant Structure</i></b>      | <ol style="list-style-type: none"> <li>1. Observation lab: used available microscopic slides and live or preserved plant samples.</li> </ol>                                                                                                                                                                                            |
| <b><i>Plant Reproduction</i></b>   | <ol style="list-style-type: none"> <li>1. Observation lab: used available microscopic slides, models, and live or preserved fruits.</li> <li>2. Addition of a monocot (lily) and eudicot (rose) flower and comparison of all plant characteristics was included.</li> <li>3. Included monocot and eudicot plant dissections.</li> </ol> |
| <b><i>Populations</i></b>          | Estimating population size using an online growth simulator                                                                                                                                                                                                                                                                             |
| <b><i>Animal Phyla</i></b>         | <ol style="list-style-type: none"> <li>1. Observation lab: used available microscopic slides and live specimens.</li> <li>2. Lab also included YouTube videos.</li> </ol>                                                                                                                                                               |
| <b><i>Fetal Pig Dissection</i></b> | No change.                                                                                                                                                                                                                                                                                                                              |

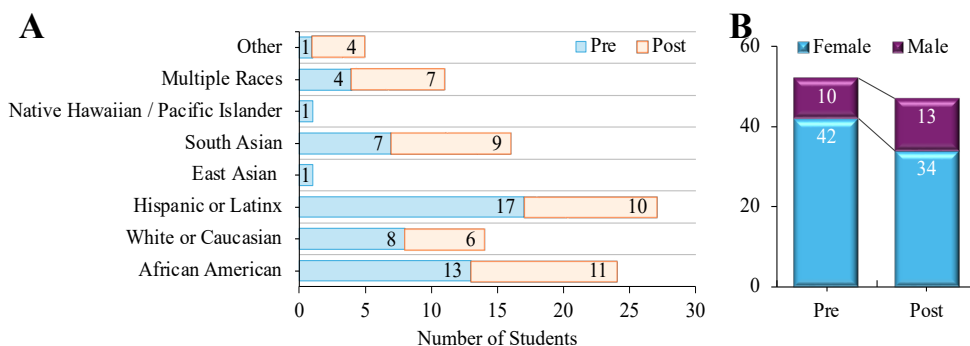
|                                                              |                                                                                                                                                            |
|--------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Digestive System</i></b>                               | 1. Observation lab: used available models and available microscopy slides                                                                                  |
| <b><i>Musculoskeletal, Nervous &amp; Sensory Systems</i></b> | 1. Observation lab: used available models and available microscopy slides.                                                                                 |
| <b><i>Circulatory System</i></b>                             | 1. Observation lab: used available models and available microscopy slides.                                                                                 |
| <b><i>Respiratory System</i></b>                             | 1. Observation lab: used available models and available microscopy slides. 2. Added BIOPAC to examine lung capacity.                                       |
| <b><i>Excretory &amp; Reproductive System</i></b>            | 1. Observation lab: used available models and available microscopy slides.                                                                                 |
| <b><i>Plant Project</i></b>                                  | 1. mini-CURE: piloted during Fall 2022 semester. Low student compliance so we have not currently assigned this.                                            |
| <b><i>Exercise Physiology Project</i></b>                    | 1. mini-CURE: Use of BIOPAC for data collection.                                                                                                           |
| <b><i>Animal Biodiversity Show and Tell</i></b>              | 1. Compare and contrast species within the animal kingdom. This may be assigned if we do not have live specimens for the <u><i>Animal Phyla</i></u> topic. |

### ***Assessment of student demographics and outcome***

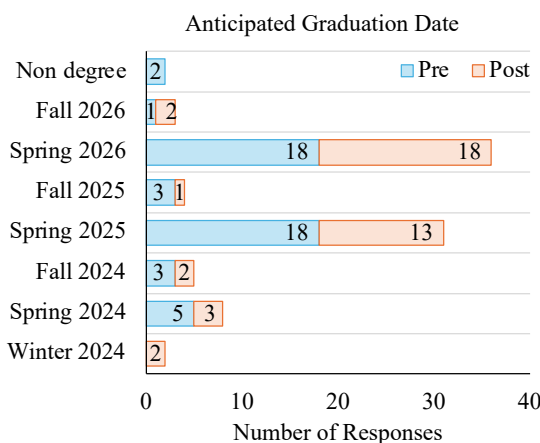
The Basic Biological Sciences II (BS2411) course meets once a week for three hours and 10 minutes. The students enrolled in the BS2411 course in the Fall 2023 (56 enrolled) and Spring 2024 (55 enrolled) semesters were provided with both a printed copy and a digital copy of the new OER lab manual. The students were given a beginning-semester pre-survey and an end-of-semester post-survey that determined their demographics, assessed their views on their learning, and their perception of the OER lab manual. Three instructors were assigned to the Fall 2023 and Spring 2024 semesters, with a single course coordinator that determined the weekly lab schedule, lab report topic,

and exams. In order to maintain grade consistency across all sections, the course coordinator reviewed all exams, provided a grading rubric for the lab reports, and provided the letter grade scale for final grade assignment.

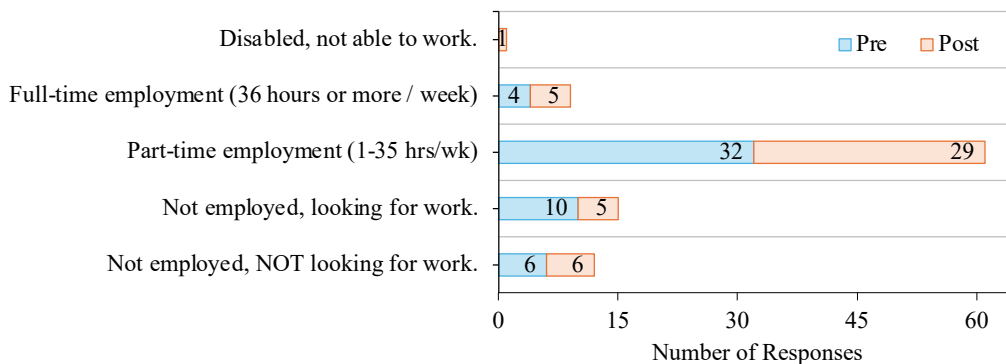
All surveys were posted on SUNY-OW's learning management system, BrightSpace. Since survey responses were anonymous, the pre-semester survey may have included students that withdrew from the course mid-semester. The post-semester survey may have included students that opted for an Incomplete grade, but not those that withdrew from the course since the survey was posted after the course withdrawal deadline. The survey questions were measured using a Likert scale of 5-Strongly Agree to 1-Strongly Disagree (Jebb et al., 2021).



**Figure 1.** Student demographics in the BS2411 course. Pre- ( $n = 52$ ) and post-course ( $n = 47$ ) surveys assessed A. Student race and/or ethnicity, and B. gender. While other options were included, these were the only choices selected by the students.



**Figure 2.** Student academic standing in the BS2411 course. Pre- ( $n = 52$ ) and post-course ( $n = 47$ ) surveys determined that majority of students were in their 2<sup>nd</sup> or 3<sup>rd</sup> year, with anticipated graduating dates within 2-3 years from taking the course.



**Figure 3.** Student employment status. Pre- ( $n = 52$ ) and post-course ( $n = 47$ ) surveys show that majority of students were either employed or looking for employment.

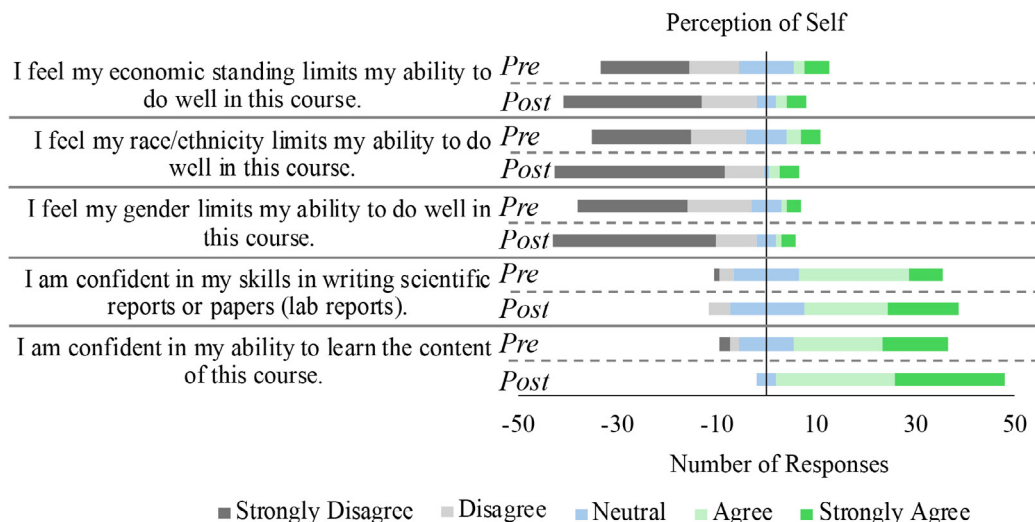
Student grades were compared from the Fall 2023 and Spring 2024 semesters, to Fall 2019 (61 students), when a paid lab manual was used and prior to remote learning during the pandemic. The course coordinator taught all sections of the Fall 2019, BS2411 lab course. The purchased lab manual lacked CURE components and were included in the OER lab manual. Also newly implemented in the Fall 2023 and Spring 2024 semesters that was not required in Fall 2019 was the submission of a photo of each completed lab on BrightSpace (the LMS). The OER lab manual structure was organized with pre-lab hypothesis questions, post-lab discussion questions, and other critical thinking questions. Submission onto BrightSpace provided instructors with immediate feedback on student learning.

Grades from the introductory biology courses are based on direct scores acquired from exams, quizzes, and lab reports, and are not curved. Thus, the grades from semester to semester are not normalized over time. The lab report scores, midterm and final exams, and overall grades were averaged, and SEM were calculated across all BS2411 lab sections for the Fall 2023 and Spring 2024 semesters. There was a total of 10 students that were missing an exam or lab report grade and were not included in the grade comparisons. Grading assessments for the semester included two written lab reports and two lab exams that evaluated learning from the first half and the second half of the semester. For both Fall 2019 and the Fall 2023/Spring 2024 semesters, the first half of the semester covered topics from *Cellu-*

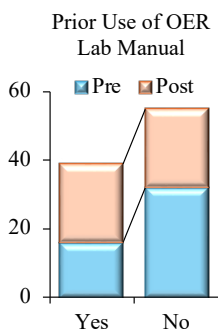
*lar Respiration to Populations*, while the second half of the semester started with *Animal Phyla* and ended with *Excretory and Reproductive Systems* (**Table 1**). The first lab report was on the topic of photosynthesis, and the second lab report was on exercise physiology lab (see **Table 1** for topics). The exercise physiology is a new mini-CURE that was introduced to the BS2411 lab course during implementation of the OER lab manual. This unit asks students to determine the class demographics (gender, height, weight, fitness level, etc.), and the class decides on what type of comparisons they would like to make. Then, using a BIOPAC (Biopac Systems), students will proceed to measure breathing rate, lung capacity, body temperature, and pulse rate under conditions of rest, light exercise, vigorous exercise, and a cool down period. Since the paid lab manual did not have this CURE component, the second lab report assigned in Fall 2019 was a general paper on the physiological systems and how they function to maintain homeostasis. The DFW rate is determined as any grade that is below a C, since this is the minimum grade required for major students to pass the course.

### Statistics

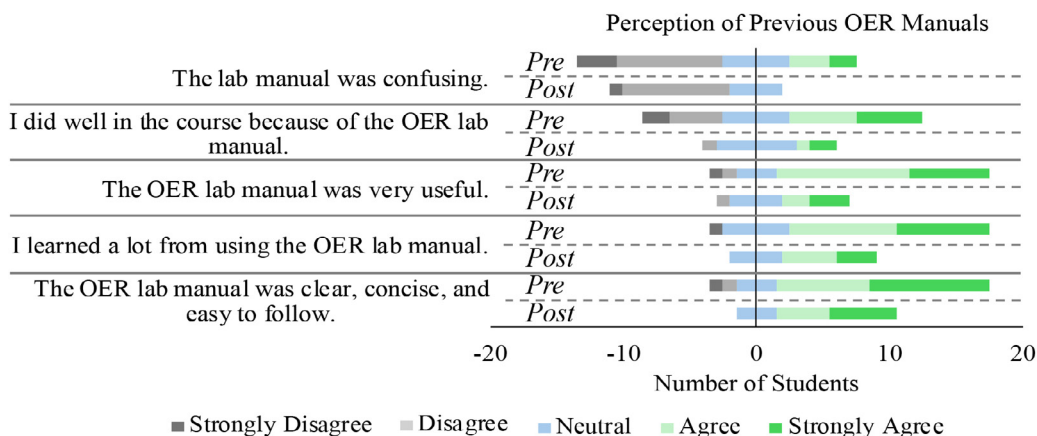
Survey questions were statistically compared between pre- and post-course using a nonparametric Mann-Whitney test, with  $p < 0.05$  as the threshold for significance. Grade comparisons were analyzed using a two-way ANOVA, followed by Bonferroni *post hoc* tests with  $p < 0.05$  as the threshold for significance. All statistics were performed using OriginPro software.



**Figure 4.** Student perception of self. Pre- ( $n = 50$ ) and post-course ( $n = 46$ ) surveys examined student perception of their demographics (gender, race/ethnicity, and economic standing), on their overall learning abilities.



**Figure 5.** Prior use of OER lab manuals. Pre- ( $n = 13$ ) and post-course ( $n = 21$ ) surveys examined students perception to prior use of OER lab manuals.



**Figure 6.** Perception of OER lab manuals. Pre- ( $n = 23$ ) and post-course ( $n = 21$ ) surveys examined students perception to prior use of any OER lab manuals.

## Results

### *Student Demographics*

**A**s of Fall 2023, the student demographics at SUNY-OW are: 30.5% Hispanic, 27.6% White, 22.7% Black, 11.3% Asian, 3.9% unknown or multi-racial, and < 1% Native-American or Pacific Islander. There are 59% female to 41% male, and a large proportion of students (~85%) receive some sort of financial aid or scholarship. The student enrollment in our physical and life sciences majors have held steady with ~25% Hispanic and 30-35% Black.

Similar to the University enrollment, the collected demographics from students that completed the survey at the beginning and at the end of the BS2411 lab course did not differ significantly. Most students were Hispanic and/or Black (Figure 1A), female (Figure 1B), and were 2<sup>nd</sup> or 3<sup>rd</sup> year undergraduate students (Figure 2). Comparable to our prior collected demographics (Poon, 2023), the majority of students were employed part-time or looking for employment (Figure 3). Demographics from the pre- and post-course survey as well as our prior assessments also did not differ, suggesting that regardless of who took the survey, the results well represent the average population of the students participating in this course and at the university.

Students were asked questions to assess their perception of themselves and on their abilities (Figure 4). Resembling our prior assessment, most students did not perceive their demo-

graphic to be a barrier in their performance in this course and felt confident in their aptitude.

### *Student perception of OER and purchased lab manuals*

Students were asked if they had previous experience with an OER lab manual in any lab course and were assessed on their perception for this past use of an OER lab manual. About half of the respondents (23) responded yes to using an OER lab manual in the past (Figure 5). Those that had used an OER lab manual were overall positive, and there was no significant difference between responses collected from the beginning of the semester in comparison to the end of the semester. Only 3 students provided additional comments regarding their previous use of OER lab manuals:

- It was overall interesting and easy to use.
- Not well put together, not updated, not always accurate.
- Please keep it free, I'm broke.

Students were also asked if they had previous experience using a purchased lab manual and were assessed on their perception of their prior use of a purchased lab manual (Figure 6). Most students felt that the paid manual was useful, and responses were consistent from the beginning to the end of the semester. Additional comments by students focused on the expensive nature of the lab manual, with one commenting that they did not purchase a manual at all. Some of the additional comments

regarding their previous use of paid lab manuals include:

- I purchased it for an old chemistry course, and it just had the questions. It did not have background reading, just the method and questions about it.
- It was a course at another school and purchasing the manual was mandatory. It was extremely overpriced.
- Purchasing a lab manual at my other school was mandatory and was extremely overpriced.
- I didn't get one.
- It was helpful because it was required to complete the labs. However, if the same lab manual was provided for free it would have benefited me just as much if not better due to not having to purchase it.
- It was expensive.
- This is my first semester at this school but at my last school they made us buy them. There was no choice, and they were pretty expensive.
- Expensive.

During the implementation of the new BS2411 lab manual, we also assessed student perception for the newly created BS2411 OER lab manual (Figure 7). While the perception was generally positive and similar to prior OER lab manual use, some of the additional comments that the students provided

did not align with the overall scores. Only 5 students provided additional comments regarding their previous use of OER lab manuals:

- It's ok.
- It was just annoying jumping around the manual and having to draw.
- I don't like it.
- It is awesome.
- Leave it the way it is.

### ***Grade comparisons between the OER and purchased lab manual***

The grades were also compared from the BS2411 courses during Fall 2019 when students had to purchase their lab manual (Dolphin, 2015) to Fall 2023 and Spring 2024 when we used the OER manual (Poon et al., 2023) (Figure 8). A significant main effect was found across grades ( $F(4, 465) = 28.36, p = 0$ ). A significant interaction effect was also found between grades and the lab manual used ( $F(4, 9) = 19.07, p < 0.001$ ). Bonferroni *post hoc* test reveals that a significant increase was found for Exam 1 ( $p < 0.001$ ) and a significant decrease for Exam 2 ( $p < 0.001$ ), with no significant differences between the first and second lab reports (Figures 8A, 8B). While there was no significant difference in the overall grade distribution (Figure 8C), the percent of DFW for the Fall 2019 semester was 32.4% while the DFW rate for the Fall 2023 and Spring 2024 semesters was 24.5% and 16.7%, respectively. In the Biological Sciences major, a grade of C or higher is need-

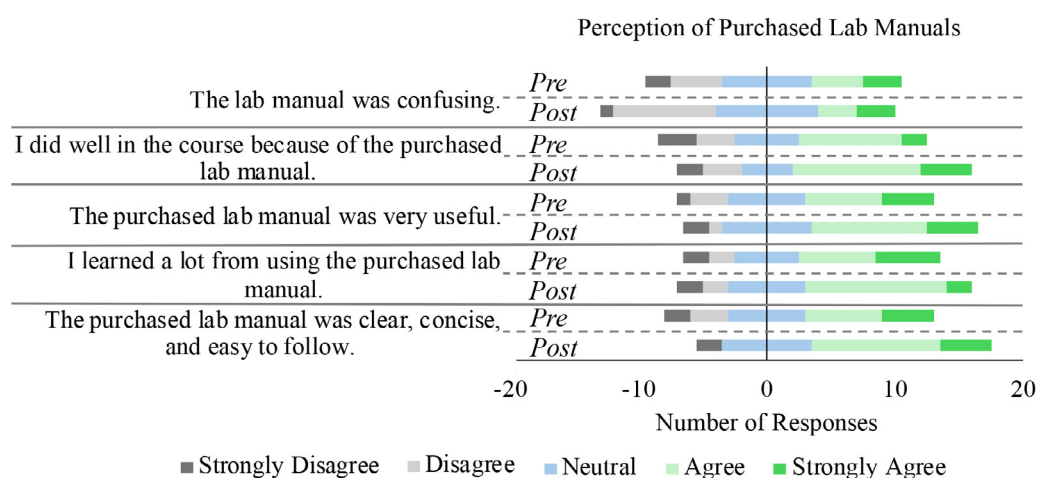
ed for all required major courses, thus our DFW scale considers grades lower than a C as a Fail. The results show that implementing the new OER lab manual improved the passing rate in the introductory biology lab course and may be essential for student retention in the major.

## Discussion

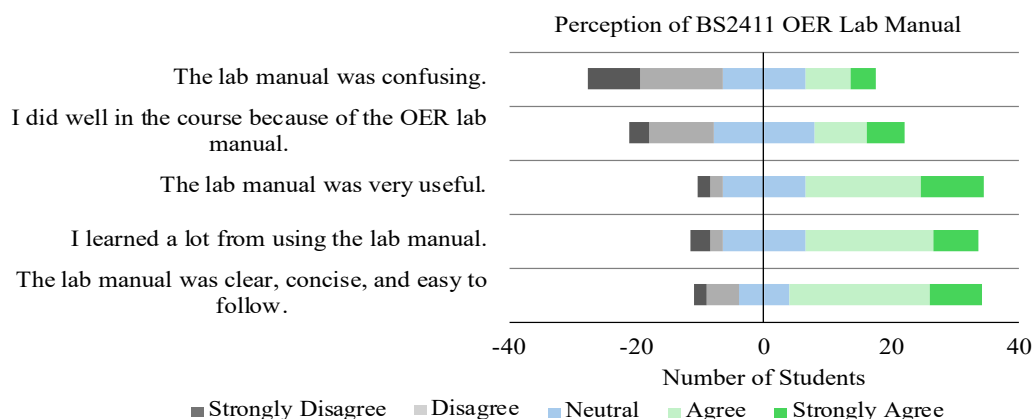
### *Student perception of self*

The assessment of student perception in several sections of an introductory biology lab course (BS2411) at SUNY-OW shows that the student demographics aligned with the enrollment at the institution. We also found that regardless of the identity of the student, the majority were overall confident in their ability to do well in this course. This finding is similar to our prior student assessments across several STEM disciplines, including computer science and chemistry majors (Poon, 2023). This is in contrast with a few

existing studies that show a correlation between self-perception and academic strength (Bauer et al., 2023; MacPhee et al., 2013) and the status of the student and their future STEM careers (Uludüz & Çalik, 2022). These other studies may have other confounding factors that may differ from the environment at SUNY-OW. For example, in a study by Loeb et al, URM students in primarily white institutions show a drop in subjective social status, and it is related to lower academic performance (Loeb & Hurd, 2019). In contrast, Black students attending a Historically Black College or University has increased student motivation that is based on educational social capital and cultural education (Freeman et al., 2021). While the focus of this study is not specifically on these factors, it suggests that SUNY-OW's unique environment and emphasis on social justice and DEI issues could increase student confidence on their abilities to succeed in STEM.



**Figure 7.** Prior use of purchased lab manual. Pre- ( $n = 13$ ) and post-course ( $n = 21$ ) surveys examined students perception to prior use of paid lab manuals.



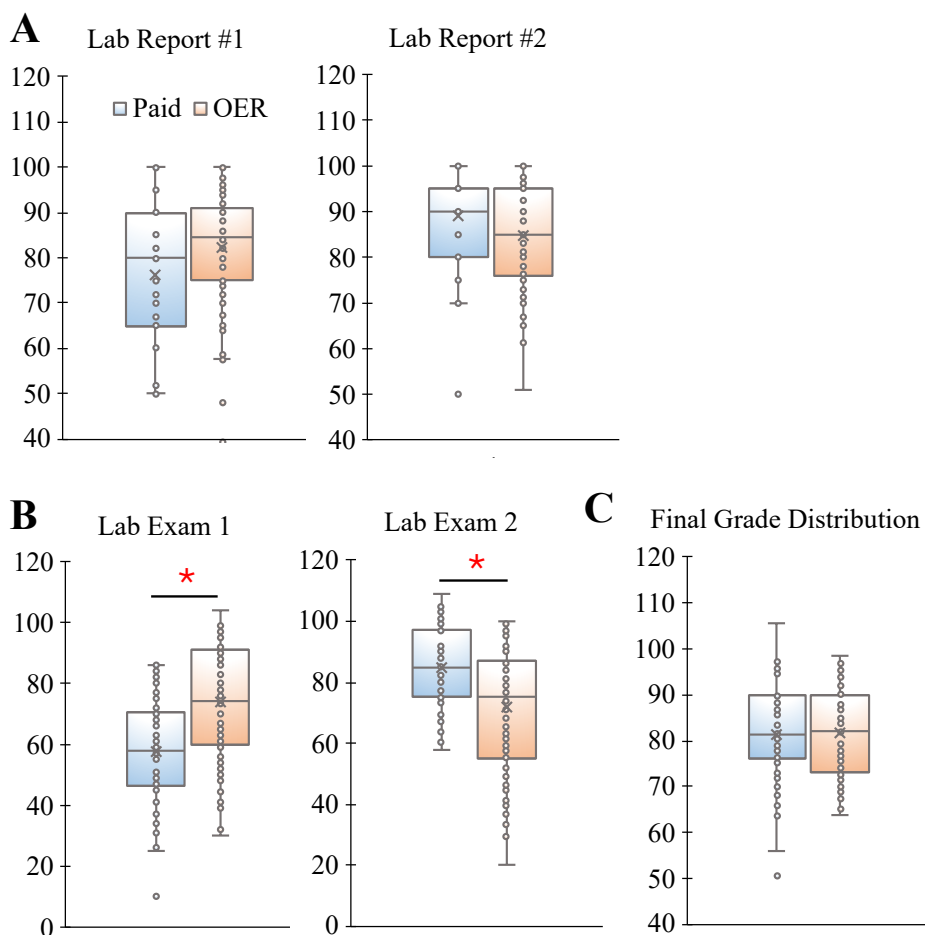
**Figure 8.** Perception of the BS2411 OER Lab manual. Post-course survey ( $n = 45$ ) capture student perception of the new lab manual.

### ***Grade outcomes and a reduction of DFW rates using the OER lab manual***

The grade comparisons between the purchased lab manual and the newly created OER lab manual show no significant difference across lab reports or final grade scores, with significant differences in lab exam grades. The first lab report on the topic of photosynthesis showed no significant difference in scores, suggesting that the OER lab manual is similar to the purchased lab manual. However, the second lab report on the exercise physiology experiment had a larger range of score when using the OER lab manual. The exercise physiology is a mini-CURE where students needed to perform data analysis and interpretation to produce a high-scoring lab report. Students also need to incorporate information on the physiological systems into their *Introduction* and *Discussion* sections to create a rationale for their hypotheses and interpret their data. In contrast, the second lab report

assigned when using the purchased lab manual was a summary of the physiological systems on maintaining homeostasis. Although the mini-CURE lab report on exercise physiology has more complex components in comparison to a general report on physiological systems, the average lab report grades remained the same. This suggests that students were able to maintain a similar or higher level of learning while employing critical thinking skills to analyze and interpret their collected data.

The first lab exam was significantly increased when using the OER lab manual. Several units of study in the purchased lab manual from Fall 2019 are primarily observation labs whereas our OER lab manual embedded more hands-on activities, such as comparison of floral types for the plant labs. The additional activities for the first half of the semester on plant anatomy and physiology may account for the significant increase in the first exam grades. The additional comparison of mono-



**Figure 9.** Course grade comparison. Grades were compared from the Fall 2019 semester ( $n = 53$ ), which was prior to pandemic-related remote learning and when a purchased lab manual was used, to the Fall 2023 and Spring 2024 semesters ( $n = 94$ ) when the OER lab manual was adopted into the course. A. There wasn't a significant difference in lab report grades between the purchased and the OER lab manual. B. While the first exam scores were significantly higher using the OER lab manual ( $*p < 0.001$ ), the second lab exam was significantly decreased ( $*p < 0.001$ ). C. The final grade distribution did not change between the purchased lab manual and the OER lab manual.

cot and eudicot floral types allowed the students to integrate each component of plant anatomy and physiology and may have improved learning. While the second half of the semester also embedded additional hands-on activities, such as the addition of the Bio-Pac for physiological measures, eight topics

were condensed across four weeks to accommodate the addition of the exercise physiology mini-CURE. The fifth week focused on the exercise physiology mini-CURE, which embedded the conceptual content from the animal physiological systems and were applied to data collection, analysis and the sci-

entific method. This may have resulted in the lowered second exam grades, since students received far more topics in a shorter amount of time.

There was no significant difference on the final grade between the Fall 2019 and the Fall 2023/Spring 2024 semesters, suggesting that the OER lab manual did not greatly impact this metric. However, the implementation of the OER lab manual consistently reduced the DFW rate. This is in line with other studies showing a similar decrease in DFW rates after adopting OER materials (Colvard, 2018; Suriano, 2024). The national passing rate for the introductory biology courses is between 50-70% (Freeman et al., 2011), and is much lower for URM students (Haak et al., 2011; Villarejo et al., 2008). The adoption of OER materials has been shown to reduce the success gap between white and URM students in STEM fields, and benefits both financially disadvantaged groups and students of color (Colvard, 2018; Marsh, 2022). Coupled with SUNY OW's student population that consists of a large proportion of minorities, females, and economically disadvantaged students, this suggests that increasing the passing rate with the OER lab manual may increase retention of disadvantaged students in the major.

### ***Student perception of OER***

Student perception of purchased and free OER lab manuals shows a general trend related to textbook cost. While the feedback did not seem to differ between the effectiveness of the purchased or OER lab manuals, the stu-

dent comments focused on the cost factor of a lab manual. This aligns with other studies examining student perception to OER materials that show positive student attitudes to OER use (Higgins et al., 2023). In conjunction with the grade assessment, the OER lab manual is seemingly comparable to the purchased lab manual. A positive attribute is the lower cost, thus reducing financial stress and burden to students. It has been shown in several studies that working has a negative impact on student grades (Kalenkoski & Pabilonia, 2010; Stinebrickner et al., 2003), although there are some studies that show little impact (Dadgar, 2012). This aligns with the large proportion of the surveyed students at SUNY-OW that were working or seeking part-time employment, presumably to afford textbooks needed for coursework. This may account for the lower DFW rates when using the new BS2411 OER lab manual, since previous studies have shown that textbook acquisition is related to course passing and withdrawal rates (Jenkins et al., 2020; Spica & Biddix, 2021). Although student stress levels were not assessed, it is clear that access to a free lab manual impacted course passing rates.

### **Conclusions**

The implementation of the new BS2411 OER lab manual in large part was successful and greatly benefitted students. Due to the limited availability of OER lab manuals in the content area of plant and animal anatomy and physiology, this manual is available to other institutions with

comparable curriculum and may be modified for their specific needs. Further, SUNY-OW's lab manual will be updated annually to incorporate newer technologies or mini-CUREs and shared through SUNY Soar, SUNY's online OER repository.

## **Limitations**

There were a few limitations to this study, including comparison of students between Fall 2019 to the Fall 2023/Spring 2024 semesters. To maintain equity, all students from the Fall 2023/Spring 2024 semesters were provided with the OER lab manual, so this study lacks the same semester parallel comparisons for the purchased lab manual. Instead, students from the Fall 2023/Spring 2024 semesters were asked post-reflective questions on any purchased lab manual use. Additionally, the grades from prior to the pandemic were compared to the Fall 2023/Spring 2024 semesters. This limitation is because pre and post pandemic student behaviors may be different. The smaller sample size at SUNY-OW also might not be easily generalized to larger universities with dissimilar student demographics.

The multiple instructors from the Fall 2023/Spring 2024 semesters are an introduced variable that was controlled by having a course coordinator to normalize all content across different course sections. However, a limiting variable in this approach is that the course instructors created their own exams with the course coordinator providing the specific content to be tested and reviewing the exams. Also, while the course instructors and students were provided with a lab report grading rubric (please see the online lab manual), there may have been inherent differences in lab report grading. The grade outcome for Fall 2019 was controlled, since only one instructor taught all sections of the course.

Lastly, due to the anonymous nature of the student surveys, results could not identify if the same students completed both the pre- and post-course surveys. Also, grades of disadvantaged student demographics could not be compared because of the anonymous nature of the study. However, due to the large proportion of disadvantaged students at SUNY-OW, this implies that the OER lab manual's reduction in DFW rates most likely impacted students in these demographics.

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