Evaluation of Students Scientific and Medical Literacy After Performing Laboratory Exercises in a Microbiology Laboratory for Non-Majors

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Abstract

Introduction to Microbes and Disease was designed to introduce students to the field of Microbiology, with a focus on medicine and disease. In this course, students develop a comprehensive understanding of the structure of biology of microbes and how the human immune system interacts with them to fight disease. All undergraduate students directed on a health science course path will benefit from this introductory course, but this course does not fulfill requirements for Biology majors. The newly developed course was developed in 2013 and was first offered in the fall semester of 2014.

Pre-assessment and post-assessment exams were used in the Microbes and Disease - Biology 2510 (Introduction to Microbes and Disease) for the spring 2017 semester in which the total enrollment was 140 students. In this study, the assessments were used to examine the confidence and competence in biological concepts and lab techniques in the biology lab course for non-majors. The assessments were evaluated quantitatively and qualitatively. Lab experiment reports were used to examine the collaboration and student-learning occurring in lab. Grades for individual assessments and laboratory reports were collected, and analyzed using Microsoft Excel.

Scatter plots illustrated the grade distribution of 98 pre and post assessments representing all students enrolled in BIOL 2510 for the 2017 spring semester. Differences between pre and post assessment grades and laboratory report grades are indicated by line charts These graphs also provided comparisons between the different lab sections.

This science education project addressed active learning themes, the importance of weekly lab write ups, collaborative group work and confidence and competence of biological concepts and laboratory techniques..

Introduction

The nursing program at North Carolina Central University is well respected and as a result is in high demand. Introduction to Microbes and Disease, is “a course designed to introduce students to the field of Microbiology, with a focus on medicine and disease. Students will develop a comprehensive understanding of the structure and biology of microbes and how the human immune system interacts with them to fight disease” (North Carolina Central University Course Catalog). Laboratory exercises, quizzes, and the lab report (identification of an unknown organism) are reinforcements of the concepts discussed in lecture. The laboratory provides and opportunity for examination of organisms through use of different microbiological techniques., that are geared toward expanding biological knowledge.

A deep learning approach allows students to understand the subject matter, beyond what is originally presented to them, thus engaging with the topic and interacting beyond the usual acceptance of authority (Cranston, et al. 2015). A surface learning technique differs in that students tend to take a far more narrow approach to their education (Prosser and Trigwell, 1999). Further more, surface learning can be encouraged by populated class sizes. Large class sizes have been studied for many years by various science education researchers. The impact of class size on student learning and achievement have been reported, (Walker et al, 2008; Leight et al. 2012) to possibly cause some students academic challenges related to large enrollment well before an examination is given. This behavior in some cases encourages passive student behavior in acquiring knowledge, poor attendance, and minimal effort to develop the needed study skills.

Techniques to encourage deep, interactive student learning are best employed in a laboratory setting (Cranston et al; 2015). The laboratory experience can be viewed as a space to alleviate student passiveness and encourage participatory learning. Labs provide an environment that promotes student collaboration ensuring that their learning experience is maximized. More importantly, research shows that active participation is an important factor in the achievement of deep learning, whilst a passive reception of knowledge takes a more basic education route (Stranger-Hall, 2012).

Active learning practices in the laboratory that include inter-personal activities can help the students regain their level of attention and connection with lecture material (Lujan et al., 2012). When applying active learning strategies, in the lab, students are given more learning responsibilities and as a result become more actively engaged in the educational process (Rivaz et al., 2015). These experimental practices encourage deep learning and allow the focus to be on understanding and comprehension, before evaluation and the worry of lecture tests. More importantly, an active deep learning lab approach may minimize the uncertainty and guessing probability on assessments (Walker et. Al., 2008).

In cooperative laboratory experiments, students are encouraged to work collaboratively in small groups to achieve a common goal rather than individual grades (Armstrong et al., 2007). Students work together in small groups or pairs (Ruddick, 2013), and listen and understand the viewpoints of their peers. The students in these lab groups can become intrinsically motivated to work collaboratively on an experiment, and foster deep learning (Sandahl, 2009). It is believed that students in these groups can support each other not only intellectually, but also emotionally, to accomplish a shared goal (Giuliodori et al., 2008). They can use effective methodology to elaborate on the material in a more familiar way to help improve the understanding of other students (Armstrong et al., 2007). Collaborative learning is being utilized in various disciplines such as biology, geoscience, and psychology; and is gradually becoming more common at some universities (Gilley & Clarkston, 2014). For example, Leight et al. (2012) reported findings suggesting that the students who work collaboratively pool their knowledge and understanding rather than just rely on the top student to provide all of the answers. Similar results were reported by Cortright et al. (2003), Gilly & Clarkson (2014), and Rivaz et al. (2015). Cranston et al (2015) demonstrated that deep learning in the laboratory setting prompts students to truly analyze and understand various scientific phenomenon, while supporting ongoing learning and developing necessary experimental practice. The students' constructive interactions with peers and instructors, significantly correlated with improvements in lab report grades, and the acquisition of critical thinking and problem solving skills as examined in the in-class assessments.

This experiment was not the typical blind study, as I was aware of the experimental motive and procedure. However, the students in each lab class were unaware of the assessments used or the specific organization of each lab grouping.

The rationale for this study conducted over the course of two consecutive semesters (Fall 2016, Spring 2017), is based on students being paired in groups made up of students scoring high on the pre-assessment and students scoring below the average on the pre-assessment. The goal was to identify Students Scientific and Medical Literacy After Performing Laboratory Exercises in BIOL 2510: Introduction to Microbes and Disease. We also wanted to investigate the role of collaborative lab exercises that were being used to promote a deeper understanding of the laboratory content. . Therefore, it was essential to optimize the level of scientific laboratory technique understanding of Biology non-majors in BIOL 2510. This was done by the following:

(a) examining the difference in preliminary and post assessment grades in all laboratory sections of BIOL 2510 (sections 01-04)

(b) collecting quantitative data on the effects of blind student pairing via post-assessment outcomes;

(c) comparing individual laboratory post experimentation reports for three major experiments

(d) comparing final laboratory grades for all student enrolled in BIOL 2510 (Spring 2017);

(d) assessing the impact of collaborative laboratory experiments using post-assessment grades.

Methodology

Course Description:

The study conducted here is based upon the findings of the Biology 2510: Introduction to Microbes and Disease. This course is specifically for Biology non-majors seeking admittance into nursing school. This is a one credit hour class designed for students in allied health programs. It includes preparing stained smears, culturing micro-organisms, conducting immunology experiments, performing tests to identify bacteria and studying microbial growth control methods.

Course Evaluation:

In BIOL 2510, the non-Biology majors meet for 10 weeks of consecutive lab experiments. The lab course makes up 100 points out of a 400 point course. Each lab is worth 5 points for the pre-lab write up and 5 points for the laboratory post-lab write up. Pre and post assessments were used as attendance checkers for the initial and terminating lab meetings for the semester. And, were also graded to be used as an evaluation of student learning and understanding.

Assessment Format:

The format of the Pre-assessment consist of five introductory questions, followed by twenty-five multiple choice questions which examined the students basic knowledge of biology as well as confounding microbiology objectives. The objectives that were tested are as listed in the table below:

	Objectives:
a)	Demonstrate safe practices in a microbiology laboratory
b)	Explain and correctly demonstrate use of the scientific method
c)	Demonstrate proper usage, identify the parts/functions of the following microscopes
d)	Transfer living microbes using aseptic technique
e)	Demonstrate proficiency and use of laboratory techniques (streak plate isolation technique; bacterial staining techniques; wet mounts; and proper culture handling)
f)	Visually recognize and explain the macroscopic and microscopic characteristics of bacteria
g)	Understand and explain environmental factors that influence microbes

Students completed pre-assessment test during the first week of classes, and were paired based on their scores to ensure optimal collaborative and active learning practices. Students who high performing (scoring 80% or higher) were paired with students who performed lower (80% or lower). Students were not aware that they were specifically grouped by score.

The post assessment that was administered followed the same rubric. All twenty-five multiple choice were identical to the pre-assessment questions. However, the preliminary questions regarding grade, expected occupation, etc. were not included in the post-assessment. The students were not made aware that both assessments were identical.

The purpose for giving the same assessment at the beginning of the semester and at the end was to measure a change in score in order to test the effects of blind student pairing and collaborative active learning in a laboratory setting.

Laboratory Reports:

In BIOL 2510, the laboratory report grades for all ten laboratory experiments were analyzed to determine the effects of active and collaborative learning in the lab classes throughout the semester. Students were encouraged to discuss lab tactics and objectives during class time to ensure they reported and expounded upon the correct information in their weekly lab reports. All laboratory report grades were recorded and three specific labs were plotted for comparison. These labs were selected due to their topics, (Gram stain, bacterial titration, and antibiotic sensitivity testing) including main microbiology objectives important to the biology non-majors, such as the nursing students.

The laboratory report template for BIOL 2510 is as follows:

Title: The title should be concise and specific and tell the reader what you did

Purpose: Most lab reports do not include a formal introduction and instead substitute a purpose. The purpose of the experiment should be stated in one or two sentences. You should know the purpose of the experiment before you start.

Methods: Most lab reports do not include all the details a journal article requires. Normally the procedure can be listed and referenced to the appropriate laboratory manual pages. If modifications have been made to the methods in the lab manual, these need to be clearly described.

Results: All data and observations should be included in the lab book; however, what you think should have happened or the methods section are not included. Types of results may include:

Measurements- Report measurements using standard metric units. Any time a number is presented, it must have units. Numbers should be written as numerals when they are greater than ten or when they are associated with measurements; for example, 8 mm or 20 g. In a list of objects including both numbers over and under ten, all numbers may be expressed as numerals. Example: 17 bacteria, 2 yeast, and 1 protozoan. If a number starts a sentence spell out the number, do not use a numeral. Example: ten mannitol salt agar plates were streaked…

(If necessary) Calculations: The equation should be indicated. In a lab report, even if you use a calculator, you must set up the problem.

(If necessary) Tables: Number each table and provide a title and legend that contains all the information needed to interpret the data. The reader should be able to understand the content without the text. The title should be located at the top of the table. Columns and rows should be labeled clearly.

Figures- Figures include graphs, photographs, drawings, and diagrams. All figures should be numbered and have a title and legend that contains all the information needed to interpret the data. The reader should be able to understand the content without the text. Figures should be labeled at the bottom. If the photograph is of an object under the microscope, the total magnification should be indicated.

(If possible/necessary) Plate counts. Include results for all dilutions, even if they are too numerous to count (TNTC) or 0. You should indicate the type of medium plated and temperature of incubation. See Table 1.

Discussion/Conclusion: The discussion section interprets the meaning of the results and draws conclusions from the data that have been presented. If data can be interpreted in more than one way, all possibilities should be mentioned and the authors should indicate which alternative they think is correct and why. Results should be discussed even if they are unexpected or negative. For example, the presence of unexpected bands on agarose gels should be explained. This section should also address any discrepancies in the results. The meaning of your results should be summarized in two to three sentences at the end of the section. In lab reports, experiments do not always work. This section allows the researcher to explain what might have gone wrong with an experiment.

Data Collection and Analysis:

The grades that the students received for pre and post assessments were entered in excel alongside the grades obtained from lab reports and final lab grades for spring 2017 laboratory students.

The following comparative analyses were conducted:

1. Comparison of original assessment with post assessment average grades between all four laboratory sections, illustrated by a Figure 1.
2. Comparison of laboratory report grades for three specific labs outline key objectives from the following labs: LAB 3 (gram staining), LAB 6 (Titration of bacteria), and LAB 9 (Antibiotic sensitivity testing). This data is portrayed using a Figure 2.
3. Comparison of final laboratory grades between all four sections during the spring 2017 semester is illustrated in Figure 3.

Results

This project included a total of 84 students who were enrolled in BIOL 2510: Introduction to Microbes and Disease course, in the Spring 2017 semester. Data collected from students in the 2017 spring semester laboratory sections generated a set of results on (a) the students in each section who completed the pre and post assessment, (b) laboratory report grades for three specific labs outline key objectives in the labs 3 (gram staining), 6 (Titration of bacteria), and 9 (Antibiotic sensitivity testing), (c) final laboratory grades between all four sections during the spring 2017 semester for 10 consecutive labs. The number of students included in each of the following result section was 84 in total. All of the students were enrolled in one lecture section taught by the same instructor. All laboratory sections were taught by Biology graduate teaching assistants. Laboratory section 1, taught by lab teaching assistant Chioma Azih had 20 students. Laboratory section 2, taught by lab teaching assistant Maya Barlow had 22 students. Laboratory section 3, taught by lab teaching assistant Erika Baker had 24 students, and laboratory section 4, taught by lab teaching assistant Margie Stringfield had 22 students.

Figure 1: Average pre and post assessment grades for students enrolled in BIOL 2510. Spring 2017

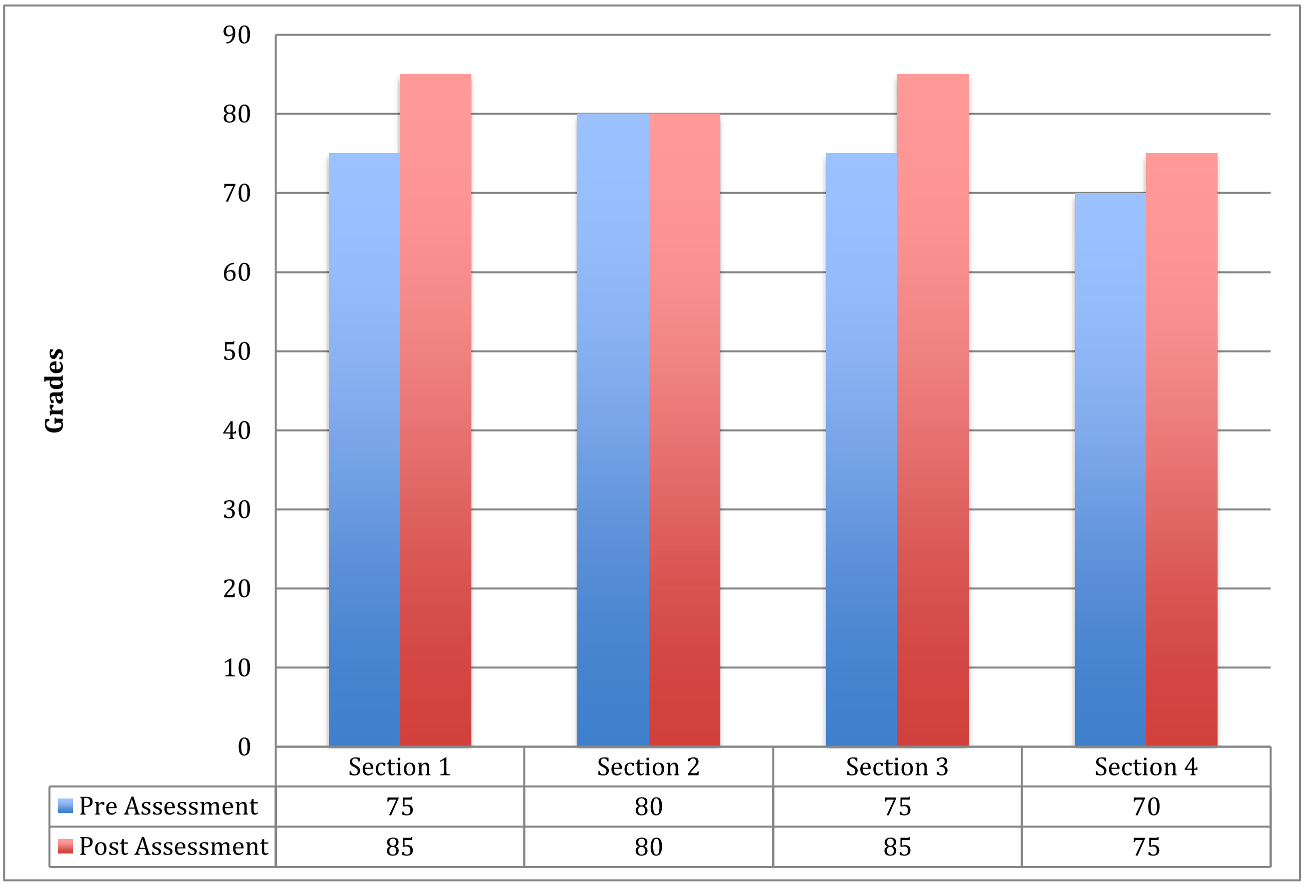

Fig 1: This figure illustrates the grades of all 84 students across the four laboratory sections. There is a clear increase in post assessment grades in 3 out of 4 sections taught by four different teaching assistants.

Figure 2: Average laboratory report grades for labs 3,6,9: Gram staining, bacteria titration, and antibiotic sensitivity testing labs, respectively.

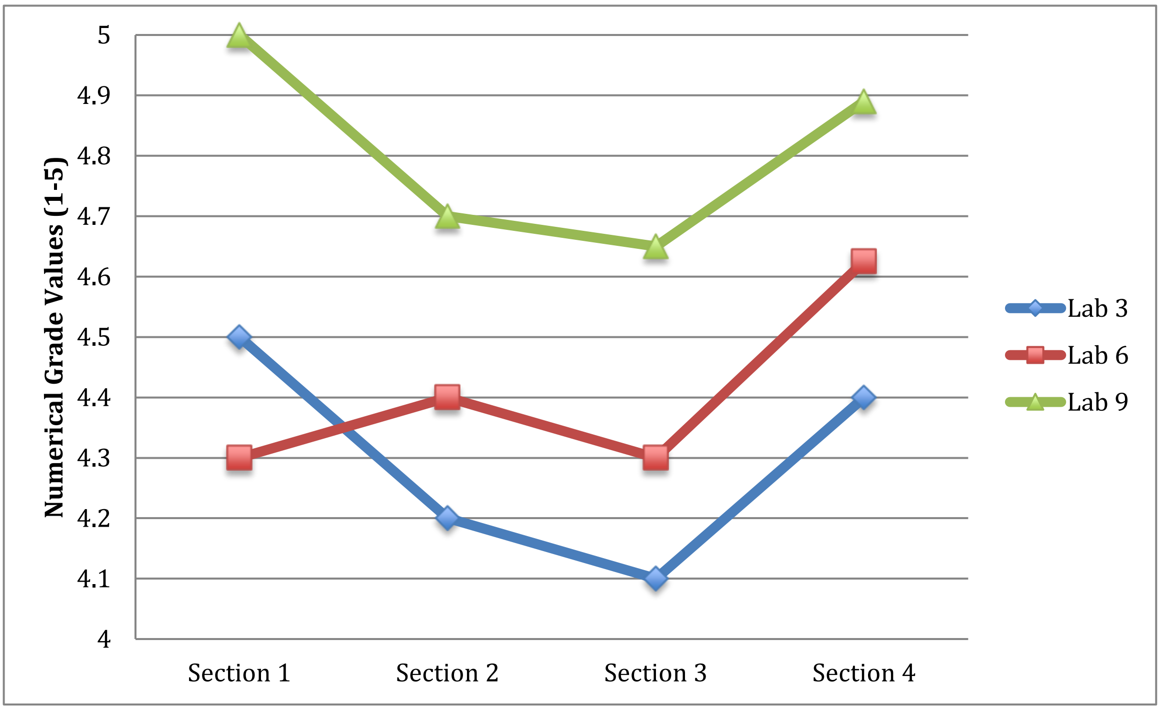

Fig 2: These labs were performed three weeks apart from one another and illustrated continued learning and knowledge building with specific concepts.

These three specific laboratory reports were chosen for evaluation due to their importance and relevance to Microbiology for BIOL 2510, according to the objectives on the course syllabus**.**

Figure 3: Average final lab grade for each section of BIOL 2510

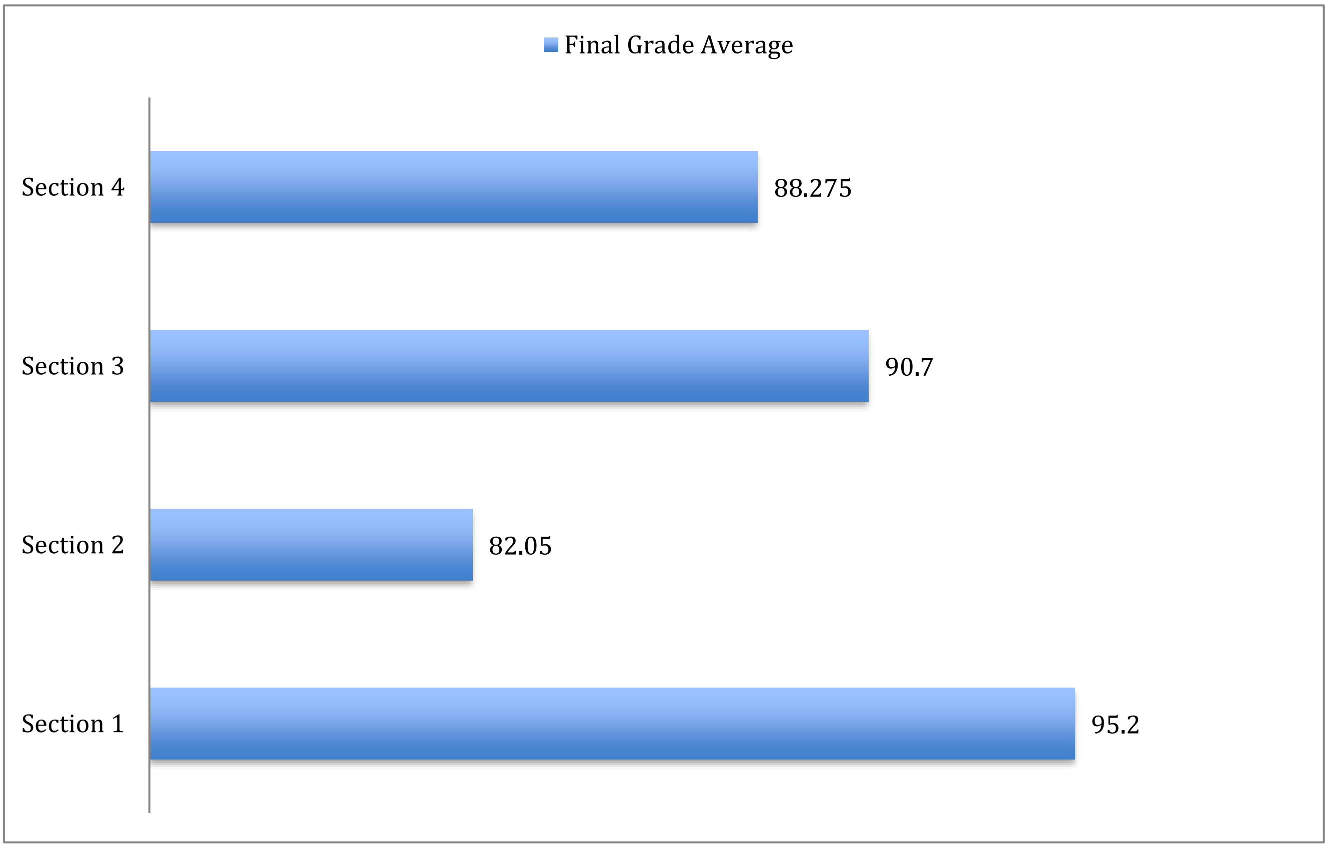

Figure 3: Each lab sections average illustrates that most lab grades were between A averages (90-100) and B averages (80-90).

For this science research project, it is understood that the only evaluations conducted and analyzed were among the spring 2017 laboratory cohort. However, as the instructor for the fall and spring lab course I would like to insert the final grade comparison for the fall 2016 and spring 2017 laboratory course. This will possibly shed light on the impact of grouping students, as this practice was not introduced until spring 2017.

Figure 4: **Comparison of average final lab grades between Erika's 2016 and 2017 laboratory classes**

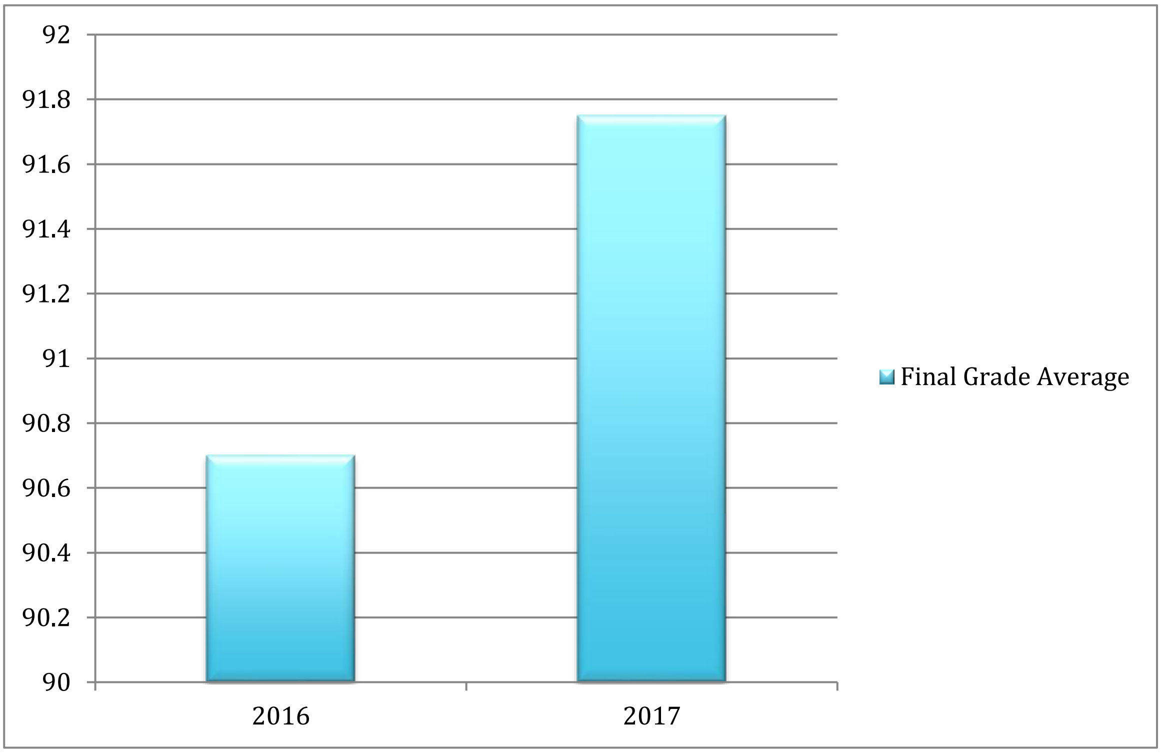

Figure 4: The spring 2017 final laboratory grades are slightly higher than fall 2016 final laboratory grades.

This is interesting due to the fact that, the same instructor, using the same laboratory experiments, taught both courses; the variables- lab team grouping and collaborative lab procedures.

Discussion

After the results of this study were compiled, examined, and analyzed, three major themes emerged from this project, (a) the enhancement of assessment and laboratory report performance as a result of collaborative learning, (b) the benefits of strategically grouping students in teams to optimize learning, (c) the students reaction to collaborative learning and lab practice in BIOL 2510.

There are several national and international pedagogical studies that have been and are currently being undertaken to address the enhancement of STEM student learning. Each section was allotted an example lab report to layout the type of report was expected, along with the template. The students made it clear that they were not familiar with hands-on labs and writing lab reports. Therefore, resources were given to them to ensure their success in the lab sections. Communicating with students was key to capitalizing on their active and collaborative learning experience.

In this study the collaborative learning techniques were illustrated through ten interactive learning laboratory experiments for all sections of BIOL 2510. All 84 students completed an individual pre-lab write up based off of the provided lab experiment protocol posted each week and then completed the in-class interactive lab with their assigned group members, followed by the post-lab report.

(a) The enhancement in student performance was observed in the post assessment exam averages as well as the lab report averages. The difference between the post and pre- assessment averages plotted in figure 1, show noticeable increases in averages for scores for three out of the four laboratory sections. When the individual assessment grades were plotted we were able to see one particular students great increase 10 points. It was also noted that there were very few students who scored lower on the post-assessment than on the pre-assessment.

(b) The students sitting through BIOL 2510 were new to the setting of an interactive experimental hands-on lab. The lab TAs worked with students on interactive experimental procedures, following proper lab protocol, and scientific deep thinking. This course offered students exploratory opportunity in the field of active learning and hands on science in the microbiology field in these three major areas:

1. Arranging specific groups to set students up for optimal active learning practices and collaborative learning students who scored less than 80% stated that they were not confident about the foundational biological concepts in which they needed to build on to be successful in this course.

2. In figure 2, we can see gradual increase in post assessment grades for three main experiments which extrapolated major objectives in the microbes and diseases course for pre-nursing majors.

3. There were a few cases in figures 1 and 2 where a drop or decrease in academic performance but the overall grades illustrated by figure 3 portrays overall scientific understanding and positive collaborative effects of interactive learning in the BIOL 2510 scientific laboratory course.

(c) The reactions of the students during lab experimentation time was sometimes truly priceless. They were really intrigued by the experiments conducted throughout the semester. Labs 3 - Gram Staining; Lab 6 – Bacteria Titration; and Lab 9 – Antibiotic Sensitivity Testing, were among some of the favorites. Often times, they would collaborate and bounce ideas off of one another. The scientific thinking and active learning skills really developed as the semester progressed.

This research experiment provided the BIOL 2510 lab with the first assessment (outside of the student rating of instruction) since the course was implemented in 2013. The findings in this experiment could improve the quality and productivity of the lab to better aid the pre-nursing students in the future. For instance, there should be active learning feedback opportunities, reflections, and feedback from the students on how to improve the course. Perhaps, the most informative tool would be a questionnaire to get the opinion of the student on what they believe works best. Lastly, this lab would be more relevant if the experiments were more geared toward the nursing specialty as it pertains to laboratory procedures.

Conclusion

In conclusion, the science education research aspect was intellectually sound and informative despite certain challenges. The intrinsic variability in the data sets was fully recognized in this research activity in that (a) the average of the laboratory grade indicated the probable benefits of active learning and collaborative classroom but suffered from the fact that there weren't previous grades to collaborative lab grades available for comparison, (b) the TA-to-TA variability within each lab report grade may have made it harder to examine the impact of active learning in the lab but the technique for each TA is constant within their specific lab. These differences were taken into account when analyzing data. It was evident that this active learning exercise of implementing blind collaborative groups in the BIOL2510 benefited the students in more ways that just enhancing their grade. However, this lab style benefit in a single course may be much more fully realized and intensified when subsequent courses in the 4-year course also utilize this active learning and assessment practice.

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Appendix

1. Assessment Form

Assessment Questions:

Subjective:

1. First and last name?

2. What is your current Major ?

3. What is your desired career?

4. What subjects in biology are of most interest to you?

5. What do you hope to learn in this class?

6. How prepared do you feel for this course?

Objective:

7. Which of the following is **not** considered a microbe?

A. bacterium
B. alga
C. mushroom
D. protozoan

8. 40.When a trait is not expressed but is carried in the DNA of an individual it is said to be __________________. (1 point)

A. not expressed

B. hiding

C. dominant

D. recessive

9. 4.Suppose that a group of scientists accepts a theory as offering a convincing explanation of observable data. Ideally, how should those scientists react to new data that appear to contradict the theory? (1 point)

A. They should let the public decide whether the new data are convincing, because science should be democratic.

B. They should investigate whether the new data are accurate, because every theory is open to analysis.

C.They should ignore the new data, because the new data are most likely incorrect.

D.They should accept the new data, because data are facts and facts are more certain than theories.

10. 8.Dr. Flores tested the effectiveness of a flouride gel on reducing the number of cavities in humans. He applied the gel to 50 test subjects, each of whom had cavities in the past. After 6 months, the number of new cavities in the subjects had decreased.

Dr. Flores's study was flawed. What did it lack? (1 point)

A. a sample

B. a dependent variable

C.an independent variable

D. a control group

11. Which part of the skeletal system offers protection? (1 point)

A. femur

B. rib cage

C. pelvis

D. vertebrae

12. Which of the following is not found in animal cells? (1 point)

A. Cell Membrane

B. Ribosomes

C. Chloroplast

D. Nucleus

13. Which of the following is listed in order of highest level of organization to lowest level of organization? (1 point)

A. tissue, cell, system, organ

B. system, organ, tissue, cell

C. organ, cell, tissue, system

D cell, tissue, organ, system

14. Which of the following is not a reason for a cell to divide? (1 point)

A. Repair

B. Hunger

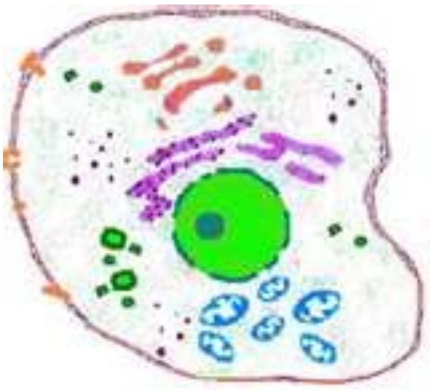
C. Reproduction

D. Growth

15. Science can be influenced by race, gender, nationality, or religion of the scientist. (T/F)

16. The use of sterile techniques and agar media enabled early microbiologists to:
a. study pure cultures
b. demonstrate the nature of infectious disease
c. study mixed cultures
d. study agar-metabolizing cultures
e. disprove spontaneous generation

17. What type of cell is this?



A. amoeba
B. animal
C. plant
D. bacterium

18. Plants get the energy they need to grow from the
A. air
B. water
C. sun
D. soil

19. A plasmid is a small, circular DNA molecule carrying genes of interest (T/F)

20. The proposed mechanism that explains the observable patterns of evolution?

A. Darwinism
B. Natural selection
C. Specific selection
D. Selective breeding

21. Central idea to Biology?
A. DNA→ RNA→ Protein
B. RNA→ DNA→ Protein
C. Protein→ RNA→ DNA

D. RNA→ Protein→ DNA

22. What skill is a scientist using when she listens to the sounds that whales make?

A. making a hypothesis
B. drawing conclusions
C. making observations
D. interpreting data

23. In an experiment, the one variable that is changed is called the?

A. controlled variable
B. independent variable
C. dependent variable
D. experimental variable

24. What are the correct order of steps in the scientific method?

A. ask a question, make a hypothesis, test the hypothesis, analyze results, draw conclusions, communicate results
B. make a hypothesis, test the hypothesis, analyze results, ask a question, draw conclusions, communicate results
C. ask a question, analyze results, make a hypothesis, test the hypothesis, draw conclusions, communicate results
D. ask a question, make a hypothesis, test the hypothesis, draw conclusions, analyze results, communicate results

25. All of the following are examples of involuntary reflexes except?

A. breathing
B. raising your hand
C. blinking
D. heartbeat

26. During cellular respiration, the majority of energy that is released occurs in the cell's?

A. mitochondria
B. nucleus
C. ribosomes
D. cytoplasm

27. When water passes through the cell membrane because of diffusion, its called?

A. cellular respiration
B. photosynthesis
C. osmosis
D. water treatment

28. When a cell takes in a particle by surrounding it, this is called?

A. engulfing
B. eating
C. passive transport
D. entrapment

29. Where does glycolysis take place?

A. cytoplasm
B. mitochondrial matrix
C. chloroplasts
D. mitochondria

30. If you wanted to determine the phenotype of an organism, what procedure would you follow?

A. Observe physical characteristics
B. DNA sequence the parents
C. DNA fingerprint the organism
D. Do a dihybrid cross

2. Lab Syllabus (attached below)

Laboratory Schedule:

Week 1: Pre-assessment & Syllabus Overview

Week 2: Microscopy, Observation of Stained Specimens, Aseptic Technique & Culture Transfer

Week 3: Aseptic Technique and Gram Staining of Bacteria, Streak Plating, Technique, Phase Contrast

Microscopy

Week 4: Pure Culture Isolation/Streak Plating, Bacterial Conjugation

Week 5: Bacterial Conjugation

Week 6: Titration of Bacteriophage

Week 7: Selective and Differential Media, Nasal Flora

Week 8: Spring Break

Week 9: Disinfectants and Antiseptics, Antibiotic Sensitivity Testing

Week 10: ABO Blood Typing

Week 11: Effects of Hand washing/ Post Assessment

General Lab Objectives:

- Demonstrate safe practices in a microbiology laboratory.
- Explain and correctly demonstrate use of the scientific method
- Demonstrate proper usage, identify the parts/functions of the following microscopes.
- Transfer living microbes using aseptic technique.
- Demonstrate proficiency and use of the following in the laboratory: streak plate isolation technique; bacterial staining techniques; wet mounts; and proper culture handling.
- Visually recognize and explain the macroscopic and microscopic characteristics of bacteria.
- Understand and explain environmental factors that influence microbes.

3. University Undergraduate Catalog 2013-2015 (Archived Catalog)
http://ecatalog.nccu.edu/preview_course_nopop.php?catoid=3&coid=4162