Training Future Scientist Program Teaching and Learning Strategies for Biology Non-majors

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[Abstract] Pre-service teachers (PSTs) often are non-science majors and struggle to understand science content. The focus of this pilot study was to identify the teaching and learning strategies to help these PSTs understand biology concepts. Results from quantitative surveys revealed four to five strategies the PSTs identified as most or as least beneficial. Research findings support the use of caring in action, teaching in the student's zone of proximal development and sociocultural theory and beliefs. The implications from this study for science teacher education programs are critical if the goal is to produce future teachers that understand the science they teach.

[Keywords] teaching and learning strategies, Science for non-majors, Biology for non-majors

Introduction

Duchovnay and Ba (2002) reported marginalized urban schools face a host of challenges from lack of resources and ineffective curricula, which both negatively impact effective teaching and learning science. They also reported that effective science and technology education is vital for urban students. According to the research from the Association for the Advancement of Science in 1989 and 1993, the National Academy of Science in 2011, and the National Research Council in 1996, the primary goal is to produce pre-service teachers (PSTs) and future teachers that show caring in action, which can improve student science learning for marginalized students.

The primary rationale for this researcher as she trains PSTs, is to identify what students know in biology, and to equip them with strategies to help them understand and learn biology to transform their future teaching. The purpose was to determine if PSTs modeled caring in action as espoused by Gay (2010) and adopt some of these teaching and learning strategies to understand science as this can influence their future teaching. The intervention was to provide access to nine teaching and learning strategies that support female pedagogy in classroom communication, and the attributes and teaching style of this veteran teacher researcher. The research objective for this study was to identify which teaching and learning strategies were most and least beneficial to the PSTs in studying biology content.

The research question that guided this study was: What teaching and learning strategies were most and least beneficial to help pre-service teachers understand biology concepts?

Literature Review

Self-reporting of PSTs revealed that students enrolled in regular science courses are not exposed to the hands-on, minds-on science that students in Advanced Placement and Honors courses experience, regardless of socio-economic status (SES) of the students. These discoveries contradict the primary goal of the Association for the Advancement of Science in 1989 and 1993, the National Academy of Science in 2011, and the National Research Council in 1996, and indicate a failure in preparing science teachers. By failing to achieve this goal, US students are experiencing the brunt of this deficit in their educational preparation. This was the researcher's history repeating itself, attending segregated public schools in the late 1970's, except that these PSTs were 96 % female and 91 % White female. Determined to make a change to transform these PSTs, the researcher wondered if the strategies she had used for over fifteen years

teaching science in a secondary gifted school in the Midwest serving predominately underrepresented students from diverse backgrounds would work with these White females who were older adolescents.

According to Brickhouse, Lowery, and Schultz, K. (2000), females lag behind males in science. However, it has been the researcher's experience that females have outperformed males in high school science courses when their instructor is a female. Brickhouse et al. (2000) reported females only take the required science courses and rarely choose non-required courses. This influences how female students view themselves with respect to persons that engage in science.

Gaudin (2013) during a Google+ "Fireside Hangout" talked with President Obama, who stated,

> We need to have more girls interested in math, science and engineering. We have half the population way underrepresented in those fields. That means we have all talent downstream that is not being encouraged (p. 1).

Gay (2018) reports females communicate differently than males. Lakoff (1975, 2004) was among the first to suggest this difference in male versus female discourse. Gay (2018) reports White females use a more affiliative accommodative and socially bonding language mechanism. This research supports why some of these strategies were so often selected by these PSTs. Johnson (1993) suggests women are empowered through cooperation, interdependence, collaboration and community building, which were fostered by the majority of the strategies implemented with these PSTs.

Conceptual framework

The rationale for using the *caring in action* approach with PSTs (Gay, 2010) precipitated from the success the researcher had as a secondary teacher. A non-major biology course using Gay (2010 & 2018) culturally relevant teaching (CRT) and Vygotsky's (1978) teaching in the student's zone of proximal development and socio-cultural philosophies produced a student-centered approach for these PSTs. The tenet of culturally relevant teaching in this project focused on the first tenet of culturally responsive caring – teacher attitudes and expectations. Teacher expectations and sense of professional efficacy are interrelated. Teaching efficacy stems from the beliefs teachers hold about their abilities to positively affect the academic achievement of particular students. The rationale for this type of caring is to improve competence, agency, autonomy, efficacy and empowerment in both the role as teacher and/or learner when working with students who are marginalized and/or underserved.

Vygotsky (1978) stressed the fundamental role of social interaction in the development of cognition as a person build community as a central role of making meaning in their learning. He also identified the zone of proximal development as the key concept in understanding the theory.

> [T]he distance between the actual developmental level (of the learner) as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers (Vygotsky, 1978, p. 86).

Another group of researchers identified the zone as the level of potential a learner has when provided access to proper instruction either from a teacher and/or knowledgeable other (Puntambekar and Hubscher, 2005). Bredo (1997) identified this region as a learner's developmental readiness in a specific domain. Bruner (1984) stated a learner's zone of proximal development allows the learner to work on a difficult task as long as the teacher and/or knowledgeable other works with them. Therefore, the learner constructs new knowledge and skills from the knowledgeable other which produce more knowledge to accomplish the understanding of biology. Both of these perspectives are critical for this study since this is a new approach for these students and a new opportunity for the research to see if what worked with predominately underserved students would work with these White females.

Methods and Research Contexts

This pilot study implemented in the Department of Biology of this public predominately White university in the Midwest replaced the traditional non-major biology course pedagogy which had included a PowerPoint (PPT) presentation, stand and deliver lectures with minimum student engagement and inquiry. Many of the PSTs expressed a lack of success in biology and/or hated biology in high school. The researcher thought this student-centered approach could work for most students. The original pacing of this course was adjusted to promote mastery, teaching in the PSTs zone of proximal development, confidence and a transformative shift in the students' interest and understanding of biology.

The new evaluation for the course was comprised of six components: 1) daily quizzes; 2) daily iClicker review questions (4-6 questions) incorporated in a 50-minute PPT presentation; 3) study guides for each summative assessment, plus a whole class review; 4) classroom activities to engage students using white boards to promote cooperative-learning and inquiry with PSTs and peers; 5) 5-6 summative exams; and 6) one weekly 2-hour hands-on, minds-on lab experience.

Participants

The students were second year PSTs that were 96 % female, and 91 % White female from two different semesters. The first semester students volunteered to use the different strategies based on past data from African American female students, which were the same ethnicity as the researcher. The second semester students based their decisions on which strategies the first semester students chose based on the exit survey results from the first semester students which were shared on the first-day of class for the second semester. The ethnic make-up of each class was approximately 9 % African American females, 91 % White Americans (4 % males and 96 % female).

Teaching and Learning Strategies

Culturally responsive teaching (CRT) espoused by Gay (2018) is traditionally focused on the perspectives of ethnically diverse students as conduits for teaching them more effectively. Genderinclusive teachers can also use CRT pedagogy, which is based on the assumption that when academic knowledge and skills are situated within the lived experiences and frames of reference of the students, they are more personally meaningful, have a higher interest appeal, skills are learned and/or adopted more easily and thoroughly. There are four pillars of practice CRT teachers identify as effective, but this project focuses on the first pillar, culturally responsive caring which targets the teachers' attitude and expectations. Combined with student-centered teaching the nine teaching and learning strategies were formulated. The nine teaching and learning strategies were divided into three categories: validating, empowering and transformative. The validating strategies were: daily quizzes, iClicker questions, completing and reviewing the study guide for exams, creating flashcards from PPT slides, and re-writing notes. These strategies teach to and through the strengths of students in a way that is culturally and/or gender validating and affirming. The empowering strategies were: reviewing PPTs presentations and whole class review sessions. These strategies enabled the PSTs to change their behaviors and exhibit culturally relevant and responsive behavior with their peers especially during the whole class review session strategy, because these strategies used a cooperative-learning approach. The transformative strategies were peer study groups and individual review session with the professor. These strategies are explicit about respecting cultures and experiences of historically marginalized US minorities.

Table 1
Teaching and Learning Strategies Categories

Student Outcome	Definition	Teaching & Learning Strategies
Validating	Teaches to and through the strengths of students that is culturally and/or gender validating and affirms.	• Daily Quizzes • iClicker Questions • Completing & reviewing Study guide for exam • Creating flash cards from the PPT slides • Student re-writing notes
Empowering	Enables students to be better human being and more successful learners.	• Reviewing PPT • Whole class review sessions
Transformative	Very explicit about respecting cultures and experiences of historically marginalize US minorities, and it uses these as worthwhile resources for teaching and learning.	• Peer Study groups • Individual review session with the Professor

Validating Strategies

These five validating strategies gave the students immediate feedback on what worked and what did not work for them. The daily quiz was created by the researcher and contained five to eight questions reviewing the primary objectives of each daily lecture and administered in a testing lab on campus after every class period. Each quiz was available for 30 hours after each lecture.

The strategy answering iClicker questions was implemented using a student response system to give immediate feedback of mastery and/or non-mastery of biology content, student attendance and student engagement. This strategy was incorporated in each daily classroom lecture to track each student's attendance and content understanding.

Completing and reviewing the study guide for exams with the professor as a whole class was a strategy to allow students to compare their responses to the correct responses for each question. Creating flash cards from PPT slide*s* was a strategy where the student turned the PPT slides into flash cards by placing three PPT slides on one page with lines for additional notes on the opposite side.

Students re-writing their notes required the student to immediately revise their notes after class to fill in holes for incomplete statements during the lecture. Students also could define words and create detailed diagrams to add to the notes provided during the lecture.

Empowering Strategies

The purpose for the two empowering strategies was to build the PSTs confidence and stamina to learn and understand the course content and aid each PST to become a better science teacher. Reviewing the PPT from each lecture was selected for students that need assistance with notetaking by allowing them time to add new information not included on the PPT in the notetaking section of the PPT. The whole class review sessions were implemented by dividing the class into four quadrants with 15-25 students in each group. Each group was assigned select questions from the study guide to record their answers and subsequently

choose one student to share their responses after each group completed their assigned questions with the whole class review.

Transformative Strategies

Finally, the rationale for the two transformative strategies was to motivate these students to share with their peers their new knowledge and strategies to overcome challenging course content. The individual review session with the professor strategy was valuable for students that were struggling, reticent in a social setting, and/or their schedule did not match any of the other review sessions provided. The researcher was very comfortable supporting these young White female PSTs because it reminded her of the support and role-model effect she had on her secondary students who were predominately African American.

The peer study groups contained 6-10 students who volunteered to work cooperatively with one another to address specific questions and concerns from each student. The researcher encouraged these students to facilitate additional peer study groups in their dorms and/or other learning communities to accommodate students that could not attend the original peer study group with the professor due to scheduling conflicts.

Data Analysis and Findings

Surveys were conducted each semester that included a Likert scale ranking for each of the nine strategies. Data in Table 2, column one, are presented as the percentage of PSTs that strongly agreed or agreed that a teaching and learning strategy was beneficial. Data in column 2 are the percentage of PSTs that strongly disagreed or disagreed that a teaching and learning strategy was beneficial, N = 110 PSTs. The second semester PSTs made a prediction on the first survey which strategies the PSTs would find most and least beneficial to learn biology Table 3.

In this pilot study, we sought to unearth which teaching and learning strategies were the most and least beneficial to these PSTs to understand biology content. Table 2 displays the teaching and learning strategies that were the most and least beneficial to these PSTs to understand biology content. This pilot study addressed one research question, *What teaching and learning strategies were most and least beneficial to help pre service teachers understand biology concepts?*

Table 2

Teaching & Learning Strategies Identified as Most and Least Beneficial; N = 110

Most beneficial strategies	Average Score (%)		Least beneficial strategies	Average Score (%)
Reviewing Power point	82		Daily Quizzes	46
Completing & reviewing study guide	79	PPT	Creating flash cards from slides and/or class notes	39
Answering iClicker questions	68		Review sessions with the Professor	29
Class review sessions	50		Peer study groups	22
			Re-writing notes	18

The most beneficial strategies from the exit surveys from these PSTs to study the biology content from both semesters were: 1) reviewing the PPT (85 % and 79 %); 2) completing and reviewing the study guide for exams (84 % and 74 %); 3) answering iClicker questions (77 % and 59 %); and 4) class review

sessions (57 % and 42 %). The least beneficial strategies for these PSTs were: 1) daily quizzes (46 % and 46 %); 2) creating flash cards from PPT (36 % and 42 %); 3) review session with the professor (33 % and 25 %); 4) peer study groups (36 % and 7 %); and 5) re-writing notes (13 % and 22 %). The results from each strategy decreased slightly between the semesters, but the least beneficial strategies had an average percent score between 18 – 46 %.

Results from the *first-day survey and exit survey* for the second semester students compared with the predictions from these students on the first-day survey largely did not match what these students reported on the exit survey. See Table 3. The only strategy that matched the students' prediction from the first-day survey was reviewing PPT (81 % and 79 %). Despite the difference on how the students' rated the strategies, several of the strategies were used by these PSTs in the course and the PSTs consistently showed an increase on each course exam versus the daily quiz scores.

Table 3

Pre-service Teacher Results from Second Semester; N = 40

Teaching & Learning Strategies	Predicted (%)	Actual (%)
Answer iClicker questions	98	59
Completing & reviewing study guide	97	74
Daily Quizzes	87	46
Creating flash cards from PPT slides and/or class notes	87	42
Class review sessions	84	42
Reviewing Power point	81	79
Review sessions with the Professor	79	25
Peer study groups	63	7
Re-writing notes	49	22

Discussion

The four most beneficial strategies supported the research of Bravo (2007) who reported having an opportunity to choose your own strategy could cause a paradigm shift for females to promote culturally responsive and relevant teaching as well as gender equity. Rennie and Parker (1997) discussed the pedagogic approaches that are more "gender inclusive" which are: 1) cooperative-learning groups; 2) hands-on and minds-on activities; and 3) access to role models and mentors like the researcher. Both of the empowering strategies were two of the most beneficial strategies the PSTs' rated $\geq$ 50% or higher. Reviewing the PPT (82%) from each lecture empowered the PSTs to better understand and learn the biology content information on the PPT. The PSTs also used other resources such as, personal notes, examples discussed in class, textbook readings, and Internet resources, etc. to help the PSTs better understand and learn the information discussed in class.

The validating strategy completing and reviewing the study guide (79%) when partnered with the second empowering strategy, participating in whole class review (50%) with the professor provided the students an opportunity to ensure the responses they recorded on their study guide were correct and the students were not studying incorrect information. This strategy also revealed misconceptions and/or wrong responses in addition to providing students that had not completed their study guide an opportunity to begin working on completing this valuable review tool. Whole class review sessions support the constructivist philosophy that provides review access to the entire class since the peer study groups only provided review opportunities to one third of the class. The final validating strategy, answering iClicker questions was rated

68% which provided the students an opportunity to determine what they knew from each lecture and what they still needed to learn. The data retrieved from these questions provided the researcher evidence on what her students knew and how and what to discuss for the next class lecture.

The five strategies that were least beneficial to the majority of the PSTs support the research of Bravo (2007) and Rennie and Parker (1997). Small group review sessions with the professor (29%) and peer study groups (22%) were introduced because the majority of the students were female and this strategy aligns with Maslow's Hierarchy of Needs philosophy (Maslow, 1971) which caters to the affective domain of female students. Another attribute of these strategies was teaching in the student's zone of proximal development, espoused by Lev Vygotsky in his sociocultural theory (1978) which was a positive instructional match, especially since the majority of student learning is essentially social.

The two validating strategies that were least beneficial to the majority of the PSTs were daily quizzes (46%) and creating flash cards (39%). These two strategies were introduced to show these PSTs how the biology content fit together in small sections to avoid cramming for the tests. Even though these two strategies were least beneficial, taking the daily quiz allowed the PSTs to know what to review further for the high-stakes summative assessment. The primary goal of these two strategies was to help increase PSTs' science content knowledge. The overall quiz average for each semester was <70% and the overall summative assessment average each semester was > 82 %. This difference possibly supports using Lev Vygotsky (1978) philosophy by teaching in PSTs' zone of proximal development, using his socio-cultural theory and the PSTs taking a daily quiz so the PSTs knew what to review for the high-stakes assessment. The final validating strategy to rewrite their notes (18%) was rated least beneficial, but this strategy required PSTs to immediately begin this strategy after class.

Suggestions and Educational Implications

Allowing the PSTs to voluntarily choose and use one to two of these teaching and learning strategies to hopefully produce outcomes that were validating, empowering and transformative for White female PSTs was the primary goal of this pilot study. The rationale for introducing these nine teaching and learning strategies can possibly empower the diversity of learners most higher-education institution are exposed to in the 21st century that can benefit the students as well as faculty and institution these students choose to attend. Access to these strategies could produce the paradigm shift these White females needed to be successful teachers in their educational program as posited by the researchers cited. Adoption of these strategies could help these PSTs: 1) understand and master the science concepts for this course; 2) identify the concepts they struggled with and a strategy to help them understand this concept; and 3) equip the PSTs with teaching and learning strategies they could use in other courses and/or share with other peers that have similar issues with learning. The biggest attribute this researcher shared with these predominately White PSTs was she believed in them first and modeled caring in action, with a goal of enabling these future teachers to become competent and confident to teach science in their future classrooms.

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