Biozobots: An Investigation into using robotics in an introductory biology course

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ABSTRACT

Creating meaningful learning environments that support university students in their early STEM courses has become a focus of interest for many universities. This research investigated an active learning environment where students used Ozobot robots to visualize complex concepts such as Metabolism, Photosynthesis and Cellular Respiration in an Introductory Biology course. Three conditions were employed over three semesters including a Control, Non-reflective, and Reflective condition. In both the Non-Reflective and the Reflective condition, students programmed robots to visualize concepts in the three topics of interest. Quantitative analysis using Kruskal Wallis revealed significant differences on unit tests between the Reflective and the other two conditions. No difference was found between the Control and the Non-Reflective condition. Qualitative analysis revealed three themes Engagement, Visualization, and Social.

Keywords: Introductory Biology, Photosynthesis, Metabolism, Respiration, Ozobots,

INTRODUCTION

Few students enter the university intending to fail. However, many students struggle, and as many as 30% of freshman students drop out (College Drop Out Rates, 2020). Further, according to federal data, the four-year graduation rate at a public university in the United States is only approximately 33% and the six-year graduation rate is only approximately 60% (Undergraduate Retention and Graduation Rates, 2020). Numerous causes are offered for students' difficulties including financial issues, time management issues, college readiness, lack of maturity, etc.

In addition to the issues mentioned above, many students in college today are first-generation college students. According to the NCES, this demographic is one where neither of the parents of these students has any postsecondary education experience (NCES, 2017). Other definitions of this demographic also stipulate that a first-generation student may also be the first sibling in the family to attend a college or university (Graves, 2018) further limiting their access to help and support from family. First-Generation students commonly come from low-income backgrounds with 27% coming from families earning $20,000 or less and 50% coming from families earning between $20,000 and $50,000 (Horowitz, 2019). Finally, minority students were more likely to be first-generation students with 27% of Hispanic students and 14% of African American students reporting First-Generation status (NCES 2017).

First-generation students often lack the critical cultural capital necessary for navigating college, creating additional challenges and barriers. Cultural capital is regarded as "Knowledge and experience, acquired over time, from family, friends, mentors, or teachers that impart status, dispositions, cultural and linguistic expertise, and credentials" (Hinton, 2015, p. 303). These students are often not familiar with the norms and culture of college and the resources available for assistance. For example, they are less likely to take advantage of their schools' services such as tutoring services or feel uncomfortable about going to an instructor's office to clarify a concept that they find puzzling (Horowitz, 2019). Even if they access financial aid or scholarships, their family may not be able to support them financially resulting in their working a job on top of attending college (Rondini, 2019). When combined with the traditional freshman struggles, the challenges associated with first-hgeneration student status may contribute to less engagement with their studies.

Many students also encounter difficulties in their early science courses in college. Substantial research has shown that the success of students in STEM fields is dependent on their high school preparation (Tyson, Lee, Borman, & Hanson, 2007 & Wang 2013). However, for many Black and Hispanic students, a general level Life Science course is the highest-level science course that they have completed in high school. Fewer have completed Chemistry I or Physics I much less Chemistry II or Physics II. This situation is further exacerbated for English Language learning students who also are underrepresented in higher-level Science courses (Johnson, 2019). This lack of preparation creates knowledge gaps through which students struggle in college and leaves them ill-equipped for the rigors of college-level science. This lack of readiness for college-level work in Biology may be particularly true for small regional colleges with students coming from rural school districts. Students coming to college from small, rural districts are also disadvantaged in their ability to access advanced science coursework or may have studied under teachers without the required science teacher credentials (Everhart, 2016, Malkus, 2016).

Large lecture forums are the traditional setting within many early college science courses. Walker, Cotner, Baepler, and Decker (2008) describe several challenges for this instructional design including low attendance, lack of student engagement, little immediate feedback on student understanding, and little opportunity for student engagement with course materials. In this mode, students become passive learners receiving information as opposed to active learners constructing information. In the first years, lack of engagement and absenteeism can have a damaging effect on student course grades as well as social integration into the college environment (Rissanen, 2018). Since students' sense of belonging and connectedness to the university are important predictors of retention, it is important to find ways to maximize their potential for academic success.

Noting these factors, the researchers sought to create an active learning environment in an introductory biology course. This course featured a recitation period where small groups of students met to discuss course concepts within the week that they were introduced. Researchers noted that students' greatest difficulty was understanding concepts of metabolism, photosynthesis, and cellular respiration, Thus, the researchers sought to use Ozobot robots to visualize these concepts. This research was carried out across three semesters 1) a non-Reflective Ozobot semester, 2) a traditional semester, and 3) a Reflective Ozobot semester. This research was guided by the following research questions:

1) Is there a significant difference in unit test grades between the control class and the classes that used the Ozobots to visualize complex processes in biology? Is there a significant difference between the class that used the Ozobots without reflection and the class that used the Ozobots with reflection?
2) Is there a significant difference between fmale and female students using Ozobots to visualize complex processes in biology?
3) What are the perceptions of the students and teaching assistants regarding the use of the Ozobots?

LITERATURE REVIEW

Active Learning

Active learning has garnered strong advocates among universities seeking to elevate and advance student learning outcomes. Various definitions have been suggested for active learning. Bonwell and Eisen (1991) define active learning as those pedagogical strategies that promote "involving students in doing things and thinking about what they are doing" (Bonwell & Eison, 1991, p. iii). Mizokami (2014) asserts that active learning to be "all kinds of learning beyond the mere oneway transmission of knowledge in lecture-style classes (=passive learning)" (Prince, 2004, p.79.) however, considers active learning to be where students to do meaningful learning activities and critically think about what they are doing while they engage as active participants in the learning process. Fink (2003) conceptualizes a more "holistic" p.106 view of the learning process composed of both passive and active learning. In the passive phase, the learner is receiving information and ideas. However, the active learning phase is divided into two parts: Experiences and Reflection. Experiences may be Doing "where the learners actually do what we want them to learn such as designing a dam for a reservoir or Observing is where the learner watches or listens to someone else doing something to what they are actually learning as in observing the phenomena under discussion. Reflection, she posits, may be done by intellectually mature students on their own, but for most students, it is essential to include it as part of the learning process. According to Fink (2003), reflection provides students opportunities to think about what they are learning. Regardless of the definition, numerous studies in STEM courses have found benefits such as higher grades or course retention when they employ active learning strategies (Bernstein, 2018)

Several studies have investigated active learning in large lecture biology classes using a variety of active learning techniques. Dyer and Elsenpeter (2016) investigated the use of creative and interpretive active learning assignments across several semesters. In this study, instructors identified several difficult topics for students such as cellular respiration, photosynthesis, protein synthesis, etc. Students, working in small groups, were instructed to create a 3D simulation for the class explaining the concept through interpretive dance, Claymation, or other strategies. Researchers found that active learning simulations increased student satisfaction and student confidence in learning the material. Similarly, Cleveland, Olimpo, and DeChenne-Peters (2017) found no difference in student attitudes when active learning strategies such as clickers, group discussions, and in-class worksheets were used across weekly classes or consolidated into one weekly class. Finally, Corkin, Horn, and Pattison (2017) found that students who are engaged through active learning instructional strategies such as clicker questions and think-pair-share discussions had higher levels of perceived instructor support, expectations for learning, and higher levels of interest in the course than those who participated in a traditional course.

Introductory College Biology

Introductory college biology courses are widely regarded as gateways to undergraduate degrees and careers in the biosciences (Scott, McNair, Lucas, & Land, 2017). Students are expected to enter these courses with a clear understanding of the basic concepts and vocabulary of biology as well as the scientific method (Barral & Ardi-Pastores, Kottmeyer, Van Meter, & Cameron, 2018). To help students meet this level of academic rigor, high schools can align their courses with standards such as the Next Generation Standards for Science (NGSS) for Biology or offer Advanced Placement Biology courses to their students (Dirks & Knight, 2016). The required fundamental concepts are well-articulated in the Next Generation of Science Standards (NGSS) and while not all states have adopted the NGSS standards, many are similar in spirit (Dirks & Knight, 2016, Next Generation Science Standards, 2013). The NGSS standards for biology are divided into five major topic categories including 1) Structure and Function, 2) Inheritance and Variation of Traits, Matter and Energy in Organisms and Ecosystems, 4) Interdependent Relationships in Ecosystems, and 5) Natural Selection and Evolution. The standards emphasize critical thinking and blend science and engineering practices (professional disciplinary tools and processes) with core disciplinary concepts and crosscutting concepts (concepts which have application across multiple disciplines of science) (Houseal, Gillis, Helmsing, & Hutchison, 2016). Similarly, Advanced Placement courses that offer college-level curriculum and exams are another means of introducing students to the level of academic rigor necessary for success in college. In her study of introductory biology students, Neitzel (2019) found that students who reported that their high school biology class had been rigorous felt that their introductory biology course positively impacted both their future career and their self-confidence.

At the college level, it is expected that the introductory biology course will enable students to continue to develop and expand the knowledge, attitudes, and skills for biology that they began studying in high school. Students who enroll in the course are typically freshman and sophomores who need the course as a requirement for upper-level STEM classes or are taking it as a required science course for a nonscience major. In the past, the introductory course was a survey of the biosciences that touched on a large variety of biology subfields to prepare students for upper-level classes (Simurda, 2012). This breadth at the expense of depth approach became problematic. It often led to shallow coverage of the many diverse subfields which hampered students' forming deep conceptual understandings (Perini, 2012).

In the early part of the 21st century, reforming Biology education became a priority among several national scientific bodies. The National Research Council's Committee on a New Biology for the 21st Century (NRC, 2009) recommended that the study of biology be interdisciplinary and connected to real-world problems. In their recommendations, they asserted that 21st century biologists are not scientists who "know a little bit about all disciplines, but a scientist with deep knowledge in one discipline and a "working fluency" in several" (p. 7). This was followed by the American Association for the Advancement of Science (AAAS, 2011) report, *Vision and Change in Undergraduate Biology Education, A Call to Action,* which called for more active learning experiences in Introductory Biology courses. Bruce Albert, editor in chief for Science, also challenged the biology community in this document saying "My hope is that we can change the focus of introductory courses to cover much less material in order to give students the chance to learn what science is and the opportunity to experience science", (p. 7). The trend toward depth over breadth continued in Gregory's (2011) national survey of biology professors regarding the essential topics that should be included in an Introductory Biology courses. This survey found extensive agreement that course content should be streamlined and should focus on a more limited scope and sequence including "evolution, cell structure, DNA structure and replication, mitosis, meiosis, Mendelian genetics, cell cycle, protein synthesis, membranes and transport, respiration, photosynthesis, and enzymes" (p. 15). In their follow-up report, the AAAS (2018) found that while the reports had stimulated some "points of light" much work remained to be done.

Ozobot Robotics

The increased interest in STEM education and robotics has generated a plethora of robotics platforms, each with unique skills and capabilities. The robots used in this study are Ozobot Evo, a small robot weighing 17 grams that can make sounds and display flashing lights as seen in Figure 1. There are two ways to interact with the Ozobot Evo: online through Ozoblockly, a drag and drop coding system, or completely screen-free through tracks drawn on paper with sequences of color codes. In the Ozoblockly mode, students can create a program on a computer screen or tablet by dragging and dropping commands into a sequence. When the program is completed, the user holds the Ozobot Evo close to the screen, and commands are transmitted through flashes of colored light. In the track mode, Ozobot Evo uses sensors on the bottom to detect lines drawn on paper. Black lines can be interspersed with color sequences of red, blue, green, or black that enable the robot to speed up, slow down, or execute special moves. For the purposes of this study, we used the track mode. An example of the track mode from this research can be seen in Figure 2 where Ozobot is being used to model Photosynthesis.

Ozobots as Nonlinguistic Representations in Science

Much of science information is conveyed by nonlinguistic representations such as graphs, charts, diagrams, and pictures (Perini, 2005). Scientists use models and other representations to explain complex data, test hypotheses, or to predict what's going to happen (Scientific Modeling, n.d.). Scientific literacy, thus, encompasses not only being able to read scientific texts, but also the various models and representations. Therefore, it is incumbent on teachers to use nonlinguistic representations to promote understanding of phenomena and "to develop students' ability to think with representations as scientists do" (Eilam & Gilbert, 2014, p. 3). Enabling students to create nonlinguistic representations such as models, maps and graphic organizers, drawings, and kinesthetic activities can have a strong effect on student sense-making and student achievement Koba & Tweed, 2009). This can be accounted for by Clark & Pavio's (1991) Dual-Coding Theory which asserts that the brain stores information in two interconnected information processing channels: verbal and visual. This theory posits that these channels are synergistic and that Information presented in both forms enables stronger retention and easier retrieval.

Ozobot tracks can be seen as a means of modeling scientific concepts and processes. The tracks can blend graphics, lines, words, and animation into a cohesive illustration of a scientific model. The lines can indicate the direction or progress of a concept. The graphics can illustrate the ongoing actions or reactions. The words can label the various areas of the model. Finally, the movement of the Ozobot can simulate the pace of the action within the model through the speed codes or the loss or gain of some part of the model through the spinning codes. Thus, the combination of the Ozobots and their tracks becomes nonlinguistic representations that blend graphics, lines, words, and animations which helps the student organize concepts and ideas and create meaningful understandings.

METHODOLOGY

Research Design

This mixed-methods study employed a quasi-experimental quantitative design and a qualitative phenomenological design. The quantitative study used a non-equivalent groups, post-test only design to compare two instructional interventions with a control group. Quasi-experimental designs are characterized by two or more existing groups not formed randomly. The main purpose of the phenomenological qualitative research was to investigate the lived experiences and perceptions of the students and teaching assistants involved in this research.

Participants

The participants in this study were drawn from the students enrolled in an Introductory Biology course taught by the same instructor in a Hispanic Serving regional state university in South Texas. This research was conducted over three semesters reflecting the three conditions Non-Reflective, Reflective, and Control. As seen in Table 1, there were a total of 168 students (N=168, 84 males and 84 females) who took part. They were drawn from all undergraduate levels (N=168, 108 Freshman, 32 Sophomores, 15 Juniors, and 9 Seniors).

Instrumentation

The exam that is used to assess the effectiveness of our exercise is one that is normally given as the second hour exam in the course and is the exam covering metabolism, photosynthesis and cellular respiration. The exam is composed of 50 multiple-choice questions having anywhere from 3 to 5 answers to choose from. They are also instructed, on some questions, to answer, any and all that apply, or choices such as A and B but not C, or A and C but not B. They have 60 minutes to take the test. There are also 2 bonus questions that generally deal with writing the balanced equations for photosynthesis and cellular respiration. The bonus questions are 5 points each.

Data Sources

Data for the quantitative assessment was drawn from scores for the Unit tests. In all conditions, these scores were not examined until the end of the semester.

Data for the qualitative investigation was drawn from student interviews, teaching assistant's reflections, and instructors' observations. Students were solicited by the non-teaching researcher to participate in a semi-structured interview during the semester about their perceptions of using robots in an Introductory Biology class. Questions included topics such as what they thought about the use of the Ozobots in their class, how they felt it helped their learning, and whether working with the Ozobots boosted their confidence. Two students participated in the interview. One was a female history major in her early 20s. The other was a male biology major also in his early 20s.

The teaching assistants' reflections were created after the end of the semester and addressed their perceptions of the experience and the impacts they observed on students. They responded to questions about their perceptions of student engagement, student learning, and student collaboration. After each class, the researchers discussed their observations of the class.

Procedures

Two interventions were investigated in this study and compared with a Control condition, Non-Reflective, and Reflective. All students in this course were required to attend a lecture class as well as a once-a-week recitation class where topics presented in the lecture were discussed. This research was conducted in the Recitation classes during the weeks that Metabolism, Photosynthesis, and Respiration were discussed. Three Ozobot Tracks were developed for these biological processes as seen in Figure 3. Over the three semesters, one of the three conditions was implemented in the class.

Non-Reflective Intervention. In the Non-Reflective class, students were introduced to the Ozobots and how to program them using color codes. Each week, the teaching assistant reviewed the content and the instructional technology researcher made suggestions on how to program the Ozobots. Students in small groups were given Ozobot tracks for the topic with blank codes. Each group selected appropriate codes, programmed the Ozobots, and observed their motions. The teaching assistant and the researchers moved among the groups troubleshooting and talking with students about what they observed. At the end of the unit, students took the unit test.

***Reflective Intervention*.** In the Reflective condition, students were introduced to the Ozobots and shown how to program them using color codes in the Recitation class. Each week, the teaching assistant reviewed the content and the instructional technology researcher made suggestions on how to program the Ozobots. Students in small groups were given Ozobot tracks for the topic with blank codes as seen in Figure 2. Each group selected appropriate codes, programmed the Ozobots, and observed their motions. The teaching assistant and the researchers moved among the groups troubleshooting and talking with students about what they observed. After the Ozobot exercise, students were given an in-class assignment with short-answer questions reflecting on what they had observed. At the end of the unit, students took the unit test. This test included the same set of questions and the same amount of time as those in the Non-Reflective and Control conditions. However, it was delivered online using Blackboard and Respondus Lockdown Browser due to COVID19 shutting down the university.

Control. In the Control condition, the students attended the lecture class and the recitation class. In the recitation class, students discussed the topics that had been presented in the lecture class. At the end of the unit, students took the unit test.

Data Analysis

Quantitative

As the assumptions of a parametric test were not met (Field, 2009), a Kruskal-Wallis test was used to determine statistically significant differences in scores from the Control, Non-Reflective, and Reflective group.

Qualitative

Qualitative data was analyzed through reading, color coding, categorizing, and identifying units of meaning from the reflections and interview. The codes were constantly compared through and across interview transcripts and the reflections and revised as fresh meanings emerged.

Results

Quantitative

Data was gathered from the test scores from this unit in the course in each of the semesters and was analyzed through SPSS. Descriptive statistics can be seen in Table 2 for the scores on the unit test for all classes. The Kruskal Wallis analysis of variance for independent measures was used to determine statistical differences among the groups. As seen in Table 2, the mean for the Non-Reflective group 63.87, the mean for the Control was 66.17, and the mean for the Reflective group was 75.85. A statistical difference was found among groups $H(2)$ 10.894, $p = .004$. Post hoc tests were conducted to test pairwise comparisons. We found that test scores from the Reflective condition were significantly different from Control ($p = .006$) and from Non-Reflective ($p = .019$). No difference was found between Control and the Non-Reflective group ($p = .642$).

To answer Research Question 2, a Kruskal Wallis analysis of variance for independent measures was conducted to determine statistical differences between males and females in the reflective class. As seen in Table 3, the mean score for females was 73.54 and the mean score for males was 78.71. A comparison of the scores can be seen in Figure 4. No statistical difference was found between males and females, $H(1)$ 1.671, $p = .271$.

Qualitative Results

To answer Research Question 3, researchers analyzed qualitative reflections and interview notes. Based on the analysis of the qualitative data, three major themes emerged on the use of the Ozobots to support student learning in the classroom. As seen in Figure 5, the major themes are Engagement, Visualization, and Collaboration.

Engagement

Student engagement is the catalyst that propels student success in college courses. It is defined as "the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education (Student Engagement, 2016, para 1). According to Skinner and Pitzer (2012), student engagement is crucial to student learning for three reasons. First, they contend, it is a necessary condition for learning. Second, engagement influences students' experiences in school both psychologically and socially. Finally, engagement is a critical factor in student's academic success as it develops academic resilience and enables students to deal with ordinary stressors, challenges, and setbacks. Student engagement is a multidimensional concept with three components, emotional, cognitive, and behavioral (Fredricks, Blumenfeld, & Paris, 2004). Our analysis of the qualitative data yielded themes under each of these components.

Behavioral Engagement. Behavioral engagement traits within the classroom are considered to be attendance, attention, and involvement in learning and academic tasks (Finn & Rock, 1995). These types of traits were observed by one of the teaching assistants and mentioned in the reflection.

One assistant noted that attendance at the recitation sessions increased for the sessions where the Ozobots were in use.

> In addition, there was an increase in class attendance for lectures in which the Ozobot was used in teaching.

He further noted that:

> The students were actively involved in the learning process, paying more attention, asking, and showing interest in the topic being taught.

Cognitive Engagement. Cognitive engagement refers to students' willingness to use directed or purposeful mental processes to understand complex ideas and learn difficult skills (Fredricks, Blumenfeld, & Paris, 2004). Pohl (2020) asserts that while most cognitive engagement processes are internal and thus not visible, that there are visible indicators of cognitive engagement such as valuing learning, demonstrating self-efficacy, setting personal mastery goals, investing time, attention, and attributing success to effort, appraising the task and one's ability to accomplish the task, planning, using specific study skills or strategies, monitoring progress and adjusting strategies, and self-evaluating and reflecting. While not all indicators are present in this study, a few significant ones were found in our qualitative data.

For example, one of our students confessed that while the Ozobot experience wasn't immediately helpful to him, he found himself thinking about the experience outside of class time.

> After class, I kept thinking about it. I kept seeing it play over and over in my mind.

Through this process, this student was investing time and attention in making sense of the processes that were covered in class. He revealed that he believed that this effort helped him be more successful on the unit test.

Another student shared that she preferred visual learning environments saying, "So, I am like a visual person, like a visual learner." This student had a clear understanding of her learning style and what worked for her as seen in her response below:

> Yes, it helped me understand. Like with the Photosynthesis. I didn't understand it when I read it in the textbook. I found that to be a lot more helpful like understand the process of everything much better.

Thus, she was able to identify a learning strategy that was effective for her and take advantage of the affordances that it offered.

Emotional Engagement. Emotional engagement refers to students' affective reactions to the learning environment (Fredricks, Blumenfeld, & Paris, 2004). This can include interest, boredom, happiness, sadness, and anxiety. We were able to observe some of these reactions within our qualitative data.

For example, one student expressed happiness about the Ozobot experience saying:

> When we did the Photosynthesis. I thought that was really cool on how it represented everything.

Another student shared his excitement at the Ozobot experience and his desire to know more about them saying:

> I looked them [Ozobots] up on Amazon. I wanted to know more about them.

One of the teaching assistants felt that the Ozobots created a warmer classroom environment where students were more invested in their learning. He noted:

> The Ozobot greatly improved the students learning as well as their interest in the concept and course being taught.

Finally, one of the greatest indicators of enthusiasm for the Ozobot project were the videos that students made of their Ozobots performing the commands that students had set for them on the tracks. We frequently noticed that students had their phones out and were making videos of their Ozobots for posting on social media.

However, one of our teaching assistants felt that even the novelty of the Ozobot experience wore thin after a while saying:

> but what I've seen that students I worked with is that many tend to lose interest in this side of Ozobot if it's used for too long

Visualizing

Mayer (2009) has long touted the advantages of multimedia in learning. His research has demonstrated that words and pictures are more powerful than words alone. Based on student and teaching assistant comments, that theory would seem to be applicable here.

One student stated:

> Pretty good. Like I said. I am just such a visual learner just seeing everything that happened in front of me helps so much as a learner, so I think that is really helpful

Similarly, the other student also stated:

> Yes, Like you see it right in front of you as it is happening. So, I am like a visual person,

The teaching assistant also asserted:

The Ozobot showed the concept of light-dependent and light-independent reactions of photosynthesis allowing for better understanding for the students.

Social

The intent of the Recitation period when it was initiated was to provide a collaborative forum for discussion about class content. Over time, however, this devolved into a session where students wanted to quickly complete worksheets and leave. As the instructor noted:

> nobody wants to work with anyone else so that they can complete the assignment quickly but they don't get input so they don't get their understanding challenged or improved when they choose to work alone.

However, during the Ozobot experiences, students were forced to work in groups of two to three because there were only a limited number of Ozobots. One of the teaching assistants stated:

> This allowed for collaboration and communication amongst them facilitating the learning process. They were able to communicate and assist each other with the content. In addition, the students can work in teams to recreate the Ozobot lines to depict the photosynthesis reaction. This promotes collaboration and hands-on learning which aids retention of information.

While the collaboration proved valuable for the Ozobot experience, the instructor noted that in the non-Reflective session:

> I observed that some members of the group were only interested in how the Ozobot worked and not what concept they were looking at.

DISCUSSION

While numerous studies have applied a variety of active learning strategies in Introductory Biology courses, none have attempted to use Ozobots as a means of visualizing complex processes in biology. The results of this research demonstrate that using Ozobot robots to help visualize Metabolism, Photosynthesis, and Cellular Respiration and was effective in improving student learning when combined with reflection. This is consistent with Fink's (2003) assertion that active learning should be followed by reflection whereF students process what they are learning. The unit test scores in the Non-Reflective class showed no significant difference from the unit test scores in the control class. We believe that students in the Non-Reflective class may have gotten caught up in the experience and failed to grasp the overall purpose of the experience.

Robotics competitions have become very popular in elementary and secondary school environments. However, Witherspoon, Schunn, Higashi, & Baehr (2016) found that while females were heavily involved in the younger grades, the competitors are largely male in the later grades. Knowing this, the researchers were concerned that the males in the class would benefit from the Ozobot experience more than the females in the class. Nonetheless, this research found no gendered effect on the learning in the class that experienced the Ozobots with reflection.

High levels of student engagement in the two Ozobot experience classes were evident and were manifested in three ways 1) behaviorally, 2) cognitively, and 3) emotionally. Student attendance was higher in the Ozobot sessions and students were paying more attention and asking questions. Through the visual nature of the Ozobots and their tracks, students felt they were better able to understand and process what they learned. Finally, the students enjoyed the experience. They asked the researchers where they could buy an Ozobot as well making videos of the Ozobots for social media.

LIMITATIONS AND FUTURE RESEARCH

The findings of this study are limited by several factors that could be investigated in future research. First, despite numerous pleas, we were unable to convince more than 2 students to talk with us about their experience. In the Non-Reflective offering of the course, we may have started too late in the semester to find students to interview. In the Reflective offering of the course, we completed the Ozobot sessions just before the university was shut down for COVID19. After that, there was a heightened sense of concern and fear. Students who may have been open to interviewing before, were very reluctant afterward. Future researchers could interview a broader spectrum of students to find their perceptions of how working with the Ozobots impacted their sense of engagement, perceptions of how it supported their learning, and how it supported their sense of efficacy in mastering the content. Second, we could only do three units within the semester. Future research could explore visualizing other biological processes or other scientific processes with the Ozobots to see if they also support learning. Finally, this research was conducted in a small, regional university. The results may not be generalizable to universities in other settings.

CONCLUSIONS

The purpose of this study was to investigate whether Ozobot robots supported student learning of complex concepts in Introductory Biology in a Hispanic Serving University. This research involved three conditions, a Non-Reflective Condition, Control, and Reflective Condition. Researchers found that the use of the Ozobot robots supported student learning the Reflective condition where students programmed the robots, but then reflected on the experience through written questions. There was no difference in performance between the Non-Reflective condition and the Control condition. Students felt that the experience was interesting and supported their learning.

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APPENDIX

Figure 1
Ozobot Evo

Figure 2
An Ozobot robot modeling Photosynthesis

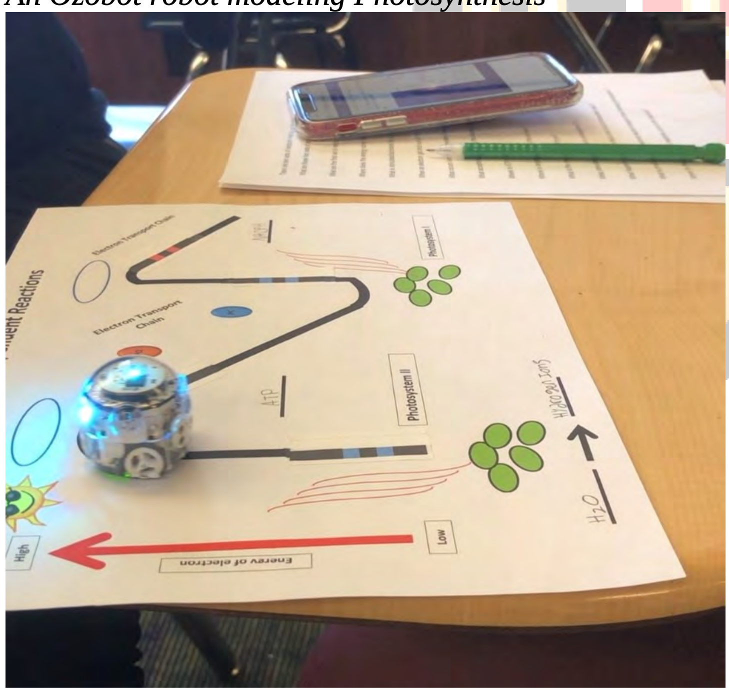

Table 1
Participant demographics

Semester	Condition	# of students	Males	Females	Student Rank

Spring 2019	Non-Reflective	56	26	30	Freshman 32 Sophomore 14 Junior 6 Senior 4
Fall 2019	Control	65	32	33	Freshman 48 Sophomore 11 Junior 2 Senior 4
Spring 2020	Reflective	47	26	21	Freshman 28 Sophomore 7 Junior 7 Senior 1

Figure 3
Ozobot Track for Photosynthesis

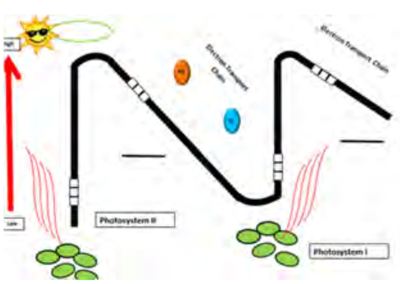

Table 2
Test score descriptive statistics all classes

	N	Minimum	Maximum	Mean	Std. Deviation
Non-Reflective	56	4.00	104.00	63.87	24.76554
Control	65	34.00	103.50	66.17	19.44469
Reflective	47	48.00	101.00	75.85	13.02878

Figure 4
Comparison of Male and Female Scores in the Reflective Class

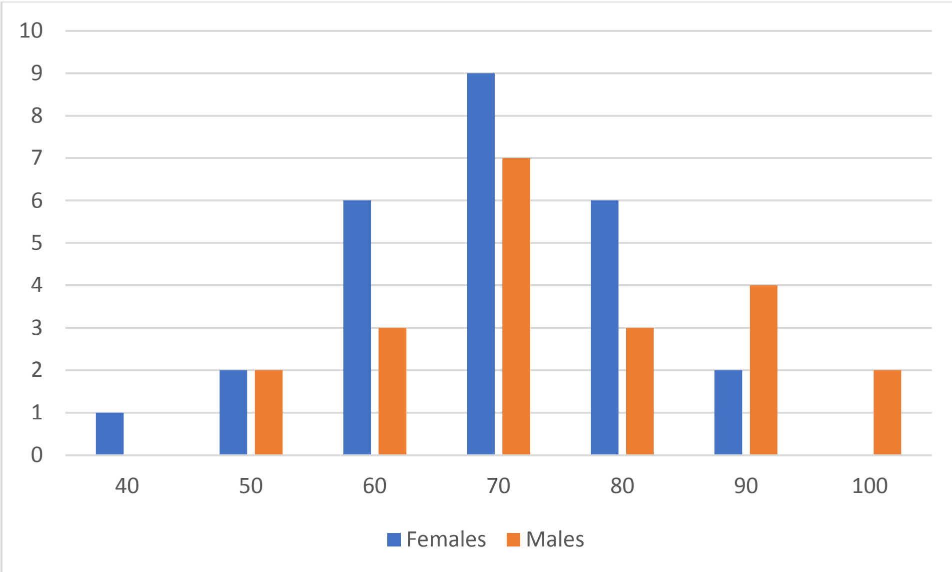

Table 3
Descriptive Statistics Reflective Scores

	N	Minimum	Maximum	Mean	Std. Deviation
Females	26	48.00	94.50	73.54	12.06
Male	21	52.00	101.00	78.71	13.9

Figure 5
Major and minor qualitative themes