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WRITING-INTENSIVE INTERVENTION TEACHING STRATEGY IN UNDERGRADUATE GENERAL BIOLOGY COURSE

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ABSTRACT

Competent writing skills are essential for academic advancement in higher education. In this article we present the findings of a study that evaluated the effects of integrating writing-intensive interventional teaching strategy on the performance of community college students in a general biology course. Students' exam grades data was collected from four laboratory and four lecture exams administered per semester for each study group. Analysis of the grades using descriptive statistics, student t-test, and analysis of variance (ANOVA) showed that incorporating writing-intensive intervention teaching strategies, such as formal laboratory reports and critique of published biological science journal articles, significantly improved student performance in laboratory and lecture exams at $p \leq 0.05$. The pooled data of students' exam grades demonstrated that 11.6% of the students earned higher grades in the writing-intensive teaching intervention group, based on the overall general biology course grade, compared to the non-writing intensive class. The writing-intensive, intervention teaching strategies reported in this paper shows promise for application in diverse academic settings in two-year colleges, by identifying teaching practices that support community college students' academic success.

Keywords: Writing-Intensive, Teaching Strategies, General Biology, Community College.

INTRODUCTION

A significant percentage of the students that enroll at community colleges are academically unprepared and as a result face several academic advancement challenges. According to the estimates of the National Center for Public Policy and Higher Education, reported by the Southern Regional Education Board in 2010, and then reported by the National Center for Education Statistics (2013), about 40% of first-year undergraduates, including community college freshman, are unprepared for college-level coursework in mathematics and reading. Consequently, many community college first year students are required to take non-credit, developmental/remedial courses in English and Mathematics. Overall, this prolongs their two year college education and leads to low graduation rates within two years, for most community college students. For example, according to the City University of New York reports (http://www1.cuny.edu/sites/cunyufs/wp-content/uploads/sites/48/2017/07/[RR1] The-State-of-CUNY-2017-for-COPS-1-003.pdf), the graduation rates in two years at the Bronx Community College of the City University of New York were 11% in 2010 and 16% in 2017. Evidently, there is a need for creative teaching strategies to address these challenges.

In addition to finding strategies for improving low graduation rates in community colleges, there is also a need to address the challenges faced by students enrolled specifically in STEM courses such as general biology. The National Center for Education Statistics 2013 report on STEM attrition showed that of the entering bachelor's degree students who declared a STEM major between 2003 and 2009, 48% left STEM fields by 2009. Of the entering associate's degree students who declared a STEM major between 2003 and 2009, 69 % had left STEM fields by 2009. The reasons students choose to leave STEM fields vary but include students' perception that STEM courses are taught in an impersonal and un-engaging manner (Seymour and Hewitt, 1997; Hanauer and Bauerle, 2012; Watkins and Mazur, 2013). The findings of our study shows that the incorporation of writing-intensive intervention teaching strategies, promotes students engagement and participation in the teaching-learning process and has the potential of improving student performance in general biology and other STEM courses.

To find solutions to the high STEM attrition rates and the low student graduation rates, several studies indicate that it is essential for community college instructors to revamp the quality of teaching techniques (Saroyan and Trigwell, 2015, Marrero *et al,* 2017). However, some of the common challenges that hinder the improvement of teaching techniques are time constraints, inadequate teaching resources, a complex climate of increasing accountability in higher education, decreasing budgetary allocations, large class sizes, and an increasingly academically diverse student population (Saroyan and Trigwell, 2015). To address these limitations, creative teaching strategies such as writing-intensive intervention classroom activities and professional development seminars, such as newly hired faculty seminar series geared towards improvement of teaching techniques, have received considerable attention and institutional support (Saroyan &Trigwell, 2015 andhttp://www.bcc.cuny.edu/ctlt/lc/). In a longitudinal study, on the influence of instruction on undergraduate student outcomes, Wang, Pascarella, Nelson Laird, and Ribera (2015) found that precise and organized instructional technique had a significant effect on deep learning and higher order thinking. Moreover, in a related study designed to evaluate the impact of teaching practices on students' critical thinking and development of competent writing skills, Abrami *et al*. (2015) also reported that student's writing and critical thinking skills improved when instructors provided students with knowledge application cases and exposed them to real-world examples within their discipline. For instance, in general biology, this would be exposure to clinical application cases such as the effects of diet and physical activities on occurrence of heart disorders and development of hypertension. In addition, Loes and Pascarella (2015) study on instructional techniques found that "how well faculty teach in the classroom has potentially important implications that go beyond a specific course to influence students' general cognitive development, institutional persistence, and timely progress toward a bachelor's degree."

Educational research conducted over the last 40 years shows that effective instructional/ teaching techniques are the most crucial variable affecting student learning outcomes and therefore directly impacts student success (Gordon, 2012; Stronge, 2010; Crockett, 2015; and Oolbekkink-Marchand *et al,* 2014). In a comprehensive report for the National Symposium on Postsecondary Student Success, George Kuh of Indiana University, Brian Bridges of the American Council on Education, John Hayek of the Kentucky Council on Postsecondary Education, and colleagues concluded that the "widespread use of effective pedagogical practices must be at the core of any agenda to promote student success" (Kuh, *et al* 2006). Such pedagogical practices include the incorporation of writing assignments as an effective teaching-learning strategy for STEM courses. Furthermore, reports show that writing-intensive courses promote learning and critical thinking (Kuh,2008; Sandeen, 2012).

Writing assignments can take many forms and include formal laboratory reports, scientific papers, student reflections, analysis of primary literature and short answer essays. In an effort to find an effective teaching-learning strategy that serves to enhance learning of new content, reinforces class lessons and improve critical thinking in general biology, this study evaluated the effects of integrating writing-intensive intervention strategies on the performance of community college students enrolled in general biology course at Bronx Community College of the City University of New York (CUNY).

Background

An assessment of academic challenges encountered by our students at Bronx Community College (CUNY) showed that a majority of our students have limited foundation in biological sciences, particularly at the time when the students enroll/register for the introductory level general biology course. The student's deficiencies were observed in the following concepts: atomic structure and chemical basis of life/organic compounds, cell structure and function, cellular respiration, membrane transport, enzymatic functions and photosynthesis. These academic challenges, suggests that repeated application of traditional-descriptive teaching methods in the biological sciences, may not be the most effective teaching-learning strategy for conveying fundamental biological concepts in introductory level courses at community colleges. To improve the quality of the teaching-learning process, we set a goal of evaluating classroom teaching strategies with the potential of promoting student performance in a laboratory based general biology course. In this study, we evaluated the integration of a writing-intensive intervention teaching-learning strategy and its impact on the development of analytical skills and overall student performance in laboratory and lecture exams in general biology.

METHODOLOGY

This study was conducted at Bronx Community College of the City University of New York, and it involved a total of 104 students. To prepare for the study, the instructor of the general biology class completed the mandatory: Human Subjects Protection (HSP) training administered by the Office of Research Conduct of the Research Foundation of the City University of New York, for all studies involving human subjects. The experimental design of the study involved designating at the beginning of each semester at least one section of the general biology classes as a writing-intensive intervention section (WI). The WI sections served as our study group. The non-writing intensive section(s)(non-WI)served as our control group. The students enrolled in the WI sections were notified at the beginning of the semester that their course work would involve writing-intensive intervention teaching-learning activities. A copy of the grading rubric for each writing intensive intervention activity was provided to the students. The grading rubric for each writing intervention activity included the following: sentence structure (2.5 points), content (2.5 points), interpretation of data (2.5 points), and application of knowledge (2.5 points). A student could earn a maximum score of 10 points. All the students were self-selected into the different sections. Students enrolled in the non-WI and WI sections were academically comparable at the beginning of each semester and no previous knowledge in biology was needed or required. The prerequisites to the general biology sequence were the same for all groups, and included a passing grade (P) in a developmental/remedial mathematics course and a passing grade in developmental/remedial reading and writing courses.

Prior to this study, the instructional techniques used in teaching general biology courses at Bronx Community College involved primarily conventional description of biological concepts and standard laboratory activities, such as exploring structure and function of a compound light microscope, development of microscopy skills, dissection of biological specimens, such as sheep brains and using quantitative and qualitative assays to identify biomolecules. These concepts were then assessed in four standard laboratory exams per semester. The laboratory exams included identification of structure/parts and 3-5 short essay answer questions. In this study, the writing-intensive intervention activities and assignments were the supplemental pedagogical teaching strategies that were employed in the WI study groups. The WI and non-WI general biology sections were taught by the same instructor.

In the general biology classes/sections, where the writing-intensive (WI) teaching intervention activities were implemented, the specific student learning objectives (SLO) were defined by the instructor and the assessment parameters measured were:

a) The students' performance in the 4 laboratory exams (%) Figure 1.

b) The students' performance in the 4 lecture exams (%) Figure 2.

c) The points earned by the students in the formal laboratory reports and science article critique summaries based on the writing-intensive intervention grading r

rubric, ranging from 1 (lowest) – 10 (highest). The points earned in the 8 writing-intensive teaching intervention assignments per semester were computed in the overall course grade (Table 1 & 2).

The rubric for grading all the writing-intensive teaching intervention assignments included: sentence structure–clarity (2.5 points), content–information accuracy (2.5 points), interpretation of quantitative data–numerical information (2.5 points), and application of knowledge–connection between course content and lab activity or journal article (2.5 points). This information was provided to students and was outlined in the grading criteria section of the General Biology Course Materials and Study Guide modified for Writing Intensive Sections. Collectively, the writing-intensive teaching intervention assignments were designed to promote the development of reading, writing and critical thinking skills. The instruction for all classes included: audio-visual material, microscopes, models, videoscope, simulated computer-based experiments, reading assignments, general biology concepts animations keyed to the lecture textbook/laboratory manual and short film/video clips designed to accommodate the diverse learning styles of students at a community college.

Statistical Analysis

The comparative effects of integrating writing-intensive intervention teaching strategies on student performance were statistically analyzed. The statistical tests were based on analysis of variance (ANOVA) and *Student t*-tests. The F-tests and p-values were determined for mean separations of laboratory and lecture exam grades. The mean values of student's exam grades were reported as X (± SE). The statistical significance of the results was determined at $p = 0.05$ or $p = 0.01$.Computer based statistics and graphics packages [Statview™ 512+ version 1.1 and JMP: statistics made visual™ version 3.0] were used in analyzing the collected data sets. The graphs were generated in Cricket Graph version 1.3.2 and transformed to publication quality in Canvas™ version 6.07. F-test in a one factor ANOVA and/or Student's *t*-test at 95% confidence level ($p = 0.05$) were used to determine the level of statistical significant differences of the student's average exam grades.

RESULTS

Analysis of the effects of integrating writing-intensive intervention activities showed that in the first (1) laboratory exam (Fig.1) there were no significant differences ($p = 0.21$) in student performance. The laboratory exams mean values (%) were 84.47 ± 3.02 in the non-WI control group and 79.39 ± 2.59 in the WI group. The scores were lower albeit not significant in the WI group. However the student performance in the fourth lab laboratory exam (Exam 4: Fig.1), revealed comparatively higher-grade scores in the WI student group (88.55 ± 1.48) relative to the non-WI control group (84.20 ± 1.70) (Fig 1). The fourth laboratory exams mean values differences were significant at $p = 0.05$.

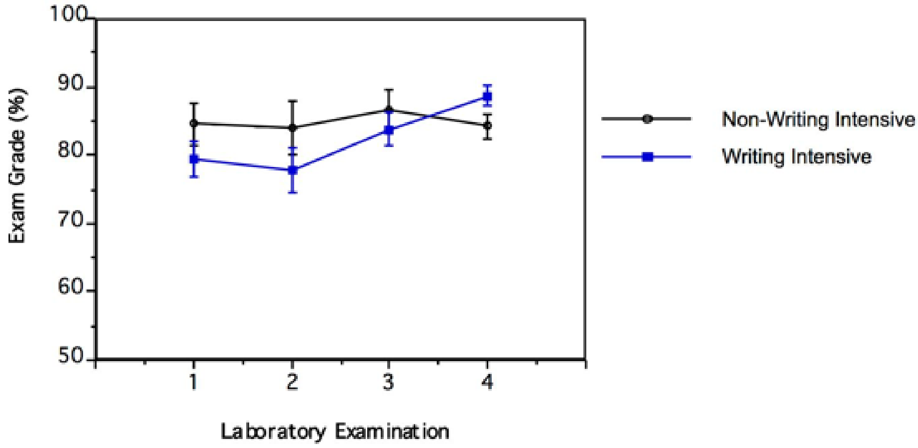

Figure 1. Performance of students in four laboratory examinations (%) that were administered in the first semester of the study.

The n values for non-WI and WI class were 17 and 23 respectively. Each class had initial enrollment of 24 students. Higher performance/scores were observed in the WI class. Statistically significant exam score differences at $p \leq 0.05$ were observed in the final lab exam (Exam 4). Error bars represent ± SE of means. The concepts covered in laboratory (lab) I exam were usage of microscope, cell structure and organization, and mitosis. Concepts in Lab II exam were chemical composition of cells, enzymes, membranes transport processes, and animal organization. The concepts in Lab II exam were more challenging relative to concepts included in Lab exam I and III overall. The concepts in Lab III were photosynthesis (computer simulated), plant organization (roots, stems and leaves anatomy) and transport of compounds in the plant vascular system. The concepts covered in lab exam IV were based on broad overview of the structure/anatomy and functions of human body systems.

In each of the four lecture exams administered during the first semester of the study, the average student performance (%) in the WI classes was comparatively higher (Fig. 2) than the non-WI control group. Statistically significant lecture exam grades differences ($t = 4.419$, $p = 0.0002$) were recorded in student performance in exam 3, based on analysis of variance (ANOVA) and Student's *t*-test. The average student grade (%) in the fourth (4) lecture exam (final exam) was lower than expected. However, the performance of students in the WI class (75.18 ± 3.42) was 9.3% higher compared to the non-WI control group (68.80 ± 4.15). The low performance recorded in both the WI and the non-WI class sections was attributed to the final lecture exam (Exam 4) being comprehensive/cumulative. It included all the concepts covered during the entire semester and test items that required critical thinking skills.

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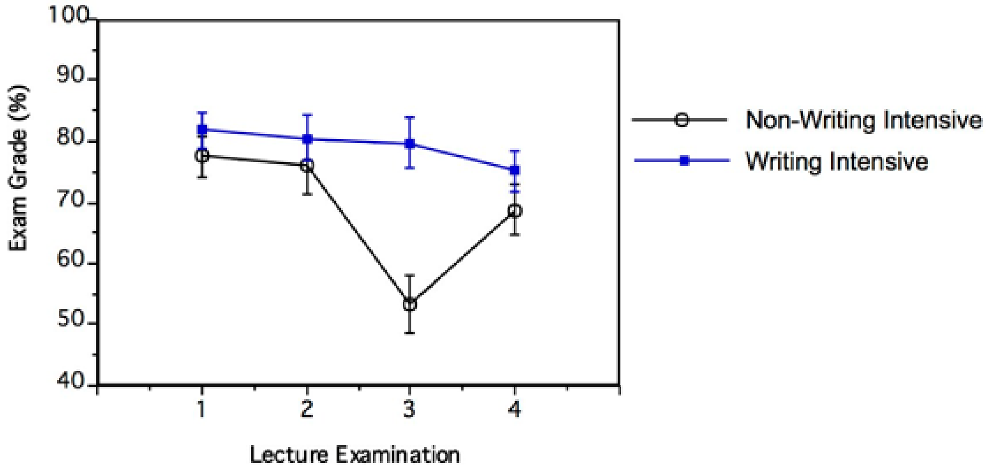
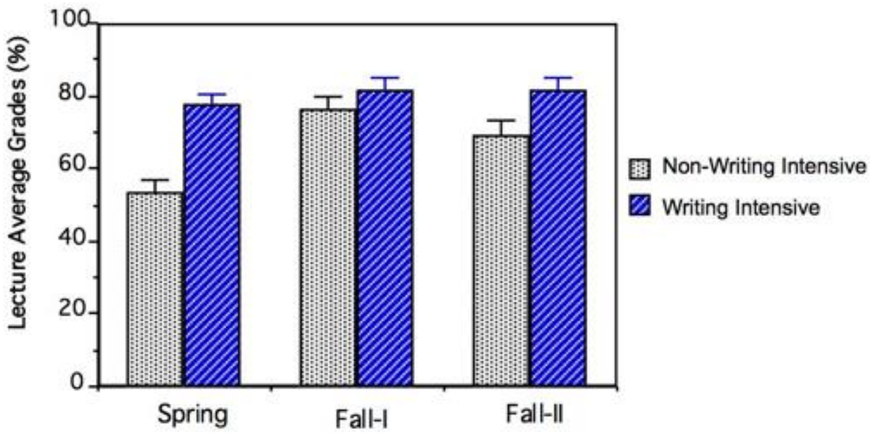


Figure 2. Performance of students in four lecture examinations (%) that were administered in first semester of the study.

The n values for non-WI and WI class sections were 17 and 23 respectively. In all lecture exams, higher mean values were recorded in the WI class sections. Statistically significant exam score differences at $p \leq 0.01$ were observed in the performance of lecture exam 3. Error bars represent ± SE of lecture exams mean/average values. The concepts covered in Lecture exam I were molecules of cells and organic molecules. The concepts in Lecture II exam were cell structure and function, membrane structure and function, metabolism, energy, enzymes, and cellular respiration. The concepts in Lecture III exam were photosynthesis, digestive system, respiratory system, cardiovascular system, lymphatic system and immunity. The final Lecture exam (IV) was comprehensive, and therefore it was comprised of all the concepts covered throughout the entire semester, including critical analysis items based on urinary system and excretion, nervous system, endocrine system, male reproductive system, and female reproductive system.

The analysis of the data, for the duration of study revealed that the average student performance in the lecture exams in all the WI classes was higher (Fig. 3), compared to the performance of the respective non-WI control group. A 43.9% better performance was recorded in the first semester (Spring) and a 6.8% and 17.0% in the second semester (Fall). A total of four classes were involved in this study in the Fall semester. The two paired groups were represented by the data for the Fall-I and Fall-II sets respectively as indicated in Fig. 3. The differences in performance were statistically significant in the Spring semester at $p = 0.001$ and in the two paired groups in the Fall semester (Fall-I and Fall-II) at $p = 0.012$. An evaluation of the overall course grades (Table 1 and 2), revealed better performance: 17.5% (first semester) and 5.6% (second semester) by students in WI class sections compared to the non-WI class sections.



Student-Groups: Spring-Fall Semesters

Figure 3. Comparative study of student's average performance in the lecture examinations (%) in the spring & fall semesters as per duration

The Fall-I and Fall-II represents four classes that were involved in the study in the fall semester. The two paired groups are represented by the data for the Fall-I and Fall-II. In the first semester (spring), the n values for non-WI class section was 24 and the n value for the WI class section was also 24. In the second semester (fall), the n values for non-WI and WI class sections were respectively 22 and 15. Error bars represent ± SE of lecture exam scores mean/average values.

Table 1. Comparative study of writing intensive intervention teaching strategy, on student performance in laboratory and lecture examinations – Semester I.

Parameters	Study Groups		*p* value
	Writing Intensive (Mean ± SE) n=24	Non-writing intensive (Mean ± SE) n=24	
Lecture Exams	77.62 ± 2.76**	53.92 ± 2.87	0.001
Laboratory Exams	84.46 ±1.89	86.16 ± 1.85	0.520
Course grades	83.56 ± 2.19*	71.13 ± 2.2	0.002

****** Mean is significantly different from the control ($p \leq 0.001$)

***** Mean is significantly different from the control ($p \leq 0.05$

Table 1. The overall student performance in the spring semester (semester I) was based on lab and lecture exam scores. The overall course grade was comprised of the computed averages of the-lecture exams, laboratory exams, laboratory reports and writing intensive intervention assignments.

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Table 2. Comparative study of writing intensive intervention teaching strategy, on student performance in laboratory and lecture examinations –Semester II.

Parameters	Study Groups		*p* value
	Writing Intensive (Mean ± SE) n=19	Non-writing intensive (Mean ± SE) n=15	
Lecture Exams	81.47 ± 2.98*	69.60 ± 3.35	0.012
Laboratory Exams	83.90 ± 2.06	85.87 ± 2.38	0.536
Course grades	84.05 ± 2.34	79.60 ± 2.63	0.215

* Mean is significantly different from the control ($p \leq 0.05$)

Table 2. The overall student performance in the fall semester (semester II) was based on lab and lecture exam scores. The overall course grade was comprised of the computed averages of the-lecture exams, laboratory exams, laboratory reports and writing intensive intervention assignments.

Student Performance in Lecture Exam (%)

Overall Student Course Grade (%)

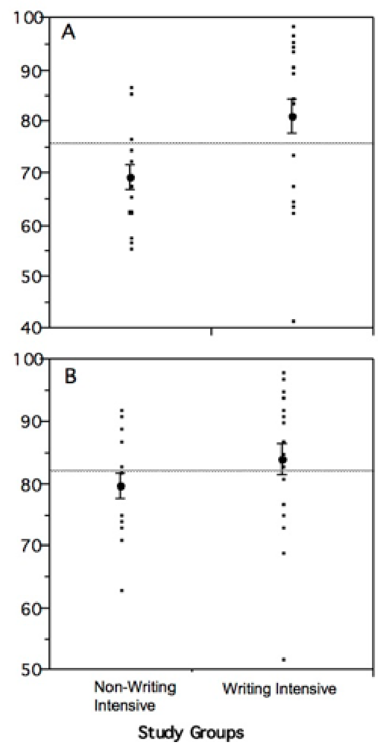

Figure 4. Distribution of mean values (•) of each student's performance in lecture exams (A) and overall course grade (B) in the first (spring) semester.

The study showed outlying data (means) of low performance by students who performed poorly despite being in writing intensive teaching intervention class. This could be attributed to external family/ personal factors that were not easily detected or corrected in class. The low n values were due to the students who withdrew from the class during the semester. Each class had 24 students enrolled at the beginning of the semester. Higher exams scores mean values were recorded in the writing intensive teaching intervention group. A similar distribution was observed in second (fall) semester of the study. Error bars represent ± SE of exams scores mean values of each study group.

The grade distribution in a course is an important indicator of each student performance relative to the average class grade. The analysis of this parameter based on the performance of students enrolled in general biology at Bronx Community College (Fig. 4), showed several low grades in the writing intensive intervention strategy instruction class. These grades were attributed to several students who were unable to submit their writing intensive intervention assignments, due to unexpected challenging academic and social factors

DISCUSSION

In this study, the effects of integrating writing-intensive activities as an intervention teaching strategy in laboratory-based general biology course was evaluated. The evaluation was based on student performance, specifically the grades of lecture and laboratory exams. The grades earned in writing-intensive assignments were analyzed and statistical tests were carried out for the separation of means in WI and non-WI groups. The assessment of the measurable students' learning outcomes such as mastering of course content/concepts and development of analytical skills was based on each student's performance in the laboratory exams, lecture exams, and the overall course grade earned by the student (Table 1 & 2, Fig. 4). The findings of our study demonstrated that higher student performance is positively correlated with the integration/incorporation of writing-intensive intervention teaching strategies. These findings are consistent with the results reported by Clare (2001), which showed that the quality of classroom assignments, instructional practices and student efforts had a positive correlation with overall student performance in a specified course. Furthermore, in an article entitled "Increasing student interactions with learning objectives". Faulconer (2017) emphasized the importance of well-defined course expectations. The author also showed that well-defined expectations are a critical tool in teaching-learning process, in the best performing institutions. Based on the findings of our study, it is evident that teaching strategies that nurture student participation in accomplishing learning objectives, including the writing-intensive intervention strategy (Table1 & Table 2), show promise of promoting course content mastery and better student performance.

Furthermore, the students enrolled in our writing-intensive intervention sections were informed at the beginning of the semester, that their general biology coursework would involve writing-intensive teaching intervention activities. In addition, a copy of the grading rubric was provided to the students. The analysis of the distribution of each student's lecture exams grade, as well as the student's overall performance as indicated by the course grade (Fig. 4), showed the gains, effectiveness, and positive impact of the writing-intensive intervention instructional/learning strategy Our finding is also supported by similar results reported by Faulconer (2017) who demonstrated that low achievement is linked to the failure of students to understand instructor's expectations, whereas, the best-performing institutions make it clear to students what is required of them to succeed. Analysis of the results in our study demonstrate that the clearly defined students' learning outcomes and instructors' expectations in the writing-intensive intervention teaching strategy had a positive effect on students' performance in the general biology course..

Further results analysis revealed that several students enrolled in WI sections earned low-test scores (Fig. 4). While, we do not have a verifiable explanation or identified factor that led to the few low students lecture exam-grades, it is conceivable that these students may have perceived the writing-intensive intervention teaching strategy, as a deviation from the traditional teaching practices in general biology. However, the benefits of the writing-intensive intervention teaching strategy were confirmed by the higher lecture exams scores and overall course grade as indicated in the student performance, in the WI groups compared to the non-WI control groups (Table 1 and Table 2). These findings of our study are consistent with the Brownell, Price and Steinman (2013) report, which also demonstrated that writing assignments have the potential of improving not only student communication skills but also overall mastery of course content material. Collectively the findings of our study are significant, moreover because traditionally course tests scores are used in the assessment of the effectiveness of a program and its impact on student academic achievement (Baker, 2001). Furthermore, testing strengthens the fabric of schooling and test scores represent the most credible method of the assessment of teaching-learning outcomes, such as student academic achievement and effectiveness of classroom instructional innovations (Wai, Brown and Chabris, 2018), including the writing-intensive intervention teaching strategy reported in this study.

Furthermore, in a similar study, Rosenshine (2012) reported that incorporation of writing-intensive activities in teaching techniques, has the potential of elevating mastery of contents and student's academic achievement. Also, in an article entitled "Clueless in Academe", Graff (2004) affirms that having students learn how to use layperson's language to describe complicated scientific concepts, through writing format, might even help them negotiate learning new material, where they are unfamiliar with the terms. Similarly, in a related study, Marrero, Riccio, Ben-Jacob, Canger and Maliti (2017), reported the benefits of incorporating writing assignments in undergraduate biological sciences research projects. In the study, students were frequently asked to draw sketches to illustrate their ideas about students in STEM courses, graph data, or interpret data visualization. The instructors clearly stated the students' learning objectives for different sessions and provided students with feedback on each aspect of their projects including the final presentations. The students presented the findings of their studies, through short research term papers and poster presentations. The students were working in collaborative groups that promoted collective and individual development of writing skills.

In a study published in 2013, Brownell, Price and Steinman hypothesized that students using the writing-intensive format would gain better mastery of the course content material. This study provides quantitative evidence, demonstrating the benefits of integrating writing-intensive intervention teaching strategy in general biology courses. This conclusion is supported by higher level student academic achievement and performance based on earned lab and lecture exam grades in the writing-intensive intervention (WI) group compared to the non-writing intensive (non-WI) control group. This finding is further demonstrated by the statistical analysis of lecture test scores, laboratory test scores, and overall student's course grades.

Implications of integrating writing-intensive intervention teaching strategies at a community college level, undergraduate science course.

This study demonstrated that the writing-intensive intervention-instructional framework supported teaching-learning process and therefore conferred academic advancement benefits to the learners. The quantitative analysis of the data showed the positive role of integrating writing-intensive intervention-instructional strategies on student performance in lab and lecture exams and the accomplishment of students learning outcomes in general biology. The learning settings in this study show promise and add a new dimension to the re-envisioned teaching-learning strategies that promote higher student academic achievement and performance in undergraduate science courses. Further research needs to be conducted on the broad application of this teaching-learning module in other STEM courses.

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