The impact of white boarding on learning by secondary school biology students

Diandra Bush
6827 Nash, Rd.
North Tonawanda, NY 14120, USA

e-mail: Bushde18@yahoo.com

Abstract

This project used a constructivist teaching method, "white boarding", in a high school biology classroom. This study was conducted to measure the effectiveness of white boarding activities. White boarding is a term used to describe the student use of a 3' x 2' sheet of tile board to record group work. After the teacher presents a question or problem, students write on the white board with dry erase markers. Here, white boarding was used to foster cooperative learning of biochemical processes in living organisms, diffusion through a cell membrane, and protein synthesis. Six biology classes that used white boarding were compared to six classes that received the traditional method of teacher-centered instruction. This interactive method, when coupled with students' focusing on problematic concepts, has been shown to increase the engagement and understanding of students in physics classrooms. This study is the first to measure the effects of white boarding activities in high school biology classes. Test scores and a survey were used to measure the academic benefits of white boarding activities. A significant ten-point increase in test scores was recorded for students who employed white boarding activities when compared to those who did not experience white boarding. Neither teacher or student gender affected the academic benefit students received through white boarding. However, there remained a difference in the amount of academic benefit realized by students through white boarding associated with ethnicity. Even so, African American students that white boarded consistently achieved higher exam scores than African American students receiving typical instruction. In spite of the known benefit associated with white boarding, 84.4% of these students disagreed with the statement that white boarding had helped them achieve higher test scores. In contrast, 91.8% of these students agreed that white boarding provided dialogue, 71.6 % agreed that white boarding aided in student learning, and 70.9% agreed that white boarding helped them to reach and develop solutions to problems. White boarding promoted a student centered learning environment, and fostered student collaborative learning**.** White boarding gave

the students the opportunity to have academic discussion in the classroom, to reach and develop a shared solution to important questions, and to resolve their misconceptions.

Introduction

Principles and practices of cognitive psychology continue to have considerable influence on educators (Eggen and Kauchak, 1999). The dominant conceptual framework in science education over the past two decades has been constructivism (Trowbridge, Bybee, and Powell, 2000). Constructivism is a cognitive view that learners actively construct or form their own understandings of phenomena (Ausubel, 1968). At present there is controversy among science teachers about how students conceptualize required content (Trowbridge, Bybee, and Powell, 2000). Under constructivism, the student learns by constructing his/her own body of knowledge from the information they possess. Unfortunately, students can construct misunderstanding. This has lead teachers to believe that they should have a greater role in tracking the progress of individuals in the classroom (personal communication, Ms.Valo, September, 2003).

In meeting with in-service high school biology teachers, several difficult topics were identified where a teaching technique is needed to help keep students on task and facilitate learning. Cooperative learning research indicates that collaboration among students increases the level of student success (Slavin, 1996). According to the National Science Education Standards, "Working collaboratively with others not only enhances the understanding of science, it also fosters the practice of many of the skills, attitudes, and values that characterize science" (NRC, 1996). White boarding may be a collaborative education technique that helps keep students on task and facilitates constructivist learning.

White boarding was first used in physics classes (Wells, Hestenes, and Swackhamer, 1995). White boarding requires a group of three to four students to share their understanding, knowledge, and experience, in response to a specific question or problem (http://physcised.buffalostate.edu/AZTEC/BP_WB/index.html). As a group, the students then develop and record their shared response on a white board. These boards are then displayed around the room and the class reviews each board and compares their separate understanding and conclusions (Henry, Henry, and Riddoch, 2003).

When I interviewed biology teachers at a faculty meeting, I found three areas of student difficulty: biochemistry, diffusion through a cell membrane, and protein synthesis. In-service teachers describe that their students' lack of understanding is due to students' not possessing a well founded framework to which newly acquired concepts can be integrated (Ausubel, 1968). This lack of integration is suspected to be at the base of student difficulties concerning concept formation and their application of acquired knowledge in exercises (Lee and Fensham, 1996). White boarding may help students integrate newly acquired concepts into their personal framework of knowledge. In addition, white boarding helps students meet New York State Standards 1 and 4 (http://www.nysatl.nysed.gov/standards.html).

- Standard 1 - Students use scientific inquiry and engineering design to pose questions, seek answers, and develop solutions.
- Standard 4 - Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science

Veteran high school biology teachers find biochemistry a difficult and frustrating topic to teach (personal communication, Ms. Valo, September, 2003). Teachers think that students tend to do very poorly on informal assessments due to the fact that they cannot understand biochemistry. According to New York State Science Standard 4, key idea 5: "students will explain the basic biological processes in living organisms and their importance in maintaining dynamic equilibrium" (http://www.nysatl.nysed.gov/standards.html). Feedback from in-service science teachers indicated that students especially have a problem with topics dealing with biochemical processes, such as biological catalysts, enzymes, chemical change, and synthesis.

In *Demonstrating Diffusion: Why the Confusion?*, Panizzon (1998) states that diffusion as a fundamental physical process, is often misunderstood. According to New York State Standard 4, key idea 1: "living things are both similar and different from each other and from nonliving things" (http://www.nysatl.nysed.gov/standards.html). Several in-service high school biology teachers describe that their students have a difficult time understanding diffusion through a cellular membrane. Students do not know, or correctly apply, the concepts of diffusion, osmosis, permeability, equilibrium, hypotonic, hypertonic, and isotonic solutions. Students do not make the logical connection between semi-permeability of cell membranes and diffusion through a synthetic membrane.

In *A Class Exercise for Teaching the Genetic Code*, Nissani (1989) states "biochemistry of protein synthesis is hard ". In addition, Burns (1993) concludes that teaching abstract concepts, like protein synthesis, is a difficult task for high school students because their learning is often characteristic of concrete thinkers (http://www.accessexcellence.org/AE/AEPC/WWC/1993/creative_exp.html). When I interviewed in-service high school biology teachers, they identified that their students have difficulty understanding protein synthesis (personal communication, September, 2003). Though New York State Standard 4, key idea 2 states that: students will "describe and explain the structures and function of the human body at different organizational levels" (http://www.nysatl.nysed.gov/standards.html), these teachers identify that students are unable to correlate one concept to another.

In this study, three problematic topics in biology education were chosen after interviewing several in-service high school biology teachers. These problematic topics include teaching biochemistry, diffusion, and protein synthesis. These teachers uniformly agreed that many students have tremendous difficulty in understanding and applying these concepts throughout the school year. The purpose of this study was to conduct an investigation into the effectiveness of white boarding in high school biology classrooms where students work in small cooperative groups to promote higher level thinking and to interpret and discuss important topics and concepts. White boarding provides a quick and clear feedback on student progress and allows teachers to observe and guide student's conceptual change. This interactive approach, when coupled with cooperative learning, allows teachers to organize classroom interactions that foster student learning of the knowledge they need to construct correct understanding.

Methodology

This study took place in a large urban high school (federally identified as high needs) in Niagara County (NY) in October and November (2003). It involved twelve biology classes (Living Environment Regents) led by two experienced teachers, Ms. Smith and Ms. Valo. These teachers volunteered to participate in this study. These enthusiastic teachers tend to emphasize vocabulary and factual skills, and de-emphasize conceptual understanding and inquiry skills. Their main classroom activities are lectures and "kit based" laboratory work. Normally, one lab per week was done by students working in pairs. White boarding was introduced about six weeks into the school year (Table 1). By this date, students were accustomed to working in a traditional teacher-centered classroom with little cooperative learning, inquiry, or application of their prior knowledge.

Six of the twelve high school biology classes were chosen in a *quasi* experimental design to employ white boarding (Cook, 1979). There were a total of 273 students, 134 who experienced white boarding (Figure 1). All classes typically contained ninth grade students. The experiment consisted of using white boards to foster cooperative group work. The control groups continued to experience the traditional approach where students generally work independently in class.

The white boarding interventions took place one instructional day before tests to summarize the concepts that had been presented the previous two or three days. The topics to which white boarding was applied were chosen based on the teacher's past experience with student difficulty understanding: 1) biochemical processes in living organisms, 2) diffusion through a cellular membrane, and 3) protein synthesis. The dates white boards were used to examine problematic concepts are listed in Table 1. The first white boarding activity on cell structure, October 20, 2003, was not included in this study. This first white boarding activity was employed with all students in all classes as an introduction to the practice of white boarding. Each date is paired with the corresponding white boarding activity topic (Table 1). The lesson plan associated with each white boarding exercise used is attached to this report (Appendices 1, 2, and 3).

For all three lessons, students were first presented with content knowledge over several days time. For all white boarding activities, students were prompted by teacher posed question at the start (Appendices 1, 2, and 3). The teacher prompt was presented in the form of a question written on the front board. The initial prompt only took a few minutes, but was necessary in order for the activity to begin. Then the groups were given approximately twenty minutes to develop and record a solution to the problem they were given using their white boards. The classroom teacher and I monitored the progress of the student groups during the white boarding activity. This monitoring ensured that the students stayed on task and could be guided if needed. The last twenty minutes of class were used for display, deconstruction, and evaluation of the answers written on the white boards. Here, the teacher brought the class back together and had them sit in a circle in their groups. Together the students and their teacher deconstructed the white boards for content and analysis. The teacher guided the students, by modeling how to deconstruct the white boards. Each group had a few minutes to explain their own board. Time was given for other students to ask questions and discuss that particular board. Finally as a class, the students decided which group's white boarded explanation made the most sense. During the entire white boarding activity, the teacher had a rubric for each group that was used for evaluation (Appendix 4). The rubric was distributed to students prior to the white boarding activity, to make students aware of the expectations for this activity. The rubric assessed the group's creativity, organization, ideas, content accuracy, and involvement. The rubric was generally used by the teacher during the last twenty minutes of class during the deconstruction, and was not given back to the students until after the activity had ended.

Data Collection and Statistical Analysis

The influence of white boarding on the learning of students was measured by three different techniques: white boarding activity points, an in class test, and a survey. For each teacher, all students were taught the same content, experienced the same white boarding activity, received identical tests, and follow-up survey.

The white boarding activities were employed using the corresponding lesson plans (Appendices 1, 2, and 3). The white boarding activities were evaluated and points were awarded using a rubric (Appendix 4). The rubric contained five different areas, where the student could receive a maximum of four points for each of the five topics for a total of twenty points. The five topics assessed included creativity, organization, ideas, content accuracy, and involvement.

An in-class test (100 points) was used to evaluate the student's knowledge of the concepts after their experience with the white boarding or lecture. The multiple-choice test consisted of questions taken from prior Regents examinations. Each of the three tests was identical for all students in the study. In order to measure white boarding's academic impact, student performance on a subsequent test was statistically compared with the test performance of students in another class receiving only traditional instruction.

A post-intervention survey was administered at the conclusion of the project. The survey contained nine Likert scale items to assess student satisfaction using white boards and one open-ended response item. Student survey responses were assigned the following values: Strongly Agree (5), Agree (4), Not Sure (3), Disagree (2), and Strongly Disagree (1). The average response was calculated for each survey item.

Data was recorded in Microsoft Excel. Each student's teacher, a student identifier, the student's gender and ethnicity, the number of points the student earned through white boarding (up to 20 points per use), and the subsequent test score were recorded (Table 2). There were a total of 127 males and 146 females that participated in the study, of which 72 females and 62 males experienced white boarding. There were a total of 109 African American students, 3 Hispanic students, and 161 students classified as "Other" ethnicity who participated in the study.

Descriptive and comparative analyses were performed using StatView statistical analysis program (version 5.0). The unpaired t-test was used to determine if the average value for given sets of data differ from one another (StatView, 1999). The null hypothesis was that given sets of data were equivalent in average value and that the different treatment the groups experience (e.g. white boarding, teacher, gender, or ethnicity), would not affect the measured average. If the t-test indicated a significant difference in average value between groups, least-squares linear regression analysis was used to determine if the average number of points earned through white boarding could predict the average number of points earned on the subsequent test (StatView, 1999). The null hypothesis was that the number of points earned through white boarding would not predict student performance on a later test.

Results

Students who experienced white boarding typically scored 9.2 more points on the same 100 point test, than did the students who did not learn through white boarding (Table 3). This relationship between teaching method and student performance on the following test was seen in each of the three cases where white boarding was employed (Table 3). On the first test, the 45 students that experienced white boarding averaged 80.0 points on that test; in contrast, the 47 students that only received lectures averaged 70.7 points on that same test ($t = -3.683$, $P = 0.0004$). On the second test, the 46 students that experienced white boarding averaged 76.3 points on that test; while the 49 students that only received lectures averaged 66.6 points on the same test ($t = -4.289$, $P<0.0001$). On the third test, the 43 students that experienced white boarding averaged 75.7 points on that test; while the 43 students that only received lectures averaged 67.2 points on that test ($t = -2.991$, $P = 0.0037$). Effect size for all students that experienced white boarding as an academic intervention on test scores was calculated (Table 4).

The effect sizes were found to be 0.73, 0.86, and 0.55, respectively for each of the white boarding activities.

To better understand the strong impact that white boarding had on test performance, the possible effect of the teacher was tested to determine if there were systematic differences in the number of points students earned through white boarding, and the number of points students earned on subsequent tests (Table 5 and 6). The t-test indicated that Ms. Smith's students and Ms. Valo's students received equivalent numbers of points on the first and third white boarding activities. On average their students received between 19.3 and 19.6 points on the first and third white boarding activities (Table 5). In contrast, a statistical difference in the average number of white board points was observed for the second white boarding activity ($t = -2.265$, $P = 0.0285$). There, Ms. Smith's students received an average of 18.8 points while Ms. Valo's students received an average of 19.6 points for the second white boarding activity (Table 5). Similarly, the t-test indicated that Ms. Smith's students and Ms. Valo's students received equivalent numbers of points on the first and second tests that followed the white board exercises. On average their students received between 69.5 and 76.6 points for the first and second tests. However, a statistical difference in the average number of points was observed for the third test ($t = -3.009$, $P = 0.0035$). There, Ms. Smith's students received 61.4 points and Ms. Valo's students received 75.8 points on the third test.

The t-test was also used to determine if gender affected the number of points students earned on any of the three white boarding activities or the three subsequent tests (Tables 5 and 6). I found no significant difference in the average number of points that female students earned relative to male students on any of the three white boarding activities ($t = 1.185$, $P = 0.2425$; $t = -0.985$, $P = 0.3299$; and $t = 1.533$, $P = 0.1328$). I also did not find a difference in the average number of points that female students earned relative to male students on any of the three class tests ($t = 1.56$, $P = 0.1224$; $t = -0.271$, $P = 0.7867$; and $t = -0.788$, $P = 0.7951$). Student performance on white board activities and student benefit from the white board experience was not influenced by gender.

Lastly, I sought to determine if the student's ethnicity might affect the significant academic benefit realized through white boarding. Hispanic students were excluded from this analysis due to small sample size (two students). A t-test detected no significant difference due to ethnicity (African-American vs. Other) when the average number of points earned through white boarding was tested (t = 1.124, P = 0.2672; t = 0.88, P = 0.3839; and t = 0.879, P = 0.3848). However, when test performance was compared, a statistical difference between student ethnic groups was observed for the first two tests (t = -2.058, P = 0.0425; t = -2.211, P = 0.0295; and t = -1.052, P = 0.2959). With Other students receiving 5.6 points more than African-American students on both Test 1 and Test 2 (Table 6). The effect size for white boarding as an academic intervention on test scores was calculated for each of the groups of students for all white boarding activities (Table 7).

When the test performance for African American students was compared by itself, a statistical difference was found for all three of the tests associated with the practice of white boarding (t = -3.158, P = 0.0032; t = -2.438, P = 0.0202; and t = -2.812, P = 0.0082). African American students that white boarded received higher exam scores than African American students who only received the traditional method of instruction. The effect size of white boarding for African American students was determined to be 0.28, 0.79, and 0.79 (Table 7).

Linear regression analysis was performed to explore the nature of the relationship between student performance on the graded white board activities and test performance. For the 45 students who completed the first white boarding exercise, their score on the first test was not found to depend on the points they earned through white boarding. In contrast, for students that white boarded, their scores on the second and third tests were found to depend on the number of points a student earned through white boarding. Linear regression analysis gave the following relationship between second test points and white boarding points (expected Test-2 points = 0.167 points + 3.961*WB2 points; with $R^2 = 0.24$). Linear regression analysis found the following relationship between third test points and white boarding (expected Test-3 points = 22.481 points + 2.749*WB3 points; with $R^2 = 0.103$). Students that scored more points on the graded white board assignment, also scored more points on the class test that followed.

When the regression analysis on the relationship between student white boarding performance and test performance was done for each teacher's third set of tests, it was determined that a significant linear relationship existed between these two academic exercises for Ms. Smith's students but not for Ms. Valo's students. For Ms. Smith's students as the number of points earned through white boarding increased, it significantly and positively determined the points earned on the third test (expected Test-3 points = 3.867*WB3 points – 1.733 points; with $R^2 = 0.203$). For Ms. Valo's students as the number of points earned through white boarding increased, it did not significantly or positively determine the points earned on the third test (expected Test-3 points = 83.743 points - 0.24*WB3 points; with $R^2 = 0.001$).

Lastly, regression analysis was performed to explore the nature of the relationship between student ethnicity, performance on the graded white board activities, and test performance. For the 16 African-American students who completed the second white boarding exercise, a positive statistical trend was observed between white boarding points and Test-2 performance (expected Test-2 points = 19.077 points + 4.769*WB2 points; with $R^2 = 0.227$). For the 29 Other students who completed the second white boarding exercise, a positive linear relationship was observed between white boarding points and Test-2 performance (expected Test-2 points = 4.272*WB2 points – 3.294 points; with $R^2 = 0.385$). A positive linear relationship between white boarding points and Test-3 performance was also observed for the 23 Other students who completed the third white boarding exercise (expected Test-3 points = 10.556 points + 3.399*WB3 points; with $R^2 = 0.243$).

The key results of this study were that students who experienced white boarding scored higher on subsequent tests than those who did not employ white boarding activity. The students that white boarded typically scored 9.2 more points on the same test than those who did not employ white boarding (Test 1, $t= -3.683$, $P=0.0004$);(Test 2, $t= -4.289$, $P<0.0001$); and (Test 3, $t= -2.991$, $P=0.0037$). In addition I found that, after white boarding, there was no influence of teacher or student gender on academic performance. There was typically no difference in student performance relative to the teacher's identity for all the white board exercises and two of the three test scores. There was also no difference in student performance relative to gender, for all white board points and test scores. Lastly there was no difference between students of different ethnic groups and points earned through white boarding. Although statistical differences were found between students of different ethnic groups for the two of the three test scores (Test 1, $t = -2.058$, $P = 0.0425$; Test 2, $t= -2.211$, $P = 0.0295$; and Test 3, $t= -1.052$, $P = 0.2959$).

The survey results were totaled for all of the students across both of the teachers' classes (Table 8). For the purposes of this study, the percentages of each of the categories, Strongly Agree, Agree, Not Sure, Disagree, and Strongly Disagree, were calculated for each survey item (Table 8). Ninety two percent of students agreed or strongly agreed that white boarding provided dialogue in the science classroom. Seventy two percent of students agreed or strongly agreed that white boarding allowed them to clarify misconceptions in science. Seventy one percent of students agreed or strongly agreed that white boarding helped them to reach and develop a solution to important questions. Sixty three percent of students agreed or strongly agreed that white boarding increased their ability to put ideas together, to see relationships, similarities, and differences between ideas. In contrast 84% of students disagreed or strongly disagreed that white boarding helped them to achieve higher test scores.

Discussion

When students study science using investigation and inquiry, they employ many different skills. Both investigation and inquiry in science always start with a problem. Woods (1991) discussed several approaches to problem solving that could easily be achieved by using white boarding to solve a scientific problem. In this study white boarding was used as a problem solving tool in three different biological areas: biochemical processes in living organisms, diffusion through a cell membrane, and protein synthesis. For each area, using white boards allowed students to create their own paths to a solution, emphasized collaborative learning, provided different roles for individuals working in a group, and helped students identify and discuss their misconceptions. According to Brown (1992), misconceptions are extremely difficult to alter through traditional instruction and persist after instruction ended.

Research on concepts, misconceptions, and conceptual change has shown that these are major problems in the teaching of science (Trowbridge, Bybee, and Powell, 2000). One problem is that the influence of student's prior knowledge on their learning of science has been misunderstood and underestimated (Osborne and Wittrock, 1983). White boarding can be used as a tool for teachers to identify misconceptions and problems with students' prior knowledge related to the content being taught. Here, white boarding was found to be a useful tool for teachers to gain insight about their students' prior knowledge, and to evaluate their understanding or misconceptions. Teachers commented that is was wonderful to be able to quickly assess each class's strengths and weaknesses on a topic.

White boarding can also create opportunities for synthesis in which students explicitly link different concepts. White boarding allows students to make connections between different concepts and phenomena themselves. Students were able to use the white boards as a graphic aid to summarize the group's insight to a question. This type of discussion web is similar to a very effective strategy studied by Arnold and Miller (1987) in which discussion and argument about concepts were encouraged.

White boarding, a non-traditional teaching method, was very effective at increasing correct student understanding. Students used the white board method in groups. It helped them to clarify and develop a better understanding of particular concepts. The survey results showed that when students were asked if white boarding allowed them to clarify misconceptions in science, 71.6% of the students agreed or strongly agreed (Table 8). Also when students were asked if white boarding helped them to reach and develop a solution to a problem, 70.9% agreed or strongly agreed (Table 8).

Pea (1995) argued that persons collaboratively construct the common ground of beliefs, meanings, and understandings when they share in an activity. White boarding allows for student-student interactions that stimulate learning through cooperative learning. Both Piaget and Vygotsky emphasized that social discretionary knowledge can only be learned from more knowledgeable peers (Slavin, 1996). In this study, students enjoyed working in cooperative groups and collectively solving a problem using the white boards to record and present their solution to the class. Having students work together in pairs or small groups has long characterized teaching science in the laboratory setting (Trowbridge, Bybee, and Powell, 2000). Recently, there has been increased interest in using dialogue between instructor and student, or student to student as a focus for teaching and learning in the classroom. According to the student survey, 91.8 % of the students agreed or strongly agreed that white boarding provided dialogue in the science classroom (Table 8). In this study, the white boarding technique permitted discourse not only among students, but also between the teacher and the students.

This study demonstrated that the academic benefit of using white boarding was significant. The students who experienced white boarding typically had a ten point increase in test scores when compared to those students who received traditional method. Bloom (1984), showed that expert tutoring improved student performance by 2 effect sizes. There are two possible reasons for this increase in effect size, either cooperative learning or interactive engagement. When cooperative learning was further researched by Johnson, Johnson, and Smith (1991), cooperative learning was found have an average effect size of 0.86. Here the effect sizes computed for white boarding activities are consistent with this average (Table 4). This indicates that the use of white boards is a very effective teaching tool in the biology classroom.

White boarding couples cooperative and collaborative groups to an activity, where students must work together to form a solution to a problem. The literature reports that collaborative learning increases retention, on-task behaviors, promotes achievement, fosters positive attitudes and self-esteem, and produces higher student achievement (Johnson, Johnson, and Smith, 1991). Both of the teachers involved in this study, voiced surprise when they saw the increase in participation among their students. My data illustrate that there is a relationship between the students who experienced white boarding and higher test scores.

Interestingly, when the students were surveyed on if they thought that white boarding helped them achieve higher test scores, 84.4 percent disagreed or strongly disagreed (Table 8). However, my data shows that the students scored ten points higher on their test when white boarding was implemented. This suggests that white boarding can be used to help students achieve higher test scores, and that the activity is so naturally performed that students do not realize that they are actually and effectively learning.

To ensure that the academic benefits of white boarding found were reliable, data was analyzed to illustrate teacher effect, gender and ethnic relationships. Only one teacher effect was noted. On Test three, Ms. Smith's students had an average of 61.4 when compared to Ms. Valo's student average of 75.8. Perhaps as the literature suggests, this is an instance where teachers are not equally effective in all the classes, grades, or subjects they teach (Luyten, 2003). In addition, Luyten (2003) states that if teachers were frequently to compare their students with those in a parallel class that teacher differences would decrease. I think that by the third implementation of the white boarding the teachers might have been ready to take their classes back into their own hands, and that this may account for the differences in Test three scores.

Though the literature typically reports that gender differences are commonly observed in biology (Deboer, 1984, She, 2000 and 2001, Phillip, Barrow, and Chandrasekbar, 2002), no gender differences were observed for either the points students earned through white boarding activities, or the test that followed. It may be that white boards help to overcome student differences in academic performance. White boarding may be a very useful teaching tool because it helps to ameliorate the performance gap associated with gender that is indicated in the literature.

I did not find a difference between student ethnic groups for the points earned from white boarding activities. Ethnic background did relate to test performance for two of the three subsequent tests. However, African American students who employed white boarding still performed better on the in class test than African American students who experienced the traditional lecture. Though the literature suggests that there is a significant difference in the performance between students with different backgrounds in biology classes (Phillip, Barrow, and Chandrasekbar, 2002; Bali and Alvarez, 2003; St. John, Hu, Simmons, Carter, and Weber, 2004), I found that white boarding was an effective tool to alleviate differences in student performance and equalize all learning. White boarding increased the performance of all students regardless of their ethnic background.

I found white boarding to be an educationally effective practice that promoted discourse and higher-level thinking in students. White boarding provided an alternate approach for students to grasp concepts, clear up confusion, and realize that there may be other paths to solving problems. In addition, when students work in small groups, and practice using and interpreting important concepts, students will learn (Trowbridge, Bybee, and Powell, 2000). Both teachers commented that they enjoyed working with the white boards and found it to be a very effective teaching tool. They also agreed that it was more difficult to employ than traditional lecture. Both teachers found that white boarding increased student participation and motivation. Their experience is consistent with the literature; reform teaching, though challenging, is often academically and personally rewarding (MacIsaac and Falconer, 2002).

In conclusion, white boarding helped students learn and provided them an opportunity to engage in academic discourse and reach a shared solution to a problem. This technique fostered collaborative learning using cooperative groups and created a student-centered classroom. White boarding resulted in a ten percent increase in test scores. Through white boarding activities, students tended to construct better individual understanding to the specific question or problem posed by the teacher. These academic benefits were consistent for different teachers and not affected by student gender. Though ethnic background occasionally related to test performance, African American students who employed white boarding performed better on in-class tests than African American students who experienced traditional lecture only. If we can get our students to learn and succeed using a tool like white boarding, regardless of their teacher, gender, or ethnic background, then why not use it.

References

Arnold, M. and Miller, R. (1987). Being constructive. *International Journal of Science Education, 9,* 553-563.

Ausubel, D. P. (1968). *Educational Psychology: A cognitive view*. New York: Holt, Rinehart and Winston.

Bali, V. A. and Alvarez, R. M. (2003) Schools and educational outcomes: what causes the "race gap" in student test scores. *Social Science Quarterly, 84(3)*, 485-508.

Bloom, B. S. (1984). The two sigma problem: The search for methods of group instruction as effective as one-to–one tutoring. *Educational Researcher, 13*, 4-16.

Brown, D. F. (1992). Using examples and alalogies to remediate misconceptions in physics: Factors influencing conceptual change. *Science Teaching, 29*, 17-24

Cook, T. (1979). *Quasi-experimentation*. Chicago: Rand McNally College Pub. Co

Deboer, G. E. (1984). A study of gender-effects in the science and mathematics taking behavior of a group of students who graduated from college in late 1970s. *Journal of Research in Science Teaching*, *21,* 95-103.

Eggen, P. and Kauchak, D. (1999). *Educational Psychology*. Columbus, Ohio: Prentice Hall

Henry, D., Henry, J., Riddoch, S. (2003). White boarding your way to great student discussions. *Science and Children*

Johnson, R., Johnson, R., and Smith, K. (1991) *Active Learning: Cooperation in the college classroom*. Edina, Minnesota: Interaction Books.

Lee, K. L. and Fensham, P. F. (1996). A general strategy for solving high school electrochemistry problems. *International Journal of Science Education, 18*, 543-555

Luyten, H. (2003). The size of school effects compared to teacher effects: An overview of the research literature. *School Effectiveness and School Improvement 14(1)*, 31-51.

MacIsaac, D. and Falconer, K. (2002). Reforming physics instruction via RTOP. *The Physics Teacher, 40*,

Nissani, Moti. (1989). A class exercise for teaching the genetic code. *The Science Teacher 56,(3)*,76-78

National Research Council (NRC, 1996). *National science education standards*. Washington, D.C.: National Academy Press

Osborne, R .J. and Wittrock, M. C. (1983). Learning science: a generative process. *Science Education,* 67(4), 489-508.

Panizzon, D. L. (1998). Demonstrating diffusion: Why the confusion*? Teachers Journal, 44(4)*, 37-39.

Pea, R. D. (1995). Learning scientific concepts through material and social activities: Controversial analysis meets change. *Educational Psychology, 28*, 265-277.

Phillips, K. A., Brown, L. H., and Chandrasekbar, M. (2002). Science career interests among high school girls one year after participation in a summer science program. *Journal of Woman and Minorities in Science and Engineering, 8*, 235-247

She, H. C. (2000). The interplay of a biology teacher's beliefs, teaching practices and gender-based student-teacher classroom interaction. *Educational Research, 42*, 125-135

She, H. C. (2001). Different gender students' participation in the high-and low-achieving middle school questioning-oriented biology classrooms in Taiwan. *Research in Science and Technological Education, 19(2)*, 148-158.

Slavin, R. E.(1996). Cooperative learning in the middle and secondary schools. *The Clearing House, 69*(4), 200-206

Stat View Reference, 1999. 3rd Ed. SAS Institute Inc. Cary, NC, USA.

St. John, E. P., Shouping, H., Simmons, A., Carter, D. F., and Weber, J. (2004). What difference does major make: The influence of college major field on persistence by African American and White students. *Research in Higher Education, 45(3)*, 209-232.

Trowbridge, L. W., Bybee, R. W., and Powell, J. C. (2000). *Teaching secondary school science: Strategies for developing scientific literacy*. Upper Saddle River, NJ:Pearson Education

Wells, M., Hestenes, D., and Swackhamer, G. (1995) A modeling method for high school physics instruction. *American Journal of Physics, 64*, 114-119.

Woods, D. R. (1991). Three more approaches to problem solving. *Journal of College Science Teaching, 21*(Nov), 100-105.

Table 1. Experimental time line and the topics addressed through white boarding. The first topic on October 20, 2003 was used to introduce all students in the study. Subsequent three topics were presented as white boarding activities in randomly selected classes.

Date	Topic
October 20, 2003	Cell structure
October 28, 2003	Biochemical processes in living organisms
November 3, 2003	Diffusion through a cell membrane
November 14, 2003	Protein synthesis analogy

Table 2. Example of descriptive and numeric data collected for each student.

Teacher	Student	Gender	Ethnicity	WB1?	Test1	WB2?	Test2	WB3?	Test3
Smith/Valo	J. Doe	F/M	A/H/O	Y/N	76	Y/N	82	Y/N	71

Key

/ = or

F = female and M = male

A = African-American, H = Hispanic, and O = Other

Y = Yes and N = No. If yes, a white boarding score was also recorded

Table 3. Mean ± standard deviation of test scores, per 100 possible points, for students who experienced white boarding versus students that did not experience white boarding.

White boarding Experience?	Test 1	Test 2	Test 3
WB1, NO (47 students)	70.7 ± 12.8		
WB1, YES (45 students)	80.0 ± 11.3		
WB2, NO (49 students)		66.5 ± 11.3	
WB2, YES (46 students)		76.3 ± 10.8	
WB3, NO (43 students)			67.2 ± 15.6
WB3, YES (43 students)			75.7 ± 10.6

Table 4. The effect size for white boarding as an academic intervention on test scores. Effect sizes are computed as the difference between the means of the experimental and control groups, divided by the standard deviation of the control group. Students who did not experienced white boarding compared to students that did experience white boarding.

White Board Experience All Students	Effect Size of White Boarding
WB1	0.73
WB2	0.86
WB3	0.55

Table 5. Mean ± standard deviation of white boarding activity scores, of 20 possible points, first by all students then for each white boarding activity listed by teacher, gender, and ethnicity. N = number of students per group.

Group of Students	WB1	WB2	WB3
All	19.4 ± 1.2, N = 45	19.2 ± 1.3, N = 46	19.4 ± 1.2, N = 43
Ms. Smith's	19.3 ± 1.3, N = 24	18.8 ± 1.5, N = 22	19.1 ± 1.4, N = 21
Ms. Valo's	19.6 ± 1.1, N = 21	19.6 ± 1.0, N = 24	19.6 ± 1.1, N = 22
Female	19.6 ± 1.0, N = 23	19.0 ± 1.4, N = 25	19.6 ± 1.0, N = 24
Male	19.2 ± 1.4, N = 22	19.4 ± 1.2, N = 21	19.1 ± 1.4, N = 19
African-American	19.6 ± 1.0, N = 17	19.4 ± 1.2, N = 16	19.6 ± 1.1, N = 20
Other	19.2 ± 1.3, N = 27	19.1 ± 1.4, N = 29	19.2 ± 1.3, N = 23

Table 6. Mean ± standard deviation of test scores, of 100 possible points, first by all students then for each white boarding activity listed by gender and ethnicity. N = number of students per group.

Group of Students	Test 1	
	WB1, NO	WB1, YES
Female	72.7 ± 11.2, N = 21	81.7 ± 11.5, N = 23
Male	69.1 ± 13.9, N = 26	78.2 ± 11.0, N = 22
African American	65.8 ± 13.4, N = 21	79.5 ± 13.1, N = 17
Other	74.7 ± 10.9, N = 26	80.1 ± 10.5, N = 27

Group of Students	Test 2	
	WB2, NO	WB2, YES
Female	66.6 ± 11.4, N = 31	76.4 ± 10.3, N = 25
Male	66.4 ± 11.5, N = 18	76.2 ± 11.6, N = 21
African American	63.4 ± 12.9, N = 20	73.6 ± 12.1, N = 16
Other	68.8 ± 9.7, N = 29	78.2 ± 9.7, N = 29

Group of Students	Test 3	
	WB3, NO	WB3, YES
Female	67.4 ± 15.8, N = 22	74.5 ± 11.4, N = 24
Male	67.0 ± 15.7, N = 21	77.3 ± 9.5, N = 19
African American	61.2 ± 18.1, N = 15	75.6 ± 12.2, N = 20
Other	69.9 ± 13.3, N = 27	75.9 ± 9.3, N = 23

Table 7. The effect size for white boarding as an academic intervention on test scores. Effect sizes are computed as the difference between the means of the experimental and control groups, divided by the standard deviation of the control group. Students who did not experienced white boarding compared to students that did experience white boarding.

Group of Students	Effect Size of White Boarding		
	WB1	WB2	WB3
Female	0.80	0.85	0.45
Male	0.65	0.85	0.66
African-American	0.28	0.79	0.79
Other	0.50	0.97	0.45

Table 8. Student responses to a questionnaire on the academic use of white boarding. For each response, the first line reports number of student responses and the second line gives percent student responses.

	Freshman	Sophomore	Junior	Senior
Class standing	134	0	0	0

Circle your level of agreement with the following statements:	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
1. White boarding increased my ability to put ideas together, to see relationships, similarities, and differences between ideas.	52 38.8%	32 23.9%	20 14.9%	14 10.4%	16 11.9%
2. White boarding decreased my ability to learn on my own and pursue ideas.	7 52.2%	21 15.7%	28 20.9%	38 28.4%	40 29.9%
3. White boarding has not enabled me to be more engaged and involved in the science classroom.	11 8.2%	18 13.4%	27 20.1%	36 26.9%	42 31.3%
4. White boarding has allowed me to clarify my misconceptions in science.	82 61.2%	14 10.4%	6 4.5%	8 6.0%	28 20.9%
5. White boarding has helped me to reach and develop a solution to important questions	79 59.0%	16 11.9%	10 7.5%	10 7.5%	19 14.2%
6. White boarding does not provide a more student-centered environment.	1 0.7%	3 2.2%	11 8.2%	25 18.7%	94 70.1%
7. White boarding provided dialogue in the science classroom.	106 79.1%	17 12.7%	5 3.7%	3 2.2%	3 2.2%
8. White boarding did not help me to learn the course content.	47 35.1%	15 11.2%	17 12.7%	8 6.0%	47 35.1%
9. White boarding has helped me achieve higher test scores.	1 0.7%	5 3.7%	15 11.2%	22 16.4%	91 68.0%
10. Please comment on why or why not white boarding was effective in the classroom	19 14.2%	33 24.6%	75 56.0%	4 3.0%	3 2.2%

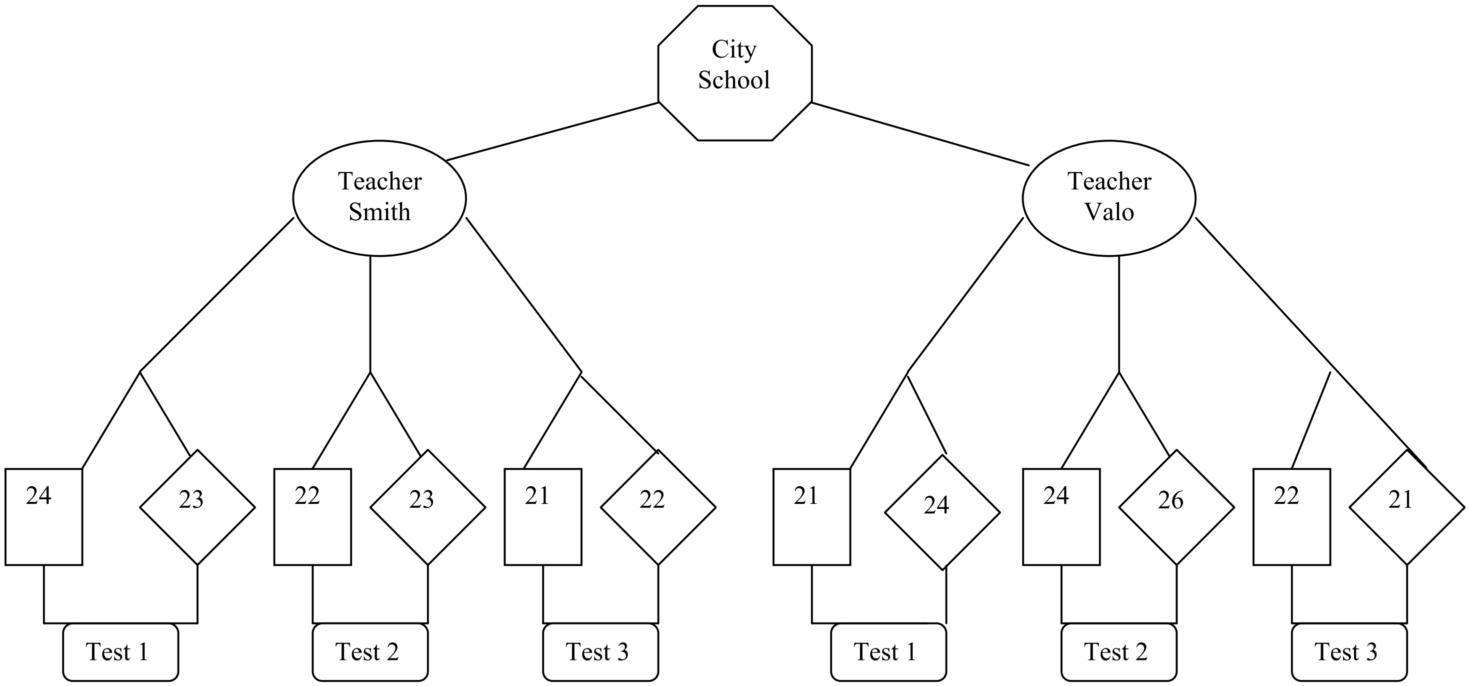

Figure 1. The experimental design employed 273 students, 134 of these students experienced white boarding. For each teacher, there were six groups of students, three who employed white boarding and three who did not. The white boarding followed the schedule presented in Table 1. The test number corresponds with the white boarding number. The square represents the students who experienced white boarding. The diamond ◊ represents the students who did not experience white boarding. The corresponding number inside the square and the diamond are the number of students that are in that class.

Appendix 1. Lesson Plan used for Biochemical Processes in Living Organisms

1) Date: October 28, 2003
2) Class Title: Biochemical Processes in living organisms
   a) White boarding activity
3) Materials:
   a) Dry erase markers
   b) White boards
   c) Erasers
4) Concepts to be developed:
   a) Standard 1 –Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions
      i) Key Idea – The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process
   b) Standard 4 – Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science
      i) Key Idea- Living things are both similar and different from each other and from nonliving things
5) Student Objectives
   a) Students will use the white boards to explain aerobic and anaerobic processes of respiration
6) Procedure:
   a) Activity
      i) Students will have had background information presented to them for the past 5 days on the processes of photosynthesis
      ii) Write small set of target questions on the board
         (1) Ask for both anaerobic equation and aerobic equation
            (a) Which metabolic process does this represent? Why? What are the products?
            (b) Use white boards to describe, draw pictures, use arrows, to illustrate your explanation
      iii) Collect and display
         (1) Sit arranged in a circle
         (2) Have students take notes
         (3) Deconstruct white boards
            (a) Self –talking -student discussion
            (b) Ask each group to explain what is happening and their reasoning
            (c) Decide together which group makes the most sense (peer evaluate)
   b) Closure:
      i) Bring back to formalize
         (1) Put terminology into place
            (a) Use vocabulary
               (i) Anerobic Phase
                  1. Fermentation, end products, energy release, glycolysis
               (ii) Aerobic Phase
                  1. Oxidation, reduction, oxidation-reduction reactions, role of oxygen
   c) Evaluation strategy
      i) Monitor student group to keep on task
      ii) Use rubric to evaluate white boards
         (1) Each group receiving a maximum of 20 points

Appendix 2. Lesson Plan used for Diffusion through a Cell Membrane

1) Date: November 3, 2003
2) Class Title: Diffusion through a cell membrane
   a) White boarding activity
3) Materials:
   a) Dry erase markers
   b) White boards
   c) Erasers
4) Concepts to be developed:
   a) Standard 1 –Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions
      i) Key Idea – The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process
   b) Standard 4 – Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science
      i) Key Idea – Living things are both similar to and different from each other and from nonliving things
5) Student Objectives
   a) Students will use the white boards to explain the process of diffusion
6) Procedure:
   a) Activity
      i) Students will have had background information presented to them for the past 3 days on the processes of diffusion
      ii) Draw an initial and end condition system on the front board
         (1) Ask
            (a) How does this occur? What was caused this to happen?
            (b) Use white boards to describe, draw pictures, use arrows, to illustrate your explanation
      iii) Collect and display
         (1) Sit arranged in a circle
         (2) Have students take notes
         (3) Deconstruct white boards
            (a) Self –talking -student discussion
            (b) Ask each group to explain what is happening and their reasoning
            (c) Decide together which group makes the most sense (peer evaluate)
   b) Closure:
      i) Bring back to formalize
         (1) Put terminology into place
            (a) Use vocabulary – hypotonic, hypertonic, isotonic
   c) Evaluation strategy
      i) Monitor student group to keep on task
      ii) Use rubric to evaluate white boards
         (1) Each group receiving a maximum of 20 points

Appendix 3. Lesson Plan used for Protein Synthesis

1) Date: November 14, 2003
2) Class Title: Protein synthesis analogy
    a) White boarding activity
3) Materials:
    a) Dry erase markers
    b) White boards
    c) Erasers
4) Concepts to be developed:
    a) Standard 1 –Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions
        i) Key Idea – The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process
    b) Standard 4 – Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science
        i) Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring
5) Student Objectives
    a) Students will use the white boards to explain the process of protein synthesis
6) Procedure:
    a) Activity
        i) Students will have had background information presented to them for the past 6 days on the protein synthesis
        ii) Use the analogy of the fanciful process of manufacturing candy at a candy factory.
            (1) Talk about the boss who sits in her office all day handing out recipe cards to messengers who go out to the various assembly stations on the factory floor and direct the assembly of ingredients that correspond to the recipes.
            (2) Combinations of ingredients must pass through several workstations before they end up as candy, the desired product of the factory.
                (a) Ask
                    (i) About proteins and how they are produced in the cell
                    (ii) Students to discuss the process of protein synthesis
                        1. The office becomes the nucleus, the work stations the ribosomes, the messenger the mRNA, the workers the tRNA, the ingredients are the amino acids
                            a. simplifies the process into six key steps
                (b) Use white boards to describe, draw pictures, use arrows, to illustrate your explanation
        iii) Collect and display
            (1) Sit arranged in a circle
            (2) Have students take notes
            (3) Deconstruct white boards
                (a) Self –talking -student discussion
                (b) Ask each group to explain what is happening and their reasoning
                (c) Decide together which group makes the most sense (peer evaluate)
    b) Closure:
        i) Bring back to formalize
            (1) Conclude by discussing the degree to which the analogy "fits" the process and the key differences between the model and the target concept.
            (2) Put terminology into place
                (a) Use vocabulary
    c) Evaluation strategy
        i) Monitor student group to keep on task
        ii) Use rubric to evaluate white boards
            (1) Each group receiving a maximum of 20 points

Appendix 4. Rubric for evaluating and scoring the white boarding activities

Name(s): ______________________________
Date: ________________________________
Activity: White boarding activity

	4	3	2	1	Score
Creative	Extremely clever and presented with originality; unique approach	Clever at times; thoughtfully presented	Added few original touches, not thoughtful	Little creative energy used; bland	
Organization	Extremely well organized; flowed smoothly	Presented in thoughtful manner, signs or organization; at times unclear	Somewhat organized; very unclear	Choppy and confusing; hard to follow	
Ideas	Establishes a clear focus with a sense of purpose and audience. Richly developed details.	Develops a focus. Details support central idea.	Unclear focus. Insufficient/ inappropriate details	Lacks focus and development	
Content accuracy	Completely accurate; all facts were precise and explicit	Mostly accurate; a few inconsistencies or errors in information	Somewhat accurate; more than a few inconsistencies or errors in information	Completely inaccurate; the facts were misleading	
Involvement	Engaging; All students enthusiastically participated	Well done and interesting; At least 3 of the 4 actively participated	At times was interesting; At least half of the students confer or present ideas	Not organized; Only 1 or 2 persons actively participated	