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The Enhanced *Flipped Classroom: Increasing Academic Performance with Student-recorded Lectures and Practice Testing in a "Flipped" STEM Course*

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Undergraduate psychology students at a mid-Atlantic HBCU were assessed on their knowledge of synaptic transmission, the multi-step process of brain cell communication. Comparison of final grades revealed that the use of the flipped classroom format along with learning techniques, self-explanation and practice testing increased the final course grade over previous semesters. Multiple sessions of practice testing integrated the use of mobile technology to make grading easier. Self-explanation required that students use online videos to explain the process in their own words. These techniques increased time studying the course material and led to higher exam grades. Thus, the use of effective learning techniques, embedded within STEM courses may play a significant role in increasing retention in STEM disciplines among African Americans.

Keywords: *STEM, education, flipped classroom, academic performance, HBCU*

INTRODUCTION

In a required course, Physiological Psychology, undergraduate psychology students at a mid-Atlantic historically Black college and university (HBCU) were assessed on their knowledge of synaptic transmission, the multi-step physiological process of brain cell communication. The students were asked to describe the neural network communication process in terms of the anatomy of the nerve cell, ion transfer across the cell membrane, and how ionic changes would register on an oscilloscope graph. These topics comprised the majority of the midterm exam and were a major component of the cumulative final exam.

All students enrolled in the course were Psychology majors and most were seniors. During discussions held during the introductory lecture, many students routinely expressed a dislike for biological science. Students commented that courses with a focus on math or biology content are more challenging. One reason for this view may be the fact that required courses within the Psychology curriculum, such as Qualitative Methods, Experimental Psychology, and Anatomy and Physiology are spread out, if taken in the recommended sequence, across six semesters. In addition, earlier math/sciences courses in General Education are ordinarily taken during freshmen or sophomore years. Therefore, it is often difficult for students to see the relationships and similarities between the subject matter of each course.

Addressing the myriad and varied reasons behind the lower numbers of college students, particularly minority students, who attain degrees in science, technology, engineering, and mathematics (STEM) disciplines are necessary in order to reverse current trends. As of 2008, less than 10% of all bachelor's degrees are awarded to African American and Hispanic students (National Science Foundation, 2010; Palmer, Maramba, & Dancy, 2011). Nonetheless, according to U.S. Census Bureau data, 2020 population projections indicate that minority populations will comprise nearly 40% (66 million people) of the American workforce (Toosie, 2012). Reducing attrition rates in STEM majors and increasing enrollment and graduation rates is vital for increasing the number of future workers and for ensuring that the STEM workforce is diverse and inclusive (National Science Foundation, 2010; Palmer, Maramba, & Dancy, 2011; Soldner et al.,

2012). Therefore, the factors influencing these students to drop out of college or to switch to non-STEM majors must be assessed (Palmer, Maramba, & Dancy, 2011).

At the university in which this study was conducted, psychology professors who teach courses with more biology or math content commonly report lower average class grades than other courses in the department. The activities communicated in this report were undertaken by a newly hired instructor in response to consistently lower average course grades (approximately 68%). Low averages were recorded for 3 consecutive semesters in the course Psychology 412, Physiological Psychology. A grade of C (70%) is considered passing and is necessary to meet graduation requirements. Various class activities were given throughout the semester that were aimed at increasing the overall class average grade and a secondary goal of encouraging students to use effective learning techniques in other science or math courses.

The need for a more effective pedagogy when teaching science, technology, engineering, and math (STEM) courses has been emphasized in various reports (American Association for the Advancement of Science (AAAS), 2010; National Research Council of the National Academies, 2003). STEM has been described as much more than math and science education, but a way of thinking that views technology and engineering as tools in solving problems and promoting innovation (Bybee, 2010). Recent attempts have been made to integrate successful STEM initiatives from around the country into a strategic research agenda (Labov et al., 2009). The goal is to determine the approaches and conditions most likely to address the country's need to increase the number of students with STEM degrees. Most of the focus has been on increasing the number of high school graduates who are prepared to major in STEM disciplines. However, another less costly approach would be to maintain the number of STEM majors who enter college until these students receive a degree (President's Council of Advisors on Science and Technology, 2012). This approach may require student academic enhancement as well as, more effective pedagogy used in STEM courses.

One teaching technique that has shown impressive results is known as the inverted or "flipped" classroom. The flipped classroom has been used increasingly to teach college courses such as physics, biology, and chemistry (Arnaud, 2013) and has also been used in K-12 classrooms (Bergmann & Sams, 2012). This technique encourages students to access course instruction that has been pre-recorded and posted online, leaving class time for problem solving or reviewing, rather than content delivery (Bergmann & Sams, 2012). In a recent interview, founders of the flipped classroom movement, Jon Bergmann and Aaron Sams, explained that a flipped classroom shifts the emphasis of teaching from the instructor to the learner (Noonoo, 2012).

The present study reports the use of the learning techniques used in a hybrid model of the flipped classroom, which consisted of self-explanation and practice testing. Students used self-explanation by creating and uploading a video of themselves narrating the process of synaptic transmission. Practice testing was used in several class sessions. During these sessions, students produced labeled cell drawings, without aid, on a blank sheet of paper. Afterward, they accessed online resources pertaining to the test information in order to check their own work. One online resource was the e-book version of the textbook. Students had the option of purchasing individual e-chapters of the textbook as the semester progressed, instead of purchasing the entire hard copy edition at the beginning of the semester. Another resource used to check their work was a set of illustrations posted on the course blog. The free blog site was developed by the instructor from a simple template provided by Google Blogger™ (http://www.blogger.com/template_designer_2#a). Since the classrooms were equipped with wireless capability, the Internet could be accessed during class time through students' mobile devices or laptop computers.

Students were able to self-test in class because they were provided with a link to the instructor's pre-recorded lectures. This allowed the use of class time to assess the level of students' retention and understanding of the course material, rather than repeating lecture content. The use of some, but not all classroom time for review and practice testing instead of lecture delivery represents a hybrid version of the flipped classroom. The inclusion of specific learning strategies focusing on the use of technology as part of the course represented an *enhanced* flipped classroom. A detailed list of the online products used in this article is presented in Table 1.

Table 1

Online Resources

Online Resources	Purpose
e-book version of textbook chapters (*Physiological Psychology* by Kalat) Cengage Learning Custom Agreement	Student textbook purchase $13/chapter
Course Blog Site- Google Blogger™	Additional course resources
Wireless class room	Access to online material while in class
Websites	
www.ITeachMeAmerica.org	Self-explanation learning technique
www.Doceri.com	"Whiteboard" presentation for Ipad
www.Quizlet.com	Electronic flashcards for practice testing
YouTube®	Uploading of Self-explanation narratives
Blackboard®	Web-based course management system
www.danielvspencer.org	Additional resources for the flipped class-room

BACKGROUND LITERATURE

The Need for Basic Academic Skill Building

When most college students read a textbook they do so with a highlighter in hand (Bell & Limber, 2010). Highlighting and annotating provides a way for students to emphasize portions of the text that are important and worth remembering. Unfortunately, most students will not remember the highlighted material, regardless of major (Faw & Waller, 1976). Although widely used, highlighting and re-reading are among the least effective study techniques, according to a recent review (Dunlosky et al., 2013). Research, cited by Dunlosky and colleagues (2013) indicated that the most effective learning techniques were frequent practice testing and distributed practice testing. Regrettably, these techniques are likely the least preferred by students because they are very time consuming.

The comprehensive review of learning strategies (Dunlosky et al., 2013) compared 10 different learning techniques that had been evaluated in cognitive and educational psychology studies. The effectiveness of each learning technique was rated as high, medium, and low based on criteria from four categories: (a) generalizability across learning conditions, (b) student characteristics (such as age, ability and prior knowledge), (c) type of material (simple concepts to mathematical problem solving), (d) and outcome measures of student performance. As stated earlier, practice testing and distributed testing received the highest recommendation as they have been found to be very effective and are easily used. Elaborative interrogation, self-explanation, and interleaved practice received moderate ranking because they were less likely to have shown effectiveness in empirical studies. Summarization, highlighting (or underlining), keyword mnemonic, and imagery and rereading received low rankings, primarily because their effectiveness in boosting student performance has not been shown.

Highlighting or underlining was found to be among the least effective learning techniques in terms of the outcome measure: student achievement. Studies have shown that when students are tested on retention, those who highlight the text do not perform differently than controls on academic assessments of the material (Fowler & Barker, 1974; Hoon, 1974, Idstein & Jenkins, 1972).

The primary responsibility of a course instructor is delivering the content material, not providing training in basic study skills. However, if students were taught more effective study skills during content delivery, then there would be the potential for not only better performance in

that one course, but a transferrable skill set that could be utilized in other courses as well. Including academic skill building as part of the course content could have a broad impact across an academic setting if the end result was an increase in student GPA.

Learning Skills and GPA

The substantial literature on student learning and achievement indicates that college GPA is related to a variety of factors. For instance, a recent meta-analysis of the Student Adaptation to College Questionnaire used a database constructed from 237 studies conducted between 1872 and 2010 (Credé & Niehorster, 2012). The analysis examined 8 broad categories that influence students' academic performance and retention of information. The categories included demographics, prior achievement, college experiences, coping styles, social support, and relationships with parents. Analysis of results from a combined total of over 44,000 respondents revealed that overall college GPA and freshman GPA were most strongly related to the criterion Academic Adjustment and not Social Adjustment, Personal-Emotional Adjustment, or Institutional Adjustment. However, the authors cited evidence of possible moderators, thereby implying that there may be other unidentified factors influencing Academic Adjustment (Credé & Niehorster, 2012).

There are also studies that have examined the relationship between particular learning and study strategies and GPA. In one study in which the Learning and Study Strategies Inventory (LASSI; http://www.hhpublishing.com/_assessments/LASSI/samples.html) was used, 8 of the 10 scales were positively correlated with GPA. The scales included Attitude, Concentration, Information Processing, Motivation, Self-Testing, Use of Study Aids, Time Management and Test Strategies (Griffin et al., 2012). It is not practical to suggest that instructors attempt to address all of these factors; however, the learning techniques discussed in this present article cover two of the correlated factors: self-explanation, as a Study Aid, and practice testing, as a form of Self-Testing.

Self-explanation is a study technique in which students explain how new information is related to known information. When used in problem-solving courses such as math, chemistry, or physics, students explain each individual step used during the process of solving a problem. For example, a study with kindergarteners showed that children who retold a story over 8 weeks improved in their understanding of structural elements and in complexity of oral language skills when compared to students who drew illustrations of the original story (Morrow, 1986). A popular form of this technique is known as the "I Teach Me®" method (www.ITeachMeAmerica.org). This method, a type of self-explanation, espouses the use of individual lecterns and whiteboards so that students of any age learn to teach to an imaginary classroom and in doing so, learn the material themselves.

Dunlosky and colleagues (2013) stated that students from early childhood to adulthood have benefited from using self-explanation as a study technique. In addition, self-explanation can be used across various types of content. In a seminal paper, Berry (1983) showed that self-explanation supported the learning of different kinds of math problems across various grade levels. The types ranged from simple addition by kindergarten students to algebra formulas for older students. The technique has also been used in learning from texts, including short narratives and longer expository texts.

Practice testing is self-testing or taking a practice test for material while it is being learned. Practice testing is distinct from a classroom test because it is considered a low stakes or no-stakes learning activity. Flash cards (including electronic versions) are considered practice testing, as well as practice problems or questions included at the end of textbook chapters. A recent review provides evidence that regular retrieval practice not only enhances student retention, but also helps students study more, to discover gaps in their knowledge, and focus their study efforts on more difficult material (Roediger, Putnam & Smith, 2011).

Although the positive effects of testing have been reported for over a century, frequent testing does have limitations, as each test requires grading. For instructors of courses with large enrollments or those with heavy teaching loads, each additional grading assignment translates into

more hours of work per class. Frequent practice testing also consumes valuable time that could be used for content delivery. While students are being tested on old material there is less time available to introduce the newer course content. This could be problematic for courses that are taught in a sequence, or in which there are multiple sections where a certain amount of content must be covered.

This study addressed these limitations in two ways. First, the synaptic transmission process was broken into smaller segments for in-class practice testing. The answers to the test were presented to the class on screen following the assessment. The students were then instructed to mark incorrect answers and to find the correct answers using their cell phone, laptop, e-book and so forth. The tests were then self-graded and handed in so that the scores could be recorded. The entire test and grading process took between 15 to 25 minutes to complete, depending on the segment being reviewed. Second, the comprehensive lecture that outlined the entire process of synaptic transmission was posted by the instructor as a YouTube® video and linked to the class Blackboard® page and to the course blog site. This allowed students to review the material frequently, without the use of class time. This teaching technique is known as the "flipped" classroom. Research indicates that the use of recorded lectures may be beneficial to student learning when used as a supplement, but not a substitution for regular class attendance (He, Swenson, & Lentz, 2012; Williams, Birch, Hancock, 2012).

PURPOSE OF THIS STUDY

The purpose of this study was to encourage the use of more effective leaning techniques for psychology students in the course Physiological Psychology. The primary goal of the study was to increase students' academic performance in the course. The secondary goal was to provide learning techniques that could be used in other STEM courses.

The flipped classroom along with practice-testing and self-explanation learning methods were used in order to increase the amount of time students were engaged in the course material. Additionally, it was used to increase the number of informal assessments (practice tests) that the students employed in learning the material. An additional aim was to have students apply higher level thinking skills as outlined in Bloom's revised taxonomy (Krathwohl, 2002). This was accomplished because students had to understand, interpret, and explain the course material in their own words in order to generate their narration.

PROCEDURES

Two interventions were chosen after carefully considering how they could best be adapted to the course. Online lectures had been introduced the previous semester in an attempt to create the flipped classroom format. However, the course content did not require that every class session be flipped, but rather that about one in four sessions use the flipped format. The topic of synaptic transmission was introduced in week three of the course, following lectures on gross brain anatomy and neural development. A 15 minute lecture was recorded by the instructor using Doceri® (www.doceri.com), an online site that creates a whiteboard effect on a tablet computer. The video content focused on illustrating the process of synaptic transmission, used concepts from physiology and cell biology, and was drawn on an Ipad® tablet. Twenty-four slides were used to explain the chemical/electrical signal transfer between a network of three neurons.

Students viewed the colored illustrations, which included a moving pointer and corresponding audio content. The instructor was not pictured on the slides. The lecture was then posted to a YouTube® site where it could be viewed by students on their laptops or mobile devices. The link to the site was posted on the course Blackboard® site and on the course blog site.

One week after the material had been introduced students were given an announced practice test, which consisted of a small portion of the process, (i.e. neuron morphology). A list of terms that had been previously posted as a Blackboard® announcement was posted on the board in the classroom. Students were given ten minutes to draw and label the posted terms on a blank sheet of

paper. When the time expired, the correct answers were presented and students were then instructed to access the course blog, the textbook chapter, which was an e-book, or any other online source to view the corrected items. Students then graded their own papers and turned them in to the instructor.

After viewing the instructor's online video lecture and participating in several practice test sessions, students were then asked to record a video of them teaching the lecture material to an imaginary class. The student video links were uploaded to an instructional site (Blackboard®) and were viewed by the instructor. Class time was spent correcting omissions and reviewing common misunderstandings or misconceptions that were revealed in the student videos. All students who completed the video assignment received maximum credit for it.

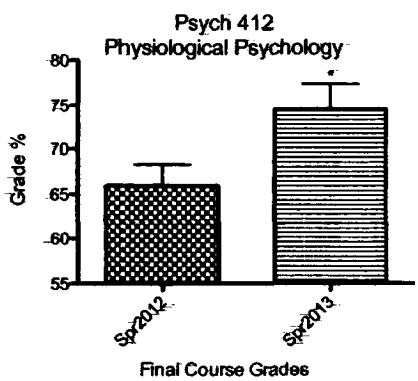
The additional feature of having students orally deliver the lecture material to the instructor in their own words relied on the ability of students to easily upload and the video recording. When stored on YouTube®, students simply posted the links on a Blackboard® Journal page created for that purpose. Larger files that could not be stored on YouTube® employed other storage sites such as Google Drive® or iCloud®. The video file could then be downloaded and attached to the student's Blackboard® assignment page. Several students used the audio feature found in Microsoft Power Point®. The self-explanation learning method employed higher level thinking skills because students had to explain, interpret, and summarize the material. Higher level thinking becomes more important as students' progress to increasingly more difficult courses, especially in STEM majors.

RESULTS

Quantitative Results

Results between subjects using a two-tailed *t*-test of student performance in the course was significantly higher (t (79) = 2.22, p = .029, Cohen's d = .5) than in a previous semester in which the learning techniques, self-explanation, and practice testing, were not used. Figure 1 shows the mean final grades of two sections of Physiological Psychology, Psych 412, taught in the spring of 2012 (M = 65.88±3.89$_{sem}$) and the spring of 2013 (M = 74.51±2.84$_{sem}$).

Figure 1

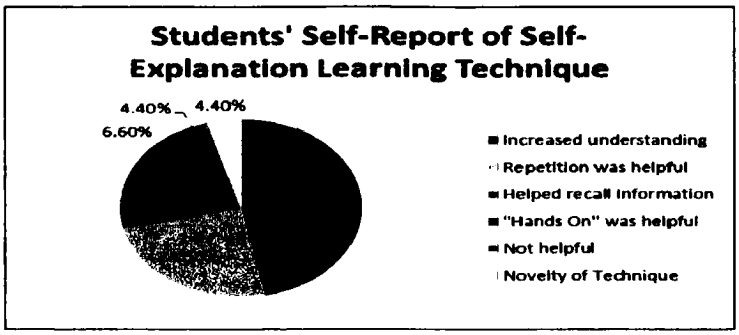


Qualitative Results

Students were asked to respond to the following question: "Did the neuron story video project help you to learn the process of synaptic transmission? If yes, please briefly explain. If no, briefly explain why not." A thematic analysis of the responses yielded six themes. Students indicated that the Self-Explanation learning method was helpful in the following ways: it introduced a novel

study technique and the "hands on" aspect of the project was beneficial. Overall, the Self-Explanation method increased their ability to recall information, whereas the repetition of information helped increase their understanding of the content. In contrast, approximately 4% of students stated that the method was not helpful because they did not understand the material (see Figure 2 for percentages).

Figure 2



These results indicate that there was a significant difference in grades between each class section (nearly one full letter grade). Additionally, a moderate effect size suggests a relatively strong relationship between the difference in performance and use of the study techniques. Moreover, these results suggest that students attributed their success in the classroom to using the aforementioned techniques. The majority of students reported that delivering the lecture material helped them increase their understanding of the course content and aided them in the recall of relevant information.

DISCUSSION

The traditional college course applies a didactic form of instruction in which students are taught the course content during a class session and the necessary learning presumably occurs outside the classroom when the student combines lecture notes, the course textbook and other resources to study the material. The time spent studying outside of class has primary importance. However, many students either fail to devote enough time to study or do not use the time spent studying in the most efficient manner (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013).

In this present study, two learning techniques were combined in an attempt to better deliver course content and to simultaneously expose students to more effective learning strategies. A simple and easy to use form of practice testing was paired with a variation of a technique not often used in the college setting, self-explanation. Self-graded practice tests were given intermittently and often during the semester. Students were asked to draw and label synaptic processes or neural anatomy without aid on a blank sheet of paper and then checked and graded their own work for immediate feedback. Time was available for the self-practice because students could access the instructor's explanation in an online video. Self-explanation requires that student describe some aspect of the learning process while the material is being learned. Self-explanation causes students to review the material more often and may enhance learning by supporting the integration of new information with prior knowledge as they create their own narratives. The student narratives were then recorded by webcam, laptop, tablet device or mobile phone and then uploaded to a storage site. The student then posted the link to the video or the actual presentation file onto a course Blackboard® Journal page designated for that purpose. Together, these techniques helped augment the more commonly used study techniques of highlighting and re-reading. They also served to provide students with a more accurate assessment of their knowledge and understanding of the material before the major exams.

The learning techniques: self-explanation and practice testing were shown to result in improved average course grades when compared to a previous semester of the same course that did not use the study techniques. An entire letter grade improvement for a class is significant and shows that introducing these learning techniques in a STEM course could play a significant role in improving African American STEM student retention.

CONCLUSION

The combined method of using self-explanation and practice testing holds promise as a way to increase academic performance in flipped courses and to foster an effective study method that can be used in subsequent courses in which the flipped classroom method is not used. Students spent more time engaging the course content in order to produce a summary of the biological process in their own words and using their own illustrations. The increased time and engagement resulted in improved performance on the midterm and final exams. Students also appreciated the flexibility of accessing course material on various mobile devices, particularly their phones. Introducing learning techniques, as a part of a STEM course, has the potential to improve African American STEM student retention, especially if the techniques were reinforced in other STEM courses.

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