Research Article

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Improving Student Attitudes and Academic Performance in Introductory Biology Using a Project-Based Learning Community

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Students majoring in non-STEM fields often identify introductory biology courses as irrelevant and overly rigorous. Resistance to enroll in a required general education science course, coupled with negative attitudes toward the subject, can adversely affect the academic performance of students; this can especially be present in students from under-represented minority groups. Therefore, instructors have to intentionally design a curriculum that overcomes these factors as they educate non-major students enrolled in introductory biology. BioArt, a learning community, was formed between introductory biology and introduction to graphic design courses to improve the attitudes and academic performance of students in the biology course at a Historically Black College and University (HBCU). The BioArt model incorporated a common theme, project-based learning, and opportunities for experiential learning. To measure outcomes, traditional examinations, non-traditional assessments, failure/withdraw rates, and student attitudes were evaluated. Using this model, introductory biology became less intimidating, more relevant, and improved academic success among freshman minority students. Thus, the BioArt model can be utilized as an intervention at different institutions of higher learning.

KEYWORDS Introductory Biology, learning community, non-STEM majors, project-based learning, URMs, art, non-traditional assessments, minority-serving institution

INTRODUCTION

Introductory biology courses usually have a negative connotation among freshman college students (1, 2). As introductory biology tends to be a course within the general education curriculum, students enroll because it is required; yet, students who are non-STEM majors, typically lack interest in or connection to the subject matter (3). Furthermore, introductory biology courses for non-majors are often viewed as containing academically rigorous and irrelevant content. The reluctance students have toward introductory biology in combination with non-major students' attitudes toward the course are a recipe for low performance (4–6). Therefore, instructors must design interventions to combat these factors as they educate non-major students enrolled in introductory biology courses.

Interdisciplinary curriculums and project-based learning have been widely accepted as interventions for transforming the classroom and increasing student success (7–9). Offering an interdisciplinary approach allows non-majors to critically think about a topic in the context of their interests and make real-world connections. Additionally, evidence shows that students earn higher exam scores and exhibit a more positive attitude toward biology after completing a course within an interdisciplinary curriculum (10). Moreover, students respond favorably to project-based learning in a biology course, with a boost in confidence and increased collaborations (11).

These high-impact educational practices (HIPs) are common practice in Scholars Studio which originated at an HBCU with the goal of transforming teaching and learning for incoming under-represented minority (URM) first-generation college students. The goal was to create interdisciplinary learning communities to increase retention and continued matriculation of URM students. While the students are from various majors, they are placed in two to four general education courses linked through a common theme and project. Additionally, students participate in co-curricular activities designed to facilitate integrative thinking. The elements that are essential to Scholars Studio are outlined in Appendix 1. The success of the Scholars Studio model led to the integration of Introductory Biology for non-majors into a studio.

This pilot study was conducted to determine the effect of project-based learning communities on the student experience and whether it would foster better academic performance. To test this hypothesis, Introductory Biology was integrated into Scholars Studio to assess the impact of a learning community, project-based learning, integrative thinking, and experiential learning on student experiences associated with biology courses. Introductory biology was specifically paired with an Introduction

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to Graphic Design course, allowing students to visualize science concepts through the creation of their own artistic images. Recent publications have highlighted the positive effects of various iterations of merging biology and art to foster collaborations and increase innovation (12–14). Through the involvement in this BioArt learning community, URM student academic performance improved, attitude concerning biology improved, and students expressed more meaningful connections to their cohort and the concepts of biology.

METHODS

Course description

Introductory Biology is a four-credit course, with a laboratory component, designed for non-majors as a general education elective. Introductory Biology has an enrollment of approximately 500 students each academic year from various majors excluding STEM. Historically, it was implemented as an in-class course; however, it had transformed first to an online and then hybrid course to meet the staggering increases in student enrollment.

Study design

One section of Introductory Biology was transformed into the Scholars Studio model in the Spring of 2019 ($n = 18$) once it was paired with Introduction to Graphic Design to create the BioArt learning community. The outcomes of this redesign were compared with the Fall 2018 hybrid section ($n = 58$) taught by the same instructor and consisted of an analysis of demographics, exam and assessment grades, drop/fail/withdraw (DFW) rates, and student surveys. This retrospective study was exempt from Bowie State University Institutional Review Board (IRB #12-49).

Scholars studio

The Scholars Studio model connects curriculum through a common theme, integrative thinking, project-based learning, and learning communities for eligible students (http://www.scholarsstudio.com/). Upcoming Studios are advertised and students enroll voluntarily in the Studio of interest. Specific examples of elements of Scholars Studio incorporated into the BioArt Studio are in Appendix 1.

The essential components of each studio include:

1. Program launch: an immersive, hands-on event at the beginning of the semester that introduces students to the theme and Scholars Studio. The launch is attended by all students in the community, the instructors, supplemental instructors, and Scholars Studio administrators. The launch includes an icebreaker, community building activities, introduction of the integrated syllabus, description of the community, and an overview of the co-curricular activities.
2. Integrated thinking: encouraged through the activities, assignments, and experiences planned throughout the semester (15).
3. Co-curricular Activities: conducted out-of-class and often, off-campus, designed to reinforce the concepts and contextualize learning.
4. Integrated syllabus: a document designed to show the connectivity of the courses in the community by describing Scholars Studio, the theme, contributions of each course, assignment deadlines, co-curricular activities, and images/designs to illustrate the theme and foster collaborative teaching.
5. Final integrated project: a cumulative project embodying the theme of the community presented by groups of students in a public setting.

Course transformation

In order to test the hypothesis and adapt the Introductory Biology course to the Scholars Studio model, the following modifications were made:

1. Class Size and Modality

A specialized section of Introductory Biology was created that enrolled a maximum of 20 students. As compared with 63 students, the course was offered as an in-person lecture and laboratory as compared with a hybrid course with an online, asynchronous lecture and in-person laboratory.

2. Learning Community and Common Intellectual Experiences

To reinforce the sense of community, BioArt students and instructors shared the common theme, "L.I.V.E: What it means to be alive," and out-of-class communication was facilitated using a GroupMe chat. Additionally, students and instructors attended the program launch, experiential learning experiences, and final project presentation. Instructors met bi-weekly to check-in and assess the progress of the project. Additionally, each course had an embedded supplemental instructor who attended lecture and held study sessions in the evening to assist in comprehension and completion of assignments.

The BioArt Program Launch expanded on the characteristic of life, various components of well-being, and the difference between being alive and living life. Students explored song lyrics from Moment 4 Life by Nicki Minaj featuring Drake, "'Cause everybody dies, but not everybody lives." (16) They competed in a Kahoot! on heart healthy facts and created mini-Zines (17), reflecting on their unique meaning of being alive.

3. Experiential Learning

Students visited the Franklin Institute in Philadelphia, PA (https://www.fi.edu/) to immerse themselves in the theme through the interaction of several key exhibits: The Giant Heart, Your Brain, Sports Zone, and Augmented Reality. The

FIG 1. Representative images created by students in the Introduction to Graphic Design course. (A) Heart collages where students displayed what mattered to them and affected their wellbeing. (B) Profile silhouettes containing images related to how students interpreted their selected disease/condition. (C) Posters used in the Virtual Reality Health Fair to discuss various conditions and how they impact the community.

trip was paired with several assignments: complete a pre- and post-journal on their expectations for this opportunity, take pictures of the various exhibits that could be used for their final projects, and create a video at the exhibit teaching a concept, such as blood flow, to third graders.

4. Collaborative Assignments and Projects (Fig. 1).

In graphic design, students applied their knowledge of biology to create various artifacts: collages, with images in a heart outline of things that matter to them, was printed on a poster for display and on buttons for dissemination; a profile silhouette containing images related to the disease they were studying was used in the final project and to make gifs.

5. Professional Development and Planning Meetings

Two faculty members met regularly for one semester prior to the implementation and attended an off-campus Faculty Think Tank Retreat. At this retreat, they actively engaged in activities to help them brainstorm and begin to create the experiences they wanted to provide for the students, as well as the syllabus and shared assignments.

Assessment of the introductory biology course redesign

Student attitudes

Students were given two anonymous surveys. The first survey was given at the beginning of the semester to assess their attitudes toward enrolling in a required general education science course using a Likert scale and free response. This survey was disseminated and analyzed by the Bowie State University Office of Planning, Analysis and Accountability (OPAA). The instructor received an analysis of the results. The free response was visualized using a word cloud created on www.worditout.com. The second survey, using a similar format, was administered via Blackboard at the end of the semester. This survey evaluated the course modality preference and improvements.

Class composition

The demographic analyses of both courses were performed by OPAA, which analyzed the rosters with a focus on gender, major, and classification. The pilot cohort included 18 students: 83% freshman, 78% female, and 11 different majors (Appendix 2). The comparison cohort included 58 students with 39.7% freshman, 69% female, and 14 different majors.

Course exam grades

Five exams consisting of multiple choice, multiple answer, true/false, and short answer were administered to students via Blackboard, approximately every 4 weeks and one cumulative final exam. The exam grades, excluding the zeros for incompletion, were averaged by module for each course.

Assessment activities

There were three non-traditional assessment activities, 30% of the overall grade, assigned to BioArt during the semester: individual students designed pamphlets to introduce a topic of their choosing to a lay audience; students were divided into groups of three to make a video on a topic of their choosing suitable for a third-grade student that was filmed on location at the Franklin Institute; and pairs of students created a children's story about an organ system of their choosing. These assessments were strategically constructed by the BioArt instructors to allow students to merge the content from both courses. Overall, they were evaluated using rubrics on content, creativity, and relevancy to audience, but each rubric was tailored to the specific assignment.

For the final project, each student chose a disease/condition of interest. Then, they were placed into groups of three by the instructors according to their chosen disease/condition. For example, the group "In Due Time" included diseases that were chronic and/or progressive: chronic traumatic encephalopathy, dementia, and diabetes. They created posters in the graphic design course that were displayed during a virtual reality health fair that was open to the campus community (Fig. 1). The posters were displayed on stands in the atrium and administrators, staff, faculty, and students interacted with the students. The presenters had HP Reveal application installed on their cellular phones to show the audience the "hidden" digital component within their silhouettes.

Measure of academic success

The course grade data was provided by OPAA. The DFW rate was calculated by adding the failing grades (Ds and Fs) and number of students who dropped or withdrew then divided that sum by the total number of students enrolled and multiplying it by 100 to display as a percentage.

Statistics

All calculations and statistics were completed in MS Excel. Standard error of the mean (SEM) was calculated by dividing the standard deviation by the square root of the number of scores for exam and assessment grades. Single factor analysis of variance (ANOVA) with *post hoc* t-tests or Student's t test were used to calculate significance among each module grouping of assignments.

RESULTS

Assessment of students' attitudes

The results of the first survey were similar between the two semesters (Appendix 3). In BioArt, the majority of students agreed that biology was interesting (75%); yet, almost half (46.7%) said that the subject was frightening. Despite being interesting, a narrow majority (53.3%) agreed that they were not expecting to learn anything relevant to their field of study. However, 86.7% of the students believed they would learn something relevant to life. Only 40% would take the course if it was not required. All students anticipated passing the course; ~69% expected As, 25% Bs, and 6% Cs (data not shown). From these results, we can confirm that the majority of students enrolled in the course because it was mandatory. However, because students found the subject interesting, yet intimidating, the introduction of a learning community to build connections and project-based assignments to appeal to their curiosity was well-suited.

Moreover, when asked about their fears concerning the course, students in both cohorts had similar concerns. In BioArt, the top fears were not understanding the material

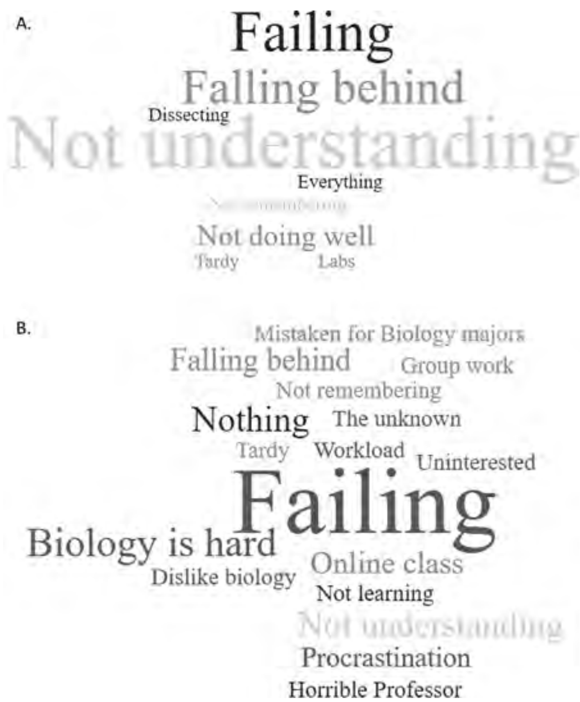

FIG 2. Word clouds depicting the fears reported by students at the beginning of the semester concerning their enrollment in the Introductory Biology Course. (A) Fears reported by students enrolled in BioArt during the Spring 2019 Semester. (B) Fears reported by students enrolled in the Hybrid Course during the Fall 2018 semester.

(30%). Furthermore, 22% expressed concerns over failing, and 17% expressed concerns about falling behind in class (Fig. 2A). Additionally, the Hybrid cohort was also apprehensive about the subject matter and course modality (Fig. 2B). In redesigning the course, we alleviated some of the fears of the students including course modality which allowed student-student interactions and the introduction of supplemental instruction sessions to ensure that students understood the material and did not fall behind.

Evaluation of student progress

The course and exam content were the same regardless of course modality. Unexpectedly, students performed comparable on each module exam (Fig. 3) with the exception of Module 4. This could have been caused by their focus shifting to completing their final projects and practicing for the presentations. However, significant differences were evident on the BioArt students' performance on non-traditional assessments compared with traditional assessments. On average, students performed worst on the first assessment assignment. This could be attributed to students showing their knowledge base for the first time in this format versus the typical quiz or exam format.

The overall average grade from all exams from both semesters administered via Blackboard was 70.5%. It has been published that students experience anxiety during exams, which causes them to perform poorly and that the grade earned may not be indicative of the information retained (18, 19). However, when students were asked to demonstrate their knowledge base through an artistic medium, the average grade from all assessments during the Spring 2019 semester was 81.6%. It is important to note that the number increases to 86.5% if the Module 1 assessment when they were acclimated is excluded. The use of non-traditional assessments may relieve some anxiety and be a more accurate depiction of information retained (20). Additionally, a prior study showed that incorporating art did not have a significant impact on learning measured by traditional means but theorized that it may have taught students to find real-world applications and learn in creative ways in other courses, thus, having a lasting impact on their future endeavors (21).

Final course grades

On average, the DFW rate of Introductory Biology was approximately 41% during the fall and spring semesters from

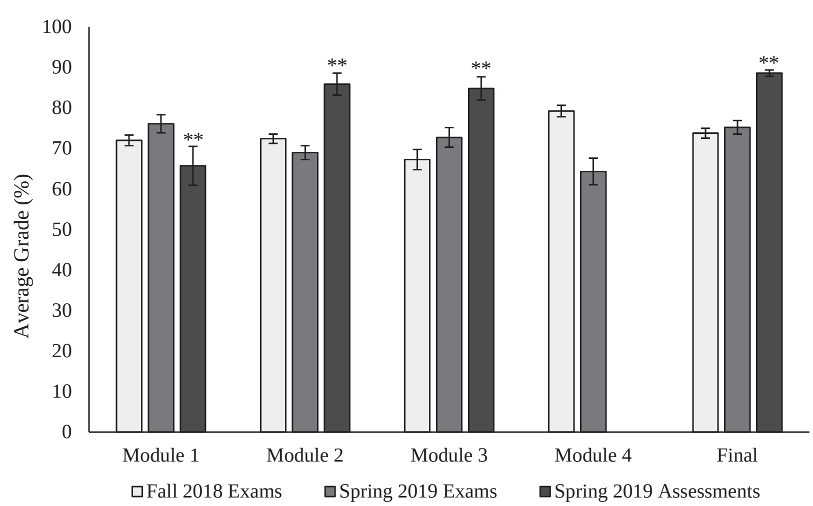

FIG 3. Average grades earned by students in Introductory Biology on module exams, final exam, and non-traditional assessments during the Fall 2018 and Spring 2019 semesters. Comparisons were made within each Module (*, $P > 0.05$; ***, $P > 0.001$).

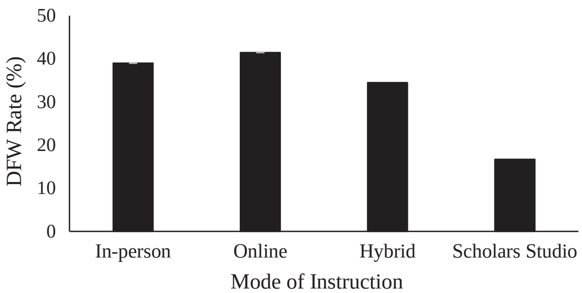

FIG 4. Average DFW rates based on course modality for Introductory Biology. In-person and online data range from 2013 to 2018. The hybrid data is from the Fall 2018 semester and the Scholars Studio data represents the Spring 2019 semester.

2013 to 2018. Ranging from 18% to 56% the DFW rate was approximately 39% for in-person courses and 41.5% for online courses (Fig. 4). In Fall 2018, the Hybrid course had a DFW rate of 34.5%. The average DFW rate decreased by almost 2.5× to 16.7% during Spring 2019 in the section using the Scholars Studio model. This decrease shows that learning communities and project-based learning have a positive impact on the academic performance of URM students in an Introductory Biology course.

Change in student attitudes

The evaluation of student attitudes was 2-fold: a focus group and an anonymous survey. After the completion of the final project, the coordinators of Scholars Studio held a post-reflections forum to discuss the experience with the students in the absence of the instructors. Overall, the students reported having a good experience through their participation in the BioArt Studio. They stated that the Introductory Biology course was "hard" in the beginning, but that they really starting learning when the information was of interest to them. Moreover, they reportedly enjoyed working together and had a positive experience in groups unlike in other courses where communication was poor and meeting together outside of class was challenging. This positive feedback marked a change in attitude from the beginning of the course and demonstrates the results of connecting to the content and each other.

Lastly, students were given a survey at the end of the semester about the modality of the course and asked for improvements. In total, 27% would not change anything and remarked how much they learned. In addition, 20% of the students remarked that they appreciated the experiential learning opportunity at the Franklin Institute and wished they were able to participate in more off-campus activities to reinforce the concepts (Table 1). The lasting impact of the experiential learning was evident by their remarks. Furthermore, studies have shown that it can lead to an increase in problem-solving abilities, an increase in the quality of their learning, and bridge the concepts learned inside the classroom to real-world experiences outside the classroom (22–24).

DISCUSSION

Introductory biology courses for non-majors are tasked with educating students from different majors with a vast array of experience and interests. A heavy content-based, one-size-fits-all approach may lead to a high DFW rate and increase in students needing to repeat the course (25, 26). The objectives of this study were to first, understand why students may not be doing well in the course and then, to transform the introductory biology course to increase student success and improve students' attitude toward the subject matter.

The pairing of an introductory biology course with an introductory graphic design course within an interdisciplinary learning community empowered students to individualize their learning experience and showcase their knowledge through non-traditional means. Thus, the focus shifts from memorizing content to learning material for personal benefit. When students find a personal connection to learning material, it is transformative, impacting their actions, thoughts, and communications about the topic (27–30). Using this approach, the biological knowledge was no longer hard to understand, and the fear of failure was removed, resulting in an improved attitude toward biology and an improvement in their academic performance in the course. This is consistent with a previous study that showed employing multiple HIPs improved learning and persistence for URM students (31).

The improvements evident in academic performance can also be linked to the mode of assessment, traditional versus non-traditional, which highlighted another dichotomy within

TABLE 1
Representative responses on course improvements for Introductory Biology incorporated in BioArt at the end of Spring 2019

Is there anything else you would like to add to improve the quality of this course?
"I loved the course. Being able to have [supplemental instructors] and the professor to help, worked very well for me personally. I am not sure how this course could be improved just yet."
"Things that can help improve this course would be to have more field trips. Going on these trips can allow students to see things from a different view and they might better grasp the lesson."
"More experiments field trips like the Franklin Institute."
"I would say more trips because the trip to the Franklin Institute really helped me understand the lesson we were on. We were able to be hands on and make learning fun."

education. The performance anxiety associated with traditional quizzes and exams has been extensively studied (32–34). It reveals that students panic while completing exams, and the resulting grade may not be an accurate representation of a student's knowledge base (18, 19). In this study, students performed comparable on identical exam questions administered online and having connections to the material did not affect traditional exam grades. However, when students were asked to demonstrate their understanding of the material through non-traditional means, the grades were significantly higher. According to these data, in some courses, it may be beneficial to assess the knowledge gained by students using traditional and non-traditional means (35–38). Moreover, the impact of the art-based collaborations with science curriculum teaches students to make real-world connections with the material and has a lasting impact on how they approach learning in the future (21).

Each semester a large number of students fail or withdraw from introductory biology courses (39–42). This failure can be attributed to differences in gender, high school courses, and attitude toward science (43). Furthermore, it was noted several decades ago that positive and high-quality exposure could change a student's attitude toward science (44). BioArt provided a unique and tailored experience, which altered how minority students felt about participating in a mandatory biology course. Through the combination of art with science, students remarked how much they enjoyed the course and the opportunities for experiential learning. As a result, the DFW rate dropped more than 2-fold in the Introductory Biology course.

The magnitude of changing the attitudes of URM students toward science is monumental. By creating a model that allows URM scholars, particularly African Americans and females in this study, to excel in biology could be extended to other STEM fields and could positively affect the achievement gap. This model could be adapted for other introductory and even advanced biology courses for STEM majors to improve persistence in and graduation from STEM majors. Importantly, the positive effect in non-major students would increase science literacy and could even increase the number of students pursing STEM majors. Changing the negative views toward science and teaching students to think creatively about a science topic will allow them to retain the information longer, thus, creating more informed citizens who are able to make decisions about their health and issues concerning the world in which they live (45–48).

In conclusion, the inclusion of introductory biology in a learning community with graphic design afforded students the opportunity to build community, connect to the content, use creative means for assessments, and ultimately, do well in the course. Although it would be beneficial to adopt a similar design for other general education courses, it may not be feasible due to large enrollment, costs of experiential learning opportunities, and demands on the instructors. However, improvements in the learning experiences would reduce the number of reenrolling students and increase the value of the general education curriculum because students would be better equipped to integrate biology into their lives. Nonetheless, it may be possible to adopt some components of this redesign; instructors should consider adding non-traditional means of assessment, introducing the sense of community within their classroom, and/or including a project-based assignment. Improving URM student success and attitude toward STEM could help close the achievement gap, increase persistent in STEM, and create more informed citizens in the world.

Limitations

This is a retrospective analysis of a course transformation that occurred. As a result, there are some limitations to the study. The sample size used in this pilot study was small, but the demographics of the students was comparable with those enrolled in other sections. However, it could affect the data analysis (49). Additionally, the comparison group was a hybrid course with an asynchronous, online lecture and traditional lab taught by the same professor. It is important to note that there can be students enrolled in the hybrid course for a second time that are at an advantage by they are accustomed to the academic process and completing college courses. Nonetheless, this was a pilot study to test the feasibility of implementing such a transformation.

The study was completed at an institution classified as a HBCU and may not be a representation of the average college population. However, because HIPs are effective for all students, a similar model can be implemented at any institution in an effort to reduce the overall failure rate of Introductory Biology courses and to close the achievement gaps of minorities at majority serving institutions (9, 42).

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.1 MB.

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