Online Pre-laboratory Modules Enhance Introductory Biology Students’ Preparedness and Performance in the Laboratory

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Introductory biology students are typically overwhelmed in the laboratory. Many of the students are unsure of how to prepare for each session. Two online pre-laboratory modules were developed to introduce the students to the concepts required for laboratory. The students studied the information in the modules and took an online quiz prior to each lab session. Of the 49 students who reviewed the first module and took the online quiz, the average quiz grade was 83.7% ± 12.8. A control group that did not review the online module had an average quiz grade of 53.6% ± 17.5. Of the 20 students who reviewed the second module and took the online quiz, the average quiz grade was 76% ± 15.0. The average quiz grade of the control group was 47.2% ± 16.5. The students were required to prepare laboratory reports for each session. Students who were required to review the modules received slightly higher grades on their laboratory reports compared to the control group. The students and faculty took a survey to determine their perceived impact of the modules on laboratory preparedness and performance. Both the faculty and students agreed that students are typically underprepared for lab (100% and 62%, respectively). Eighty-five percent of the students and all faculty felt that the modules did help them with preparation for the lab. Eighty-eight percent of the students and 76% of the faculty reported that the modules helped them to prepare their laboratory reports. These data clearly indicate that the pre-laboratory modules do enhance student preparedness and performance in the laboratory.

INTRODUCTION

At many colleges and universities, first-year undergraduate biology majors typically take introductory lecture/laboratory courses in which the laboratory component of the courses consists of several well-established “cook-book” experiments with known outcomes. These types of experiments are commonly used in the introductory laboratories because many of the first-year students have an underdeveloped basic biology knowledge base. In addition, the typical first-year student is experiencing a time of transition from an extremely structured learning environment that is common in the high school setting to an environment which requires them to take more personal responsibility for their own learning (1). Many of the students are overwhelmed by the transition and, as a result, are unsure of how to prepare for laboratory sessions. They often enter the laboratory with very little knowledge of the background information and/or experiments scheduled. Unfortunately, unless the students are thoroughly prepared for laboratory, they will be unable to perform the experiments and process the information they are required to learn from them (5). Effective pre-laboratory preparation enables the students to become more engaged, reduces student anxiety, and increases student confidence. Therefore, it is essential to ensure that first-year students learn how to effectively prepare for laboratory so that they can gain the productive experiences listed above (6).

Compounded with the lack of pre-laboratory preparation, many first-year students become quickly frustrated with the amount of information they are required to grasp during each laboratory session. During each session, students must demonstrate competence in following written and oral instruction, technical laboratory skills, observational skills, recording of results, and integrating the experiments with the topics discussed in the lecture component of the course. As a result of this frustration, some students become unable to follow the recipe-like instructions in the laboratory manual for the experiment. It is, therefore, not realistic to expect that overwhelmed and unprepared learners to be able to ascertain the underlying meaning behind each experiment they perform.

A vast majority of undergraduate educators support reform in science education that originates from “scientific teaching” – a teaching method that actively engages students in the process of science and demonstrates to them the rigor of the scientific disciplines (4). Due to its experiential nature, the typical undergraduate biology laboratory has always promoted an atmosphere of active learning which supports “scientific teaching”. Active-learning strategies in the laboratory may include such activities as small group work/problem solving, Web-based assignments, and analysis of data. Many active-learning techniques enable students to assimilate newly acquired knowledge in a small social setting (2, 3, 9). In using such techniques, students begin to develop...
higher order cognitive abilities that promote the conceptual reasoning skills required for progression through the undergraduate curriculum (1, 7, 10). In the scientific disciplines, active-learning techniques have aided in the enhancement of scientific literacy, retention, creativity, communication skills, self-evaluation skills, and preparedness for scientific research studies (1, 4, 8). Students who are unprepared for laboratory and frustrated during the laboratory session typically do not gain the benefits from the active-learning environment provided to them in the laboratory.

Consistent with the findings described above, over the past several years, Pace University-NYC introductory biology faculty have observed that their students are typically underprepared for the laboratory component of the course. In an effort to address the lack of BIO 101 student preparation for laboratory and the poor performance in the laboratory, two on-line pre-laboratory modules were designed using Microsoft PowerPoint® 2007 and multimedia supplied by both Benjamin Cummings Publishing and the Biology Project (University of Arizona, www.biology.arizona.edu). The two pre-laboratory modules that were developed introduced students to the key concepts and methods required to prepare for the BIO 101 “Determining the Properties of Enzymes” and the “Mendelian Genetics Using Corn and Carnations” laboratory sessions. These two laboratories were chosen for pre-laboratory module development and implementation because the students are required to prepare full laboratory reports in order to present, interpret, and discuss their findings following the laboratory sessions. As a result, evaluation of laboratory report grades could be used as an indicator of performance and understanding during the laboratory. After development, the pre-laboratory modules were uploaded onto the BIO 101 Blackboard® website and were made available for the students to review one week prior to the appropriate laboratory session. After the students reviewed the pre-laboratory module, they were required to take a quiz to determine their levels of preparedness. Upon completion of the quiz, the students were permitted to participate in the laboratory.

The goal of this study was to determine if the pre-laboratory modules enhance student preparedness and performance in the BIO 101 laboratory. To these ends, the grades that the students who reviewed the pre-laboratory modules received on the pre-laboratory quizzes and laboratory reports were evaluated and compared to the grades obtained on quizzes and laboratory reports of students that did not review the pre-laboratory modules. In both cases, the grades on the quizzes and laboratory reports were higher among the students that were required to review the pre-laboratory modules. Student and faculty survey results demonstrated that both groups felt that the pre-laboratory modules were beneficial to the students in the laboratory. The results from this study did indeed demonstrate that the pre-laboratory modules enhanced BIO 101 student preparedness and performance in the laboratory.

MATERIAL & METHODS

Pace University-NYC Introductory Biology

The introductory biology course for science majors at Pace University-NYC (BIO 101) is a large lecture-format course. It is the first course in a two semester sequence that introduces students to the basic principles guiding life. Topics covered in this course include basic chemistry, biological chemistry, enzymes and metabolism, cellular organization, Mendelian genetics, the chromosomal basis of inheritance, and an introduction to molecular biology. The course is composed of three different components: a traditional lecture with a typical enrollment of approximately 100 students (3 hours per week), a laboratory component (multiple sections linked to the lecture section with a maximum enrollment of 20 students; 3 hours per week), and a peer-led team learning discussion group component (multiple sections linked to the lecture section with a maximum enrollment of 10 students; 1 hour per week). The students are required to take all three components of the course simultaneously and grades from each component are considered when determining the final course grade for each student. Experiments performed in the laboratory and problem sets covered during the discussion group are directly related to the materials covered in the lecture component of the course.

Development and implementation of the pre-laboratory modules

Two 20- to 30-minute pre-laboratory module presentations were developed for this study. Both modules introduced students to the key concepts and methods required to prepare for the BIO 101 “Determining the Properties of Enzymes” and the “Mendelian Genetics Using Corn and Carnations” laboratory sessions. The modules were designed using Microsoft PowerPoint® 2007 and multimedia supplied by both Benjamin Cummings Publishing through the textbook for the Biology 101 course (Campbell and Reece, Biology 7th ed.) and the Biology Project Website (University of Arizona, www.biology.arizona.edu). Once completed, the pre-laboratory modules were uploaded onto the BIO 101 Blackboard® webpage and were made available for the students to review one week prior to their laboratory session.

Pre-laboratory module 1: “Determining the Properties of Enzymes”

For the experiment in the laboratory, the students are asked to prepare a crude extract from a turnip. The crude extract includes the enzyme peroxidase. The students are then required to determine the activity of the enzyme in the extract under different conditions (concentration, pH, temperature, and addition of an inhibitor) using a dye-coupled reaction and a visible light spectrophotometer. The pre-laboratory module for this experiment contains 17 PowerPoint
slides and focuses on two topics required to understand the laboratory. The first is a basic summary of enzyme functioning and the factors that affect enzymatic activity. Along with the summary, the students are asked to review an animation to demonstrate how enzymes work. The animation is from the materials supplied by the BIO 101 textbook publisher, Benjamin Cummings Publishing (Campbell and Reece, Biology 7th ed). The second part of the pre-laboratory module presentation focuses on the dye-coupled reactions, the spectrophotometer, the theory guiding spectrophotometry (the Beer-Lambert Law), and how to use the machine and to interpret data from the machine.

Pre-laboratory module 2: “Mendelian Genetics Using Corn and Carnations”

This experiment teaches students about the principles of complete and incomplete dominance. The students are required to count corn kernel color (complete dominance) and carnation petal color (incomplete dominance). Once the students determine the numbers of corn kernels and carnations of different colors, they are asked to perform Chi squared analysis to determine if the numerical data they obtained were within an acceptable range compared to expected results (as determined by Punnett squares). The pre-laboratory module for this experiment contains 20 slides and focuses on two topics required to understand this laboratory. The first is a summary of the principles guiding complete and incomplete dominance. In addition to reviewing the content in the module, the students are directed to answer questions related to complete and incomplete dominance on the Biology Project Website (http://www.biology.arizona.edu/mendeliangenetics). The second part of this pre-laboratory module focuses on using Chi squared analysis to interpret genetic data.

Online pre-laboratory quizzes

The two modules that were developed were linked to online pre-laboratory quizzes. The instructions in the pre-laboratory modules advised the students to make sure that they thoroughly reviewed and knew the materials in the modules prior to beginning the quizzes. Each quiz was administered through the Blackboard® platform and contained ten multiple choice questions related to the materials in the pre-laboratory modules. Several parameters were put into place to ensure that the students taking the quizzes were unable to go back and review the pre-laboratory module during the quiz for assistance with answering the questions. These parameters included: 1) Once a student began a quiz, they were required to complete the entire quiz; 2) The students were unable to go back once they completed a question; 3) Each question had a one-minute time limit; 4) Although the types of questions and the order of the questions remained the same for each student that took the quiz, the order of the answers for each question was scrambled for each student.

Assessment of the impact of the pre-laboratory modules on student preparedness for laboratory using pre-laboratory quizzes

During the Fall 2008 semester, there were seven laboratory sections associated with the BIO 101 course. The students enrolled in the seven laboratory sections were all in the lecture section that was taught by the author. There were six faculty teaching the seven laboratory sections; one faculty member taught two laboratory sections.

The seven laboratory sections were broken into two teams. One team consisted of three of the sections (Team 1) and the other team consisted of the other four laboratory sections (Team 2). The faculty member that taught two sections had one section on Team 1 and the other section on Team 2. On the first day of the lecture component of the course, the author informed the students that they should thoroughly prepare for each laboratory session. The author also informed the students that the laboratory instructors would, from time to time, give them pop quizzes at the beginning of some of the laboratory sessions to assess their preparedness. This information was also reiterated in the course syllabus. The students were not informed about the pre-laboratory modules on the first day of lecture.

One week prior to the “Enzyme” laboratory, the laboratory instructors working with the Team 1 laboratory sections told their students (n = 49) to review the online pre-laboratory module. They were then instructed to take the online pre-laboratory module quiz on Blackboard®. To gain access to the pre-laboratory module and quiz, the instructor gave them a unique password. The students were informed that they had to take the quiz in order to participate in the “Enzyme” laboratory session and that their grade on the quiz would be worth 10% of their laboratory midterm exam grade.

The Team 2 laboratory section students (n = 46) were not told about or given access to the “Enzyme” pre-laboratory module or quiz. These students were not given any additional instructions about preparing for the “Enzyme” laboratory session excluding the instructions that were given to them on the first day of lecture. Upon entering the laboratory for the “Enzyme” experiment, the students were given a pop quiz. The quiz was an identical paper version of the online quiz that the Team 1 students took. The students were informed that their grade on the quiz would be worth 10% of their laboratory midterm exam grade.

The identical procedure was followed for the “Mendelian Genetics” laboratory session, except that the two teams were switched. The Team 1 students (n = 47) were not told about or given access to the “Mendelian Genetics” pre-laboratory module or quiz. They received the identical hard copy versions of the online quiz as a pop quiz at the beginning of the “Mendelian Genetics” laboratory session. The Team 2 students (n = 20) were told about and granted access to the “Mendelian Genetics” pre-laboratory quiz and module. They were informed that they had to complete the quiz prior to entering the laboratory. The grades on the quizzes were...
worth 10% of each student’s laboratory final exam grade.

Assessment of the impact of the pre-laboratory modules on student performance in the laboratory using laboratory reports

Each student was required to write up a formal written laboratory report for both the “Enzyme” and “Mendelian Genetics” laboratories. The students and faculty were given a rubric to assist with report preparation and grading. In addition, one of the discussion group sessions that runs prior to the “Enzyme” laboratory focuses on laboratory report preparation. The reports must include the following sections: Title, Abstract, Introduction, Materials and Methods, Results, Discussion, and Citations. For the Results section of the report, the students were required to present all of their data in table or graphical formats using Microsoft Excel®. The students were instructed to prepare the reports using primary scientific publications as models.

For this study, the grades on the “Enzyme” and “Mendelian Genetics” laboratory reports were compared between the two different Teams for each laboratory session. This information was utilized as an indicator of performance and understanding during the laboratory session.

Assessment of the perceived impact of the pre-laboratory modules on student preparedness and performance in the laboratory: Student surveys

In order to assess the perceived impact of the pre-laboratory modules on the students’ preparedness and performance in the laboratory, the students were asked to fill out an online questionnaire with Likert-type and yes/no questions. This questionnaire was a modified version of the Student Assessment of Learning Gains (SALG) survey designed by Dr. Victor Strozak of the Peer Led Team Learning Biology Task Force (information found at http://www.pltl.org). Likert-type questions require that students respond to a statement by choosing whether they strongly agreed, agreed, disagreed, strongly disagreed, or were neutral with respect to the statement. The types of questions on the survey included questions to evaluate the methods that the students used to prepare for the laboratory sessions that did not require review of the pre-laboratory modules, the students’ perceived level of preparedness for laboratory when they did not review the pre-laboratory modules, the students’ perceived level of preparedness for laboratory when they did review the pre-laboratory modules, and the students’ perceived notion of the impact of the pre-laboratory module on performance in the laboratory.

Assessment of the perceived impact of the pre-laboratory modules on student preparedness and performance in the laboratory: Faculty survey

In order to assess the faculty’s perceived impact of the pre-laboratory modules on their students’ preparedness and performance in the laboratory, the faculty were asked to fill out a questionnaire with Likert-type questions. This questionnaire was a modified version of the student survey. The types of questions on the survey included questions to evaluate the faculty members’ perception of their students’ level of preparedness for laboratory when students did not review the pre-laboratory modules, the faculty members’ perception of their students’ level of preparedness for laboratory when students did review the pre-laboratory modules, and the faculty members’ perception of their students’ performance in the laboratory and laboratory report preparation when they reviewed the pre-laboratory module compared to when they did not review the module.

All six teaching faculty members filled out the survey. In this manuscript, the responses to five of the 12 questions asked on the survey are presented. The five questions described in this manuscript were discussed because they directly assess the faculty members’ opinions of the impact of the pre-laboratory modules on their students’ preparedness and performance in the laboratory.

Blackboard®

Blackboard® (http://www.blackboard.com/) is an educational platform that faculty can use to manage their courses online. It enables faculty to create a webpage for each course they teach. The webpage allows faculty to post files, administer exams, quizzes and surveys. It also enables faculty to post student grades using its grade book function and hold online course discussions. It was a powerful tool for this study because the pre-laboratory modules were posted to Blackboard® so that student usage of the modules could be easily tracked. The pre-laboratory quizzes were administered and graded using the Blackboard® platform. Finally, the student and faculty surveys were administered and the results tabulated by the Blackboard® survey manager.

Statistical analyses

One analysis involved comparison of the results related to the method of presentation of the quizzes. The grades that the students received on the on-line pre-laboratory quizzes were compared to the grades obtained with the hard copy versions of the same quizzes for both pre-laboratory modules.
using the Mann-Whitney U-test. This nonparametric test was used because the variances of the quiz grade data were not equal for both groups. The p-values from the Mann-Whitney U-test for both the “Enzyme” and “Mendelian Genetics” pre-laboratory quizzes are noted in Table 1. A p-value ≤ 0.05 was considered to be statistically significant.

Another analysis assessed laboratory report results for students that reviewed and did not review the pre-laboratory modules. An unpaired t-test was used to compare the laboratory report grades between the students that reviewed the pre-laboratory modules and the students that did not review the modules for both the “Enzyme” and “Mendelian Genetics” laboratories (Table 2). Again, a p-value ≤ 0.05 was considered as statistically significant.

For the SALG survey, the student responses (strongly agree, agree, disagree, strongly disagree, or neutral) to five representative questions were reported as the averages of the responses for each question (Table 3). For the faculty SALG survey, the faculty responses to five representative questions were also reported as the averages of the responses for each question (Table 4).

Pace University Institutional Review Board approval for these studies was granted in August 2008.

## RESULTS

### Evaluation of pre-laboratory quiz grades to assess the impact of the pre-laboratory modules on student preparedness for laboratory

One week prior to the “Enzyme” laboratory, the laboratory instructors working with the Team 1 laboratory sections told their students (n = 49) to review the on-line pre-laboratory module and take the on-line pre-laboratory module quiz. The Team 2 laboratory section students (n = 46) were not told about or given access to the “Enzyme” pre-laboratory module or quiz. The Team 2 students were not given any additional instructions about preparing for the “Enzyme” laboratory session. Upon entering the laboratory for the “Enzyme” experiment, the Team 2 students were given a pop quiz. The quiz was an identical paper version of the on-line quiz that the Team 1 students took. The identical procedure was followed for the “Mendelian Genetics” laboratory session, except that the two Teams were switched. The Team 1 students (n = 47) were not told about or given access to the “Mendelian Genetics” pre-laboratory module or quiz. They received the identical hard copy version of the

| TABLE 1. | Comparison of quiz grades between the students who reviewed the pre-laboratory modules and students who did not

<table>
<thead>
<tr>
<th></th>
<th>“Enzyme” Laboratory</th>
<th>“Mendelian Genetics” Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiz grades for students that reviewed the pre-laboratory module and took the online quiz</td>
<td>83.7%±12.8 (n=49)</td>
<td>76.0%±15.0 (n=20)</td>
</tr>
<tr>
<td>Quiz grades for students that prepared for laboratory on their own and took a pop quiz in the laboratory</td>
<td>53.6%±17.5 (n=46)</td>
<td>47.2%±16.5 (n=47)</td>
</tr>
<tr>
<td>p-value&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;.0001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;.0001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Mann-Whitney U test comparing quiz grades.  
<sup>b</sup> A p value ≤ 0.05 was considered significant.

| TABLE 2. | Comparison of laboratory report grades between students who reviewed the pre-laboratory modules and students who did not

<table>
<thead>
<tr>
<th></th>
<th>“Enzyme” Laboratory</th>
<th>“Mendelian Genetics” Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory report grades for students that reviewed the pre-laboratory module</td>
<td>89.8%±7.73 (n=42)</td>
<td>90.5%±11.5 (n=20)</td>
</tr>
<tr>
<td>Laboratory report grades for students that prepared for laboratory on their own</td>
<td>86.8%±12.6 (n=44)</td>
<td>83.6%±16.0 (n=39)</td>
</tr>
<tr>
<td>p-value&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;.399&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;.139&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Unpaired t-test comparing laboratory report grades.  
<sup>b</sup> A p value ≤ 0.05 was considered significant.
TABLE 3.
Student responses to five questions on the Student Assessment of Learning Gains (SALG) Likert survey (n = 72)

<table>
<thead>
<tr>
<th>Question</th>
<th>% Strongly Agree</th>
<th>% Agree</th>
<th>% Neutral</th>
<th>% Disagree</th>
<th>% Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding the week that you were assigned to review the pre-laboratory module and take the pre-laboratory quiz, you thoroughly prepared for each laboratory session (by reading the laboratory exercise that you were scheduled to perform in the laboratory prior to entering the room).</td>
<td>1.2</td>
<td>5.9</td>
<td>31.2</td>
<td>52.9</td>
<td>8.82</td>
</tr>
<tr>
<td>The pre-laboratory module helped you to be prepared for the laboratory.</td>
<td>55.9</td>
<td>29.4</td>
<td>13.2</td>
<td>1.47</td>
<td>0</td>
</tr>
<tr>
<td>The pre-laboratory module helped me to understand why each step of the experiment was performed in the laboratory.</td>
<td>35.3</td>
<td>45.6</td>
<td>17.6</td>
<td>1.06</td>
<td>0.41</td>
</tr>
<tr>
<td>The pre-laboratory module helped me with respect to preparing for my laboratory report.</td>
<td>54.4</td>
<td>33.8</td>
<td>7.82</td>
<td>2.08</td>
<td>1.86</td>
</tr>
<tr>
<td>Do you think that the pre-laboratory module in which you were assigned was more helpful in preparing you for the laboratory than if you were to read the lab manual to prepare for the laboratory?</td>
<td>YES</td>
<td>NO</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

TABLE 4.
Faculty responses to five questions on the Student Assessment of Learning Gains (SALG) Likert survey (n = 6)

<table>
<thead>
<tr>
<th>Question</th>
<th>% Strongly Agree</th>
<th>% Agree</th>
<th>% Neutral</th>
<th>% Disagree</th>
<th>% Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding the week that your students were assigned to review the pre-laboratory module and take the pre-laboratory quiz, your students were thoroughly prepared for each laboratory session.</td>
<td>0</td>
<td>0</td>
<td>66.6</td>
<td>33.3</td>
<td>0</td>
</tr>
<tr>
<td>The pre-laboratory modules helped your students understand why each step of the experiment was performed in the laboratory.</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>The pre-laboratory modules helped my students with respect to preparing their laboratory reports.</td>
<td>0</td>
<td>50</td>
<td>16.6</td>
<td>33.3</td>
<td>0</td>
</tr>
<tr>
<td>Were your students more prepared for laboratory after they reviewed the pre-laboratory module?</td>
<td>YES</td>
<td>NO</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Do you think that the pre-laboratory modules were more helpful in preparing your students for the laboratory than if they were to read the lab manual to prepare for the same laboratory?</td>
<td>YES</td>
<td>NO</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
on-line quiz as a pop quiz at the beginning of the “Mendelian Genetics” laboratory session. The Team 2 students \( (n = 20) \) were told about and granted access to the “Mendelian Genetics” pre-laboratory quiz and module.

The grades that the students obtained on the two quizzes appear in Table 1. For both the “Enzyme” and “Mendelian Genetics” laboratories, the students that were required to review the pre-laboratory modules performed better on the quizzes than the students that did not review the pre-laboratory modules. The students that reviewed the pre-laboratory modules received grades of 83.7% ± 12.8 \( (n = 49) \) and 76.0% ± 15.0 \( (n = 20) \) for the “Enzyme” and “Mendelian Genetics” quizzes, respectively. The students that did not review the pre-laboratory modules and took the paper pop quiz in the laboratory received 53.6% ± 17.5 \( (n = 46) \) and 47.2% ± 16.5 \( (n = 47) \) on the “Enzyme” and “Mendelian Genetics” quizzes, respectively. The differences between the quiz grades received by the students that reviewed the pre-laboratory modules versus the students that did not review the modules were considered statistically significant. These data suggest that the pre-laboratory modules do indeed enable the students to better prepare for laboratory sessions.

**Evaluation of laboratory report grades to assess the impact of the pre-laboratory modules on student performance in the laboratory**

The “Enzyme” and “Mendelian Genetics” laboratories were chosen for this study because the students are required to prepare full laboratory reports in order to present, interpret, and discuss their findings from the laboratory sessions. As a result, evaluation of laboratory report grades between the two different teams could be used as an indicator of performance and understanding during the laboratory.

The students that reviewed the pre-laboratory module for the “Enzyme” laboratory received an average grade of 89.8% ± 7.73 \( (n = 42) \) on their laboratory reports, whereas the students that did not review the module received an average grade of 86.8% ± 12.6 \( (n = 44) \) on their reports (Table 2). The students that reviewed the pre-laboratory module for the “Mendelian Genetics” laboratory received an average grade of 90.5% ± 11.5 \( (n = 20) \) on their laboratory reports, whereas the students that did not review the module received an average grade of 83.6% ± 16.0 \( (n = 39) \) on their reports (Table 2). Although neither set of data can be considered statistically significant, the students that reviewed the pre-laboratory modules did receive slightly higher grades on their laboratory reports. This suggests that the pre-laboratory modules did indeed have an impact on student understanding and performance in the laboratory.

**Evaluation of the BIO 101 students’ impressions of the impact of the pre-laboratory module on their preparedness and performance in the laboratory**

At the end of the Fall 2008 semester, the BIO 101 students were asked to complete a Likert survey to describe their perceptions of the impact of the pre-laboratory modules on their preparedness and performance in the laboratory. The results to the five most pertinent questions on this survey are depicted in Table 3. Of the 72 students who took the survey, 71.1% of them strongly agreed or agreed that they reviewed the laboratory manual each week (excluding the week that they were assigned to review the pre-laboratory module) and that they were frequently thoroughly prepared for laboratory. Just over 85% (85.3%) of the students strongly agreed or agreed that the pre-laboratory modules helped them prepare for laboratory. In addition, 80.9% of the students that took the survey strongly agreed or agreed that the pre-laboratory modules helped them to understand why each step of the experiment was performed in the laboratory. A vast majority of the students (88.2%) felt that the pre-laboratory modules enabled them to prepare their laboratory reports with greater ease. Finally, 82.4% of the students felt that the pre-laboratory modules were more helpful in preparing them for laboratory than if they were to simply read the laboratory manual prior to the laboratory session. The student responses to the survey questions indicate that, overall, the students found the pre-laboratory modules beneficial and that the modules helped them to better prepare for and perform in laboratory sessions.

**Evaluation of BIO 101 faculty impressions of the impact of the pre-laboratory module on their students’ preparedness and performance in the laboratory**

The BIO 101 faculty were asked to complete a Likert survey similar to the student survey. The faculty survey sought to determine the faculty’s perceptions of the impact of the modules on their students’ preparedness and performance in the laboratory. The results to the five most pertinent questions on this survey are depicted in Table 4. Of the six faculty members that took the survey, none of them felt that their students reviewed the laboratory manual each week. They all agreed that their students were frequently unprepared for laboratory. Fifty percent of the faculty agreed that the pre-laboratory modules helped their students understand why each step of the experiment was performed in the laboratory. The other half were neutral with respect to whether or not the pre-laboratory modules helped their students understand why each step of the experiment was performed. Fifty percent of the faculty felt that the pre-laboratory modules enabled their students to prepare their laboratory reports with greater ease. In contrast, 16.6% and 33.3% of the faculty were neutral or disagreed, respectively, that the modules helped the students prepare their laboratory reports. The faculty unanimously agreed that their students were more prepared for laboratory after they reviewed the pre-laboratory modules. Finally, 100% of the faculty felt that the pre-laboratory modules were more helpful in preparing their students for laboratory than if the
students were to simply read the laboratory manual prior to the laboratory session. The faculty responses to the survey questions indicate that, overall, they felt the pre-laboratory modules enhanced their students’ preparedness for and performance in the laboratory.

DISCUSSION

The goal of this study was to determine if pre-laboratory modules enhanced student preparedness and performance in the BIO 101 laboratory. To these ends, the pre-laboratory quiz grades and laboratory report grades that the students who reviewed the pre-laboratory modules received, were evaluated and compared to the grades received by the students who did not review the pre-laboratory modules. In both cases, the grades on the quizzes and laboratory reports were higher among the students who were required to review the pre-laboratory modules. Student and faculty survey results demonstrated that both groups felt that the pre-laboratory modules were beneficial to the students in the laboratory. The results from this study did indeed demonstrate that the pre-laboratory modules enhanced BIO 101 student preparedness and performance in the laboratory.

For the “Enzyme” pre-laboratory quiz, there was a 30 percentage point grade difference between the students who reviewed the modules and the students who did not. There was a 28.8 percentage point grade difference between the students who reviewed the modules and those who did not for the “Mendelian Genetics” quiz. For both laboratories, the students who were not required to review the pre-laboratory modules prior to the laboratory failed the paper version of the pre-laboratory quizzes. These stark grade differences clearly demonstrate that not only did the pre-laboratory modules enable the students to better prepare for the laboratory, but the differences also confirmed that the students who were not required to review the modules did not prepare for the laboratory at all. Some students did read over the laboratory manual but did not comprehend what they had read.

The differences in grades on the laboratory reports between students who reviewed the modules and students who did not were not as apparent as the differences in grades on the pre-laboratory quizzes. This may be due to the fact that the students who did so poorly on the quizzes realized their deficiencies and sought out additional means (such as extra help with the laboratory professor or discussion group peer leader) to gain assistance with laboratory report preparation. Despite these possible additional efforts, the laboratory report grades for those students who did not review the modules were slightly lower than the grade for those students who did.

The student and faculty Likert surveys clearly indicated that both the students and faculty felt positive about the impact of the pre-laboratory modules on students’ preparation and performance in the laboratory. Both surveys also included an open-ended question asking for additional input and comments. Some student comments that support the assertion that the pre-laboratory modules were beneficial include:

“I think the pre-lab module helps the student understand the lab much better and he/she can actually perform the lab and know what to do instead of being lost during the experiment.”

“The pre-lab module/quiz really helped me out with the lab and the lab report. It actually made me sit down and study what was going to happen in class. If I would have not had the pre-lab module and everything, then I would have never read the lab book to prepare for the lab. I would definitely recommend this practice for future lab classes in the following years to come.”

“I found the pre-lab module to be extremely helpful when it came to the lab report. I found that it was the most effective way to ensure that I was prepared for lab.”

The faculty also provided some comments that support the usage of the pre-laboratory modules. Some comments are as follows:

“The pre-lab module made the students focus more on the topic than usual.”

“The pre-lab module enhanced the long-term memory of the students. I definitely saw improvements. The modules facilitated the students with respect to quickly responding to the materials in the laboratory.”

“It was clear that the students were better prepared for the laboratory. They were more engaged during my lecture and appeared to be interested in performing the experiment.”

In summary, the pre-laboratory modules positively affected the learning experiences for the students enrolled in the Biology 101 laboratory. The students came to the laboratory prepared, they were more active participants during the laboratory, and their performance on the laboratory reports was enhanced. The student grades and faculty/student survey responses each support the further expansion of this program. As such, pre-laboratory modules and quizzes are currently being developed for every Biology 101 laboratory session at Pace University-NYC.

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