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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Collaborative Peer Study Group Curriculum

A Thesis submitted in partial satisfaction of the

Requirements for the degree Master of Arts

in

Teaching and Learning (Curriculum Design)

by

Jesse Wade

Committee in charge:

Chris Halter, Chair Claire Ramsey James Levin

2008

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Chair

University of California, San Diego

2008

DEDICATION

This work is dedicated to my loving partner, Aaron, who encouraged me to embark on this endeavor and supported me through the process.

I also dedicate this curriculum research to my past, present, and future students who constantly inspire me to be a better teacher.

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ACKNOWLEDGEMENTS

I would like to thank Chris Halter, my advisor, for tirelessly evaluating my project, giving me clear directions for improvement, and encouraging me to continue working on it. I also want to acknowledge Claire Ramsey for all of the advice she gave me through this process.

I want to extend a special thanks to Cheryl Forbes for all of her help and encouragement that she gave me at the beginning of this process. Not only did Cheryl help me sort out the mess of ideas swimming in my head, but she also eased my anxiety about my lack of direction. Cheryl encouraged me to persevere after every rough draft, every class, and every time I met with her during office hours. I would not have finished this project if it weren't for Cheryl's confidence in my ability to do so.

I am very grateful for the support from all of my peers in the cohort this year. I learned so much form each of them. My peers inspire me to be the best teacher I can be. I would like to give a special thanks to Orletta, for editing my paper over and over again, to Doug, for helping me formulate my ideas, and to Suzi for being my friend, confidant, and swimming buddy.

Finally I would like to thank my partner Aaron. Partner says it all.

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ABSTRACT OF THE THESIS

Collaborative Peer Study Group Curriculum

by

Jesse Wade

Master of Arts in Teaching and Learning (Curriculum Design)

University of California, San Diego, 2008

Chris Halter, Chair

There is a need for a larger and more diverse pool of workers trained in science, technology, engineering and mathematics (STEM). Even though *self-efficacy* is the primary predictor of students career choice (Lent et al., 2005), most of the high school curriculum does not foster self-efficacy in math and science. Educators may be able to increase students' self-efficacy in science and mathematics by helping students to master difficult scientific tasks through collaborative learning and by fostering metacognitive awareness. The Collaborative Peer Study Group Curriculum (CPSG) provides a social context in which students can master rigorous math and science

content and think metacognitively. In CPSG students set individual and group goals for learning. Then students take turns being teachers and learners in order to gain a deeper understanding of science and math topics. As teachers, students use vocabulary and images to explain difficult math and science content. As learners, students ask questions and take notes. Students rotate teaching and learning in their groups every time they meet, until they have mastered the unit covered in class. I implemented CPSG in three high school biology classes. I evaluated CPSG by administering self-efficacy surveys to students, by taking field notes, by audio recording the student study groups, and by interviewing students. The data indicates that the students who participated in CPSG showed deeper understanding of the material, thought more about their own learning, and were more motivated to learn science.

I. Introduction

As an eleventh grade biology teacher at Central High, a pseudonym for a small innovative charter school located in Southern California, I have the privilege of helping students prepare for college and careers in science, math, technology, and engineering (STEM). Over the past few years I have noticed that some of my incoming juniors are disinterested in science and math. At first the disinterest was surprising to me because I teach at a charter school that uses authentic curriculum and real-world projects to engage students. What was turning these students off to math and science? Why did they say, "Science isn't my subject," or "I hate math"?

Finally I gained some insight into these questions when I taught summer school at Central High. I was asked to teach biology to a small group of students who had failed their 11th grade biology class that year. The class was composed of five students, all racial-ethnic minorities from low-income households. All had failed a biology class that was known for the amount of time spent on rigorous inquiry-based labs and authentic real-world projects. How had a class with so many hands-on and minds-on lessons failed to hook these students? Did these students fail because they were missing skills that the other student's possessed? Or were they unable to see themselves as scientists? What were the barriers that stopped these students from being successful in their science class?

I decided to ask the students themselves and see what they thought the problem was. On the first day of summer school, I asked the students to provide me with a few details about their past biology experience and summer school goals on a short written survey. The first question I asked was, "What got in the way of you passing Biology

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in your eleventh grade year?" Every student responded that they had done poorly on tests and quizzes.

After reading their responses, I decided to teach the students study strategies while I taught them the biology content. My hope was that if these students could learn a few study strategies, they would perform better on tests as measured by their final grade. In turn, the success would improve their self-efficacy on tests and motivate them to study more, further improving their academic performance. I also hoped that these students would take the study strategies that they learned in the summer school class and apply them to their other classes.

I did not teach the students study strategies in isolation. The students learned new study strategies while they learned about complex biological processes. During summer school, I taught the students about neurons and neurotransmitters by using a combination of traditional teacher-centered lectures and student-centered activities. With these lessons, I taught the students a variety of study strategies like note taking strategies, reading strategies, independent study strategies, and strategies for studying in a group. Although I exposed the students to several different types of strategies, the strategy that seemed to have the biggest impact on the students was the collaborative peer study groups.

When I first taught the students about collaborative peer study groups I told them that studying with a small group can help prepare for a difficult exam. Then I told the students that we would try study groups in class. Before we started, we had a discussion about what material they thought would be on the test. Next I divided the students into two groups. In each group, I told them to look through their notes and pick out the most difficult material that they thought would be on the test. Then I had the students take turns teaching each other this difficult material using white boards for diagrams and terms. I told the students to use their notes to make sure that their peer study partners covered the material accurately and with enough detail. After roughly an hour in peer groups, the students explained complex neural pathways using difficult scientific terms. As they learned the material, their attitude about the subject matter changed. Instead of trying to avoid teaching the material, the students quickly volunteered to teach it to their peers. The students seemed proud of their mastery of the rigorous content. One student, Maria, even asked, "Ms. Wade, can I take a picture?" Puzzled, I asked her, "What for?" She then told me that she wanted to take a picture because she "had never taught anything to anyone before" and she wanted to remember this.

After studying independently at home and in a collaborative peer study group, the students took a difficult (ungraded) quiz that I designed on neurons and neurotransmitters. All of the students performed very well on the assessment. In their reflections, all of the students said that they had never done so well on a test before. Maria, wrote, "My goals for next year are to form study groups for those who will like one." What was most impressive was the enthusiasm with which the students approached school in the fall and science specifically. Another student, Armando, wrote, "One of the academic goals that I have for the fall is: applying myself to anything that I want to do, that way I can say to myself, 'I truly put my heart into it' and see for myself that I can do anything." After the summer school class, all of the students wrote about their new enthusiasm for Biology. One student, Sara, wrote, "Biology was never my subject, but the way Ms. Wade taught it to us just change[d] my point of view about it. Now I think science is very important." Another student, Brandon, expressed how summer school had changed his attitude about biology. Before Brandon was uninterested in biology, but after summer school he was so interested in biology that he would go home and study biology in his free time. Brandon told me that he "would literally sit in front of the computer just researching about a certain topic that we talked about in class."

I spoke with one of the summer school students, Carmen, a low-income Mexican-American female, almost a year after that summer school course and she told me that she is now interested in studying nursing at a four year university. Was Carmen's experience in collaborative peer study groups what changed her attitude towards science? Was Carmen able to finally see herself as a scientist? Carmen's testimony made me question how teachers can help students like her find satisfaction with, enthusiasm about, and career aspirations in science.

By using strategies that build students' positive perceptions of themselves in relationship to science and math content, such as collaborative peer study groups, teachers may increase access to science, technology, math, and engineering (STEM) education and career opportunities. Educational research on interest in STEM careers suggests that self-efficacy in STEM is a critical factor in motivating students to pursue science and math educations and careers. Researchers have identified several approaches that teachers may use to help students improve self-efficacy and motivation in STEM education such as helping students master difficult tasks, promoting collaborative learning, and fostering metacognitive awareness. These approaches were used to shape the Collaborative Peer Study Group Curriculum pedagogical approach.

II. The Need for More STEM Workers

The twenty-first century is increasingly characterized by a global marketplace. In this global marketplace, American workers will have to compete for jobs against skilled workers from other countries with competitive education systems. The United States is falling behind on critical international comparisons of educational performance. American students fare poorly on international comparisons such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) (Baldi, Jin, Skemer, Green, & Herget, 2007; Gonzales, 2004). For example, in the 2006 PISA exam U.S. 15-year-old students scored lower on science literacy than their peers in 16 of the other 29 developed nations that belong to the Organization for Economic Co-operation and Development (OECD) (Baldi et al., 2007). The U.S. (474) also scored below the OECD average (498) on the mathematics literacy portion of the 2006 PISA. Increasing access to science and math education is essential for our national economic competitiveness as we transition from an industrial economy to an information-based economy (Drew, 1996).

Minorities are the fastest growing segment of the American workforce (Hamrick & Stage, 2004). The science, technology, engineering and math work force will have to come increasingly from the nation's non-white communities, if the labor pool is to be large enough to meet the demands of the 21st century. Expanding technology and science industries need more workers and also need a more diverse workforce that will bring new perspectives to the STEM fields (Drew, 1996).

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Not only are there economic reasons for providing equitable education that increases access to STEM, but there are also ethical reasons. The middle income career sectors that are predicted to expand in the 21st century in America are engineering, computer science, and medicine (Fudge, 2007). Considering the predicted expanding careers of the 21st century, disparities in science education participation have the potential to dramatically widen the gap between the rich and poor and between the non-minorities and the minorities if these trends continue (Drew 1996). Improving access to mathematics and science education can allow individuals and groups who have been excluded from the American middle class' greater social mobility.

In addition to the ethical reasons for improving access to math and science education, there is also a pragmatic reason. As the gap between the rich and poor widens, the growing economic disparities may threaten political stability (Alesina & Perotti, 1993). In a study of 70 countries from 1960-85, Alesina and Perotti (1993) found that income inequality, by fueling social discontent, increases socio-political instability. Alesina and Perotti also found that the socio-political instability creates uncertainty in the politico-economic environment which reduces investment. As a consequence, income inequality decreases investment, which decreases economic growth (Alesina & Perotti, 1993). Americans can invest in a stable future by taking steps to close the gap between the haves and the have nots-the poor, disadvantaged and people of color. Underrepresentation of Women and Minorities in STEM Education and Careers

Traditionally white males have dominated STEM career sectors (National Science Foundation, 2005). White males also are disproportionately prepared for careers in STEM (National Science Foundation, 2005). Women and racial-ethnic minorities are not being prepared to enter these fields at the same rate as their male nonminority counterparts (National Science Foundation, 2005). Women and minorities are underrepresented in undergraduate STEM majors, bachelor's degrees in STEM, in doctoral degrees, and in science and technology careers.

Underrepresentation of Women in STEM Education and Careers

Women are not being prepared to enter STEM careers at the same rate as their male counterparts. Although the number of women choosing undergraduate majors in science and technology overall has increased over the last several decades, women are still underrepresented in STEM majors (Dey & Hurtado, 2005). Only 17% of undergraduates in STEM related majors are women, even though women make up 49% of the population of 18-24 year olds in the United States (National Science Foundation, 2005).

Considering the lack of women represented in undergraduate science and technology majors, it is not surprising that women are also underrepresented STEM careers. In 2003 3,597,100 men (of all races/ethnicities) were employed in STEM careers, compared to 1,330,500 women (National Science Foundation, 2005). The health professions, a field that is predicted to expand in 21st century as our population ages, now attracts women at a lower rate than men (Dey & Hurtado, 2005); this may

be surprising considering this field is comprised in part by the female-dominated field of nursing (Dey & Hurtado, 2005).

Underrepresentation of Minorities in STEM Education and Careers

Minorities are also underrepresented in STEM education and STEM careers. Data from a recent large-scale study conducted by the National Science Foundation (2005) illustrates inequalities in preparation for and participation in STEM careers between non-minorities and minorities. According to National Science Foundation, just 9% of male and female STEM undergraduates are Hispanic/Latino, considerably less than the 17% of 18-24 year olds in the United States that are Hispanic. The study also found that only 6% of STEM undergraduate majors are Black/African American compared to 14% of 18-24 year olds in the United States that are Black/African American. Minority graduation rates are also low. Of the 452,338 male and female students who earned Bachelor's Degrees in STEM in the United States in 2004, only 33,077 (7%) were Hispanic/Latino and only 38,050 (8%) were Black/African American (National Science Foundation, 2005).

Not only are minorities underrepresented in science undergraduate majors, but they are also underrepresented in doctoral degrees, and science and technical careers. Only 11% of STEM doctorates went to Hispanic and African American students (National Science Foundation, 2005). In 2003 African Americans and Hispanics combined composed only 4 % of the STEM workforce (National Science Foundation, 2005).

Women and minorities are underrepresented in science, math, and technology fields. Women and minorities are also underrepresented in education that prepares

them to enter these fields. There are many possible reasons why women and minorities are not pursuing STEM education and careers at the same rate as their white male counterparts.

Barriers to STEM Education

Women and minorities face several barriers that can deter them from entering STEM careers such as socio-cultural assumptions and fears about math and science, lack of effective math and science instruction, unequal access to rigorous precollege science and math classes, unequal access to college, and low self-efficacy in science and math (Brainard, 2007, August 3; Dey & Hurtado, 2005; Drew, 1996; NCES, 2002; Lent et al., 2005, Mendoza & Johnson, 2000; Muller, Stage, & Kinzie, 2001; Singell & Stone, 2007; Stodolsky, Salk, & Glassner, 1991; Zusman, 2005).

Socio-cultural Assumptions about Science and Mathematics

Socio-cultural assumptions about scientists can deter women and minorities from entering STEM fields. Women and minorities absorb messages that science is more appropriate for white males (Mendoza & Johnson, 2000). Researchers frequently speculate that women and minorities do not pursue STEM education or careers because they do not identify with the white male-dominated climate of these fields (Dey & Hurtado, 2005; Fullilove & Treisman, 1990). Women and minorities have few role models and little exposure to STEM careers (Mendoza & Johnson, 2000).

Women and minorities may also be discouraged from entering STEM careers because of attitudes about math in America. Stodolsky, Salk, and Glassner (1991) highlighted differences in attitudes about math in comparison to beliefs about social studies in their study of sixth graders. Sixth graders viewed their positive and negative experiences in math as a function of their ability to do math, while in social studies they viewed success as a function of whether the material was interesting or boring. The results of this study are not surprising considering how often teachers hear students declare "I am no good at math" or "Math is not my subject." Even worse, many Americans take pride in their mathematical ignorance, possibly because mathematical weakness has fewer consequences in our society than other failures (Drew, 1996). For example, it is easy to locate successful professional adults in the U.S. who do not know how to solve complex algebraic equations. However, it is much more difficult to find successful professional adults who do not know how to read. This may be why I have heard adults (including parents and teachers) on several occasions announce, "I am not a math person." These negative attitudes about math can discourage young people from pursuing math, especially when these attitudes are expressed by role models.

Lack of Effective Science and Mathematics Instruction

Women and minorities may not pursue STEM education and careers because they tend to be less academically prepared in pre college science and mathematics. The results of the High School Transcript Study (HSTS) which examined the actual coursework completed by a representative sample of those finishing high school in 2000, showed that only 20% of African American high school graduates, and only 18% of Hispanic high school graduates completed biology, chemistry, and physics, before finishing high school, compared to 26% of White high school graduates (NCES, 2002). According to the HSTS, 28% of White high school graduates in 2000 took pre-calculus before they graduated and 12% of White graduates took calculus before they graduated. In comparison, 16% of African Americans took pre-calculus before they graduated and of African Americans 5% took calculus before they graduated. 19% of Hispanic high school graduates took pre-calculus before they graduated and 6% took calculus before they graduated. The quantity of science units completed in high school is the best predictor of students choosing to pursue STEM majors in college (Muller, Stage, & Kinzie, 2001).

Students may have a false sense of preparedness for college science and mathematics. Research shows that high school grades have become inflated for all students over the past several decades (Dey & Hurtado, 2005). College students who earned A grades in high school essentially doubled between 1966 and 1994, while the percentage earning C or worse grades fell by one-half (Dey & Hurtado, 2005). These patterns may suggest that all students today are better prepared than those entering college two decades ago, but all students also reported that they were in need of additional academic support services (Dey & Hurtado, 2005). The percentage of students who thought that there was a "very good chance" that they would get tutoring help in specific courses during college more than doubled between 1975 and 1992. The percentage of all students who expected to get special tutoring or remediation in mathematics, science and foreign language increased between 1984 and 1993 (Dey & Hurtado, 2005). Even though today's transcripts show that students should be more prepared for college math and science, students may actually be less prepared if college course remediation is considered as a factor.

Students may drop out of STEM majors because they are not adequately prepared for college science and math. Often students, of all groups, who enter STEM courses, drop out (Brainard, 2007). About 30 percent of entering freshman plan to earn bachelor's degrees in science, math, or engineering, but only about 15 percent of all baccalaureate degrees are awarded in these fields (Brainard, 2007). The percentages are even lower among black and Hispanic students (Brainard, 2007). Ineffective precollege science and math instruction may not be the only reason that students are dropping out of STEM majors.

Ineffective college science and math instruction may also cause students to drop out of STEM majors. Although there have been many research-based recommendations about how to teach science more effectively, these new modes of instruction are not being implemented at research universities. For example, The American Association for the Advancement of Science (AAAS) and The National Research Council (NRC) recommend that teachers provide their students with inquiry based science (AAAS, 1993; AAAS, 1989; NRC, 1996). AAAS also recommends reducing the sheer amount of material covered and focusing on deeper understanding of a few key topics (AAAS, 1993; AAAS, 1989). Researchers also recommend placing students in cooperative learning groups and having students become increasingly self-directed in their learning (Zemelman, Daniels, & Hyde, 2005; NRC, 2000, 119). A special report written by Brainard that appeared in the August 3rd, 2007 edition of the Chronicle of Higher Education stated that proponents of in-depth study of fewer topics, cooperative learning, student centered learning, and inquiry learning are meeting resistance from research universities. These universities continue to have

introductory science courses that rely largely on lectures and tests and reward memorization of formulas. These ineffective teaching strategies may cause students to drop out of the STEM majors.

Students may also drop out of STEM majors because the first science and math courses that they encounter in college are "weeder" courses. An explanation of the "weeder" class phenomenon can be found in the Undergraduate Survival Guide (1998) for students entering the UC Berkeley Department of Civil and Environmental Engineering:

The most difficult of these classes (which vary from year to year) are generally known as the "weeder" courses, since they cause many engineering students to change majors because they feel they can't make it as engineers. Nobody knows for sure if the college is really trying to weed out weaker students or not, but the fact remains that many students drop out of engineering because of these courses. Our advice to you is: don't get weeded out!

Many science instructors pride themselves on using introductory courses to weed out students who are lazy or less prepared (Brainard, 2007). Unfortunately many of the students who drop their science majors are well prepared and motivated but elect to drop when faced with poor teaching methods (Brainard, 2007; Seymour & Hewitt, 1997).

Once women and minorities enter college and declare a STEM major, they may drop out because they were not prepared for college, experienced poor teaching techniques or were enrolled in "weeder" courses. Poor preparation and socio-cultural assumptions about math and science are not the only barriers to STEM that women and minorities face. Women and minorities can also be discouraged from entering STEM careers because they do not have adequate access to college or STEM majors in college.

Access to resources

Women and minorities are also prevented from entering STEM fields because they do not have access to college or STEM majors in college. Many women and minorities are unable to enter college because they do not have enough high school math and science courses to meet four year university entrance requirements (NCES, 2002). The University of California requires three years of mathematics and two years of a laboratory science; they recommend four years of mathematics and three years of laboratory science (UC, 2005). High minority enrollment secondary schools offer less demanding and less extensive science and mathematics courses, giving minority students fewer opportunities to take the courses required to help them pursue science and mathematics in college (Mendoza & Johnson, 2000). Also, minority students are disproportionately placed in lower track courses and thus have less access to higher level courses, even when they are in schools that offer these courses (Mendoza & Johnson, 2000). Tracking students in mathematics and science courses not only affects the quality, but also the quantity of the courses that the students may take (Mendoza & Johnson, 2000). Low income high schools, with high minority enrollment, also lack well-prepared teachers, physical infrastructure, and technological resources (Kozol, J. 1991; Mendoza & Johnson, 2000). These educational resource deficiencies prevent access to high quality math and science education for underrepresented and minority students (Mendoza & Johnson, 2000).

One of the biggest barriers to STEM is access to college. Minorities enter four year colleges at a much lower rate than nonminorities. Once African-American and Latino high schoolers graduate, a little over half of them enter any college, compared with nearly two thirds the of white high school graduates (Zusman, 2005). Close to half of the underrepresented students who do attend college enroll in two-year institutions. Most of these students do not transfer to baccalaureate granting institutions, and even smaller numbers actually receive bachelor's degrees or higher (Zusman, 2005). In 2000-2001, African Americans received fewer than nine percent of all bachelor's degrees, and Latinos received only six percent, even though together these two groups constitute one-quarter of high school graduates and one-third the college age population (Zusman, 2005). Although women of all groups are now entering college at a higher rate than men of all groups, women continue to be underrepresented in STEM majors (National Science Foundation, 2005).

Poverty is the biggest barrier to college (Zusman, 2005). Average tuition has risen at rates far in excess of inflation over the last two decades, and federally subsidized, need-based aid has not kept pace with tuition, leaving needy students with an increasing gap to fill from other sources (Singell & Stone, 2007). Blacks and Hispanics are disproportionately affected by poverty in the U.S. (U.S. Census Bureau, 2007) and are therefore disproportionately hurt by rising tuition costs.

Self-efficacy in Science and Mathematics

Women and minorities face many factors that may block access to a STEM career: socio-cultural assumptions about math and science, under preparation in high school science and math courses, unequal access to college, and attrition from math

and science majors in college. These factors can potentially affect one's career path, whether or not one specifically apprehends their influence (Lent, Brown & Hackett, 2000). However, the effect of these factors often depend at least partly on the manner in which the person responds to the barrier (Lent, Brown & Hackett, 2000). A person's perception of their ability in math and science can influence their goals in math and science careers. Bandura (1997) terms the perception of a person's own ability to perform a certain task or attain a certain goal with whatever skills one possesses, self-efficacy. Self-efficacy is not the skills one has; it is one's perception of one's skills. People often fail to perform even though they know what to do and have the skills to do the task (Bandura, 1997). Lent (2005) and his colleagues determined that self-efficacy was the primary predictor of the students' career goals. Beliefs in personal efficacy predict the level of interest in different occupational pursuits as well as in specific academic subjects even when the influence of ability is removed (Lent, Larkin, & Brown, 1989; Lent, Lopez, Bieschke, & Socall, 1991; Lent, Brown, & Hackett, 1994, 2000; Lent et. al 2005). The stronger people's belief in their efficacy, the more career options they consider possible, the greater the interest they show in these careers, the better they prepare themselves educationally for different occupational careers, and the greater the staying power in their chosen pursuits (Lent, Brown, & Larkin, 1986). People rapidly eliminate entire classes of careers based on perceived self-efficacy (Bandura, 1997). Therefore, low mathematical and scientific efficacy can deter students from pursing careers in science and technology.

Self-efficacy beliefs in math and science may explain differences in how individuals react to barriers such as poverty, poor instruction of math and science and lack of advanced STEM courses (Lent, Brown, & Hackett, 2000). However, perceived barriers alone do not account for the large gap that exists between women and men, and minorities and nonminorities who pursue STEM careers (Lent, Brown, & Hackett, 2000, Lent et al., 2005). Educators and policy makers must examine all of the barriers to STEM education, in order to create more equitable access to STEM careers. While there is a clear need to critically examine each of the factors that contribute to this inequity gap, and create and implement policies that will remove these hindrances to the STEM career path, I will focus on how educators can raise students self-efficacy in math and science.

I chose to examine self-efficacy for several reasons. First, self-efficacy is a barrier that I, as a classroom teacher, can do something about. I can organize my classes so that students are able to master rigorous curriculum through social interactions with their peers. Mastering difficult tasks through social experiences can raise self-efficacy (Bandura, 1997). Second, self-efficacy is the largest predictor of student's career goals (Lent et al., 2005). Third, I chose to examine self-efficacy because we lack science curriculum that raises self-efficacy beliefs in science.

Most importantly, I was inspired to research self-efficacy building science curriculum by personal experiences at the school where I am employed. I teach science at innovative charter school that implements several policies promoting more equitable access to STEM education. The charter school enrolls a diverse student body, places these students in untracked classes, teaches science and math through projects that have real-world applications, and requires all students to take four years of laboratory science and four years of mathematics in order to graduate. The school also offers financial assistance for college applications for low-income students. Although these reforms were designed to create more equitable access to STEM education, I have observed that minority students are disproportionately disinterested in math and science education and careers. Teaching strategies that increase students' self-efficacy may be able to close the interest gap between minority students and their white peers.

III. Review of Educational Research on Self-Efficacy

There is a need for a larger and more diverse pool of workers trained in science, technology, engineering and math (STEM) (Alesina & Perotti, 1993; Drew, 1996; Hamrick & Stage, 2004). However, women and minorities face many barriers to STEM education such as socio-cultural assumptions and fears about math and science, under preparation in high school science and math courses, unequal access to college, attrition from math and science majors in college, and low self-efficacy in science and math (Brainard, 2007; Dey & Hurtado, 2005; NCES, 2002; Lent et al, 2005; Muller, Stage, & Kinzie, 2000; Zusman, 2005). Educators and policy makers need to create and implement policies that will help students overcome these obstacles and access STEM careers. One way that educators can help students increase interest and provide access to STEM careers is by using teaching strategies that raise self-efficacy in math in science. Raising self-efficacy in science and math education encourages students to pursue STEM careers, and enter STEM fields.

Self-Efficacy Influences STEM Career Goals

Recently researchers have studied the variables that shape people's academic and career-related interests, choices, and performance outcomes (Lent et. al., 2005; Lent, Brown & Hackett, 1994, 2000). Lent, Brown and Hackett postulate, in their Social Cognitive Career Theory (SCCT), that self-efficacy, interest, outcome expectations, and environmental supports and barriers determine people's academic and career choice goals. Self-efficacy has been the focus of this recent research (Lent, Brown & Hackett, 1994, 2000; Lent et al., 2005), with much of the research occurring within the context of science, technology, engineering, and math-related (STEM)

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fields. Lent and his colleagues determined that self-efficacy was the primary predictor of the students' career goals (Lent et al., 2005).

Self-Efficacy Motivates Students to Pursue STEM

According to Deci (1995) self-efficacy is one of the key elements that contribute to a person's intrinsic motivation, which is the willingness to pursue something when there are no external pressures. The higher a student's efficacy beliefs, the higher the academic challenges they set for themselves and the greater the intrinsic interest in scholastic matters (Bandura & Schunk, 1981; Relich, Debus, & Walker, 1986: Schunk, 1984). For example, Bandura and Schunk (1981) studied 40 children who exhibited gross deficits and disinterest in mathematical tasks. They measured the children's self-efficacy about subtraction before and after they learned subtraction. After the students learned subtraction, they took a difficult subtraction post-test. The stronger the students self-efficacy, the longer they persisted on the difficult subtraction problems. The longer the students persisted, the better they performed on the subtraction problems. The day after the students took the subtraction post-test, Bandura and Schunk measured students' intrinsic interest in subtraction. They asked the children to choose to either work on a stack of subtraction problems or another set of digit-symbol problems. The children could choose whether they wanted to work on one, the other, or both sets of problems. The children could also determine how much time they wanted to spend on each activity. Bandura and Schunk then measured interest in subtraction by counting the number of subtraction problems that each student completed. Bandura and Schunk found that self-efficacy in subtraction was highly correlated with interest in subtraction.

When students' raise their self-efficacy in science and math, their motivation to pursue scientific and mathematical academic endeavors increases (Bandura, 1997; Bandura & Schunk, 1981; Deci, 1995). When students are motivated, they devote more time to learning (Bransford et al., 2000). As a consequence, students who are motivated in an academic area experience more success in that area (Linnenbrink & Pintrich, 2002). The increased academic success can increase their self-efficacy and self-motivation for this academic area even more, creating an upward spiral of success. Success in their high school mathematics and science classes increases student's motivation to pursue STEM careers (Lent et. al., 2005; Lent, Brown & Hackett, 1994, 2000). Increasing self-efficacy in math and science may shift the demographics of trained STEM workers toward a more diverse, equitable pool of workers.

Increasing Self-Efficacy in Science and Mathematics

If high self-efficacy is a critical component of intrinsic motivation to pursue math and science, how can teachers increase students' self-efficacy in these disciplines? Teachers may be able to increase student's self-efficacy in science and mathematics by helping students master difficult scientific tasks, by providing students with opportunities to learn through social experiences rich with speech, feedback and peer models, and by fostering metacognitive awareness.

Mastering Rigorous Curriculum Increases Self-Efficacy

One way that a person can increase their self-efficacy is by mastering a difficult task (Bandura, 1997). Successes build self-efficacy and failures undermine self-efficacy (Bandura, 1997). According to Bandura (1977), learning is rooted in

direct experience; we learn from the results of the positive and negative effects that actions produce. Some actions prove successful, while others have no effect or produce negative outcomes. Through this process of reinforcement, people eventually select successful forms of behavior and discard ineffective behaviors. Positive consequences serve as motivators through their incentive value, while negative consequences serve as de-motivators.

Not all successes, however, build self-efficacy. Only when people are successful at tasks that they perceive as difficult, do they increase their self-efficacy (Bandura 1997). Educators, however, do not agree on what makes curriculum challenging for students. Figure 1 illustrates different definitions of rigorous curriculum.

Definitions of Rigorous Curriculum

Rigorous curriculum helps "students to develop the capacity to understand content that is complex, ambiguous, provocative, and personally of emotionally challenging." (Strong, Silver & Perini, 2001, p.7).

"Truly rigorous learning- both academic and non-academic- involves deep immersion in the subject over time with learners using sophisticated texts, tools, and language in real world settings and often working with expert practitioners as mentors" (Washor & Mojkowski, 2007, p.85).

Rigorous curriculum is active, deep (rather than broad), and engaging (Lundsgaard, 2004).

Figure 1: Different definitions of rigorous curriculum.

Strong, Silver, and Perini (2001) believe that provocative and emotionally challenging ideas make curriculum rigorous, where as Washor and Mojkowski (2007) believe that sophisticated texts, tools, and language make curriculum rigorous. Although each definition of rigorous curriculum in Figure 1 has important distinctions, all of the definitions share a common feature. All of the definitions explain that rigorous curriculum offers in-depth immersion in a complex subject.

High school math and science curriculum can be rigorous because there are many concepts that are complex and can be studied in depth. Perkins (1992) with the help of his colleagues at Harvard, Howard Gardner and Vito Perrone, generated several topics in math and science that were rich and encouraged deep exploration of the curriculum. Some examples of the in-depth science and math topics that they generated are:

- Evolution and natural selection and its wide applicability to other settings like pop music, fashion, the evolution of ideas.
- 2) The origin and fate of the universe.
- Zero and the problems of practical arithmetic that this great invention resolved.
- Probability and prediction and the ubiquitous need for simple probabilistic reasoning in every day life.

These are just a few examples of rigorous content that can be taught in high school math and science courses. Students exposed to rigorous curriculum have the opportunity to increase their self-efficacy by mastering these complex ideas.

Although students in high school math and science courses may have the opportunity to increase their self-efficacy by mastering rigorous content, this does not always happen. The rigorous content presented in high school math and science classes can cause students to fail and lower their self-efficacy. This inefficacy usually feeds on itself (Bandura, 1997). The low achieving students often establish a reputation for lacking ability or underperforming and these reputations are not easily changed. These failures can turn students off to math and science. Our challenge is to use the high school math and science classes to increase self-efficacy, and not decrease it.

If students experience success when faced with rigorous math and science content, they will increase their self-efficacy in math and science tasks. After students believe that they can succeed at a task, they persevere in the face of adversity and quickly rebound from setbacks (Bandura, 1997). Students with high self-efficacy also take on more difficult tasks because they believe they can be successful (Bandura, 1997). High self-efficacy in math and science increases motivation and interest in academic mathematics and science (Bandura & Schunk, 1981; Deci, 1995). When people are motivated to engage in math and science, they will devote more time to learning it (Bransford et al., 2000). When students devote more time to learning and persevere when they hit setbacks, they are more likely to be academically successful (Bandura & Schunk, 1981), which increases their self-efficacy, creating an upward spiral of success (See Figure 2). In order to fuel this spiral of success, teachers must help students be successful in academic math and science.
Interest in and Access to STEM Careers



Figure 2: Increasing self-efficacy in science and math effects participation in STEM.

Students master rigorous material through social interactions with peers.

According to Lev Vygotsky, the Soviet developmental psychologist, learning is social (Wink & Putney, 2002). Vygotsky explained how people learned together in his theory of the zone of proximal development (ZPD) (Wink & Putney, 2002). A ZPD is the difference between what a learner can do alone and what a learner can do with assistance from "more competent peers" or adults (Vygotsky, 1978, p.86). According to Vygotsky, peers can help students learn. If students learn through social interactions with their peers, students need to be given opportunities to learn together and help each other construct meaning.

In his book, *Thought and Language*, Vygotsky wrote, "thought is not merely expressed in words; it comes into existence through them" (Vygotsky, 1986, p.218). Following this, when students share their knowledge with their peers, they must construct and refine their knowledge, leading to increased understanding of the learned material (Wink & Putney, 2002).

Verbalizing cognitive processes has been shown to help low achieving students master STEM curriculum. Schunk, in his 1982 study of children who were low arithmetic achievers, showed that verbalization during problem solving enhanced performance and increased in perceived self-efficacy and achieve higher proficiency in mathematics than children of the same demographic who are equally trained in arithmetic strategies, but did not engage in free verbalization (Schunk, 1982).

Not only can verbalization help students learn, but it can also help students remember what they have learned. Students who intentionally model activities into words, concise labels, or vivid imagery (code) learn and retain information better than those who simply observe or are mentally preoccupied with other matters (Bandura & Jeffery, 1973). When students communicate with each other about ideas, they can help each other make connections between ideas and chunk information together into familiar patterns or meaningful units (codes). When students chunk and cluster ideas, they understand and remember the information better (Bransford et. al., 2001). In Bandura and Jeffery's experiment (1973) undergraduate students were tested on their memory of the movements of people performing in a video. Students who coded the movements (into letters, numbers, or their own code) and rehearsed (either physically

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or symbolically) were able to remember the series of movements better than those who didn't code, or coded, but didn't rehearse.

Rehearsal also helps students remember information. When people mentally rehearse or actually perform modeled response patterns, they are less likely to forget them than if they neither review them nor practice what they have seen (Bandura & Jeffery, 1973). The act of explaining ideas by using speech, words, or images, helps students rehearse the information. Speaking with peers can help students learn, understand and remember rigorous math and science content.

Social Experiences can Increase Self-Efficacy

Social experiences can not only help students master rigorous curriculum, but can also increase self-efficacy. Social experiences such as speech, peer feedback, peer comparisons and peer modeling all help shape self efficacy.

Speech. Verbalization not only helps students learn the material, but it also helps students build their self-efficacy. When the students explain their thought processes and strategies to others in the group they build self-efficacy. Verbalizing cognitive processes builds self-efficacy and promotes cognitive skill development (Bandura, 1997; Schunk & Rice, 2002). For example, Schunk and Rice (2002) studied 3rd and 4th graders who had low reading comprehension skills. When the students verbalized their thought process, they were better able to comprehend the reading and reported a higher reading self-efficacy (Bandura, 1977,1997).

Peer feedback. Peer feedback can affect a person's self-efficacy (Bandura, 1977). People judge their capabilities based on the feedback and interactions they have with others (Bandura, 1977). When significant others, such as peers or parents,

express faith in one's capabilities, self-efficacy is strengthened (Bandura, 1997). Peers are an important source of validation of intellectual self-efficacy and peers' influence grows stronger as children get older (Bandura, 1997). Peers not only influence self-efficacy by giving feedback, but also influence self-efficacy by providing a basis of comparison.

Peer comparisons. People do not determine their self-efficacy by the results of their actions alone; people determine their self-efficacy by comparing their performance to the performance of others (Bandura, 1977). The impact of comparisons to others on perceived efficacy is well documented in studies in which students are given false feedback that their attainments place them in either a high or a low rank compared to a reference group (Jacobs et al., 1984; Litt, 1988). Jacobs and his colleagues (1984) studied a group of undergraduate students and how they rated their self-efficacy on anagram puzzles after they were told inaccurate average performance scores from the previous year. The students who thought that they did well in comparison to others reported a higher self-efficacy than the students who thought they did poorly compared to others. In order to increase self efficacy, students need to feel successful in comparison to their peers.

Peer modeling. Students with high self-efficacy can increase self-efficacy of other students. Peer models who express confidence in the face of difficulties install a higher sense of efficacy and perseverance in others than do models who begin to doubt themselves as they encounter problems (Zimmerman & Ringle, 1981). Zimmerman and Ringle (1981) studied the affects of children's perseverance and self-efficacy on a wire puzzle when they were exposed to four types of models, a confident model who

persevered, a confident model who did not persevere, a pessimistic model who persevered, and a pessimistic model who did not persevere. The confident model worked on the puzzle and said the following:

I am sure I can separate these wires; I just have to keep on trying different ways, and then I will find the right one...I am getting closer to finding a way to separate these wires...I'm going to stop now, but I know that I will be able to separate these wires the next time I try. (p.487)

The pessimistic model worked on the puzzle and said, "I don't think that I can separate these wires; I have tried so many different ways and nothing seems to work...I don't think that I will ever be able to separate the wires" (p.487). High persistence models worked on the puzzle for five minutes and low persistence models worked on the puzzle for 30 seconds. The model's perseverance and confidence significantly increased the children's degree of persistence on the wire puzzle. The model's perseverance and confidence also increased the children's self-efficacy estimates. Treatments that combine modeling with guided participation have proved most effective in eliminating dysfunctional fears and inhibitions (Bandura, 1977)

Seeing people similar to themselves perform successfully typically raises selfefficacy beliefs in observers that they themselves possess the capabilities to master comparable activities. They persuade themselves that if others can do it, they too have the capabilities to raise their performance (Schunk, Hanson & Cox, 1987). Coping peer models are peers who are familiar with the skill, but not yet proficient (Schunk, Hanson & Cox, 1987). Coping peers can help raise the self-efficacy for the low skilled learner (Schunk, Hanson & Cox, 1987). Schunk and his colleagues (1987) studied children learning fractions from different types of peers. Children who learned from single or multiple coping peers demonstrated higher self-efficacy, skill, and performance compared to those who learned from an adult of single peer who had mastered fractions. Peers can influence self-efficacy by listening to speech, modeling behavior, giving feedback, and providing a basis of comparison.

Metacognition Can Increase Self-Efficacy

Metacognition can build self-efficacy (Bandura, 1997). Metacognition refers to a person's ability to create learning goals and monitor their progress and understanding (Bransford et. al., 2001). Metacognitive skills include: identifying prior knowledge, defining the learning goal, identifying resources, setting priorities, recognizing when you don't understand, and seeking help when you need it (Bransford et. al., 2001; Weinert, 1987).

One metacognitive task that can help students increase their self-efficacy is academic goal setting (Bandura & Schunk, 1981). Academic goals can increase selfefficacy by increasing interest in the subject matter and increasing academic success (Bandura & Schunk, 1981). Proximal goal setting, compared to distal goal setting, yields the highest increase in self-efficacy (Bandura & Schunk, 1981; Morgan, 1985). Morgan studied undergraduate students who set interim goals for their end-of-year exams. These goal-setting students performed better on their exams and developed a greater interest in the subject compared to their peers (education). Goal-setting is not the only metacognitive task that helps students increase their self-efficacy.

Students can also increase their self-efficacy by self-evaluating their progress toward their learning goals (Schunk, 2003; Zimmerman & Cleary, 2006). Students can evaluate their progress toward their learning goals by identifying what they know, what they don't know and where they are likely to have misunderstandings or errors (Costa, 2001a). One instructional strategy that fosters metacognitive self-evaluation is having students generate their own questions (Costa, 2001a). According to Costa when students generate their own questions, they pause and perform a check for understanding, to determine whether or not they understand. They may check, for example, whether they understand the concepts or vocabulary; "they are grasping the concept; it "makes sense"; they can relate it to what they already know; they can give other examples or other instances; [or] they can use the main idea to explain other ideas" (Costa, 2001a, p.410). After students decide what they understand or don't understand, they can take steps to clarify their understanding, and thereby increase comprehension (Costa, 2001a). Because collaborative learning fosters student generated questions, discussion and feedback, it increases metacognition (Johnson & Johnson, 2001).

Collaborative Peer Study Groups

Collaborative peer study groups provide an avenue in which students can increase their self-efficacy by helping them master rigorous content, by providing them with social experiences, and by fostering metacognition. These study groups are most effective when teachers carefully form the groups.

Study Groups

When students work together in small social learning groups, it is often described as "collaborative learning" or "cooperative learning." There two terms are often used interchangeably. Figure 3 displays several definitions of cooperative and collaborative learning. Definitions of Collaborative and Cooperative Learning

"Cooperative learning refers to a set of instructional strategies which include cooperative student-student interaction over subject matter as an integral part of the learning process" (Kagen, 1994, p.4:1).

"Cooperative learning is the instructional use of small groups so that students can work together to maximize their own and each other's learning" (Johnson & Johnson, 2008).

"Collaborative learning is an educational approach to teaching and learning that involves groups of students working together to solve a problem, complete a task, or create a product" (NISE, November, 1997).

Figure 3: Definitions of collaborative and cooperative learning.

In this paper, I will use the term collaborative learning to refer to student work that takes place in small learning groups. In collaborative learning groups, students can solve problems, complete tasks, create products, or learn ideas (NISE, November,

1997). One model of collaborative learning is the collaborative study group.

In collaborative study groups students help each other learn and understand material. When students work together to learn material, students take on teacher and learner roles. When students take on teacher roles, they help students understand the material by teaching directly or answering questions. Students in the learning roles listen to their teaching peers and ask questions. Students in both roles learn through these social interactions with their peers. Students can maximize their learning when they are placed in carefully selected study groups.

Study Group Formation

In order for students to maximize the effectiveness of the collaborative groups, most researchers suggest creating heterogeneous groups (Kagen, 1994; Johnson & Johnson, 2008). When students pick their own groups, the results are not always beneficial. Student-selected groups can lead to off-task behavior and the reinforcement of status hierarchies in the class (Kagen, 1994; Johnson & Johnson, 2008). The students who are left to group together often do not communicate or function well (Kagen, 1994; Johnson & Johnson, 2008).

The heterogeneous groups should contain a mix of abilities, gender, race, ethnicity, backgrounds and confidence. Kagen (1994) believes groups should be composed of one low, two medium, and one high ability student. It is also important to consider the self-efficacy of the students in the group. Although, high ability students often have a high self-efficacy and low ability students have low selfefficacy, they do not always follow this pattern. High self-efficacy students can help students with lower self-efficacy increase their perceived competence. Peer models who express confidence in the face of difficulties install a higher sense of efficacy and perseverance in others than do models who begin to doubt themselves as they encounter problems (Zimmerman & Ringle, 1981).

Teachers, however, should be careful not to place a low student with only high students, who have already mastered the material. If students are paired with students that they believe have skills that are far above their own, they may withdraw from the study group (Meyer, 1987). Cooperative groups where low skilled students learn academic skills from coping peers (peers who are familiar with the skill, but not yet proficient), can help raise the self-efficacy for the low skilled (Schunk, Hanson & Cox, 1987).

Kagen (1994) advocates organizing groups of four students for cooperative learning experiences and suggests that students form groups of three or five when the class does not divide evenly. Kagen (1994) suggests keeping students in groups for four to six weeks so that they stay together long enough to feel interdependence, but are able to transfer their group collaboration skills to a new group. Once effective study groups are formed, students can work together to master rigorous material. *Benefits of Study Groups*

Collaborative study groups can benefit students in a number of ways. Collaborative study groups help students master rigorous math and science content, have social interactions, and think metacognitively (Bandura & Schunk, 1981; Fullilove & Treisman, 1990; Johnson & Johnson, 2001). Students can increase their self-efficacy in math and science by learning rigorous content in a social context and by thinking metacognitively (Bandura, 1977, 1997; Bandura & Schunk, 1981; Zimmerman & Cleary, 2006).

Study groups help students master rigorous material. In small study groups, students teach and learn from each other, and have multiple opportunities to talk about the subject matter. The act of talking helps students formulate their own ideas, create a deeper understanding, and remember what they have learned (Bandura & Jeffery, 1973; Schunk, 1982; Wink & Putney, 2002). Because study groups provide multiple opportunities to learn through social interactions, and the learning that results from these social interactions can boost self-efficacy and encourage students to undertake difficult learning tasks, study groups should help students master rigorous science and math content. This is exactly what we see in educational research on study groups (Fullilove & Triesman, 1990).

Research shows that collaborative study groups can actually help students master difficult material. Some of the most interesting research about collaborative peer study groups was sparked by Treisman's work at the University of California, Berkeley. Treisman created the Math Workshop Program (MWP) while he was a graduate student and TA for a calculus course at UC Berkeley. Treisman noticed that there was a large discrepancy in the performance of the African American students and the Chinese American students in undergraduate calculus classes (Fullilove & Treisman, 1990). Interested in why this discrepancy existed, Treisman spent 18 months observing both the Chinese American and African American students (Drew, 1996). He determined that the students in the two groups used very different study strategies to prepare for exams or complete course assignments (Fullilove & Treisman, 1990). The African American students were more likely to study alone and to separate their social lives from their study activities (Fullilove & Treisman, 1990). The Chinese American students, on the other hand, were more likely to combine social and study time (Fullilove & Treisman, 1990). Specifically, the Chinese Americans organized themselves into informal study groups (Fullilove & Treisman, 1990). These study groups allowed the students to share their math knowledge and to check their understanding of the concepts taught by the University (Fullilove & Treisman, 1990). As a result of these study groups, the Chinese students devoted more time to their math study (approximately 14 hours per week compared to the approximate 8 hours

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per week that the African American students studied), assisted each other with difficult problems, and asked the TA for assistance on the problems that the group could not solve together (Fullilove & Treisman, 1990). Treisman developed an experimental workshop in which he replicated the study group interactions of the Chinese American students with the African American students (Fullilove & Treisman, 1990). Treisman's workshop was very successful; the workshop participants significantly out-performed their non-workshop peers (Fullilove & Treisman, 1990). The workshop students also were more likely to stay in a mathematics-based major (65% remained) versus the non-workshop participants (41% remained) (Fullilove & Treisman, 1990). Treisman's model shows that collaborative peer study groups can help students master rigorous material.

Treisman's model also shows the importance of positive self-concept in study group curriculum. A central component of the Treisman workshop approach was that it was advertised as an honors program that was known for producing the most successful mathematics students at the University (Fullilove & Treisman, 1990). Treisman's workshop encouraged students by giving them advanced problems and contrasted with the remedial programs that traditionally serve African American and other minority students at predominantly white Universities (Fullilove & Treisman, 1990). Treisman's model shows that peer study groups help low-achieving students by challenging them with rigorous material.

Social interactions in study groups can increase self-efficacy. In three respects the social interactions in study groups can increase self-efficacy. First, collaborative peer study groups provide opportunities for students to talk about what they are

learning, and the act of talking about the material can increase self-efficacy (Bandura, 1997; Schunk & Rice, 2002). Second, study groups provide opportunities for students to learn from coping peers and compare themselves to these models. Learning from coping peer models can increase self-efficacy (Bandura, 1977; Schunk, Hanson & Cox, 1987; Zimmerman & Ringle, 1981). Third, study groups provide a place where students can get feedback from peers on their learning progress. When peers provide students with positive feedback, the students may increase their self-efficacy (Bandura, 1977).

Collaborative study groups help students think metacognitively. The structure of collaborative peer study groups fosters metacognition in several ways. First, before students in a study group can work effectively, they must decide on common learning goals. The act of group goal setting helps students think about their own personal learning goals. Second, in the collaborative study groups there is an expectation that students will have to teach what they are learning. Johnson and Johnson (2001) theorize that the expectation that one will have to summarize, explain and teach what one is learning impacts the metacognitive strategies used. Murray's research indicates that students learn and organize material differently when they are learning to teach others than when they are learning for their own benefit (as cited in Johnson & Johnson, 2001). Third, in collaborative peer study groups, students with incomplete information interact with others who have different perspectives or facts. In this way students uncover misunderstandings or missing pieces. Johnson and Johnson found that cooperative experiences promote greater perspective-taking ability which results in better understanding and retention of others' information and reasoning. Fourth, the members of collaborative peer study groups externalize their ideas, reasoning, and questions for critical examination. As a result of this externalization of thinking, considerable peer monitoring and regulating of one's thinking tend to occur (Johnson & Johnson, 2001). Johnson and Johnson (2001) explain how small collaborative groups promote regulation:

Peers stimulate and focus the exploration of ideas. In comparison, individuals working by themselves more frequently get lost in lengthy and aimless wild goose chases. Individuals generally have difficulty monitoring their own thinking. Within, a cooperative group, however, each member can monitor the reasoning of other members and help enhance the understanding of the material. In essence, the cooperative experience serves as a training ground for metacognitive skills to develop that are transfer able to individual learning. (p. 456)

Collaborative peer study groups also foster metacognition because group members often give each other feedback on their peer's contributions. Students answer questions and respond to each others comments. Finally, participation in collaborative peer study groups inevitably produces controversy. Students often disagree with the ideas, opinions, conclusions, theories, and information of their peers. This intellectual conflict promotes metacognitive activity (Johnson & Johnson, 2001).

Other benefits of collaborative study groups. Students who work in collaborative peer study groups spend more time on-task, receive more feedback, and are more motivated to participate (Kagen, 1994; NISE, 1997). In small groups, students have more extensive and quicker feedback than they have in whole-class environments where they have to wait their turn to receive feedback from the teacher. In study groups, students do not have to wait as long to ask questions and get feedback to these questions, rather they can turn to a peer and get immediate feedback. This can

increase academic achievement because students are exposed to more and different questions and answers from other students. Students may also be motivated to participate in order to avoid disappointing their group members (NISE, 1997).

In all, collaborative peer study groups can benefit students in many ways. Collaborative study groups provide a social context in which students can master rigorous math and science content and think metacognitively (Bandura & Schunk, 1981; Fullilove & Treisman, 1990). Students can increase their self-efficacy in math and science by learning rigorous content in a social context and by thinking metacognitively (Bandura, 1977, 1997; Bandura & Schunk, 1981). However, is the current science curriculum rigorous and social in nature? In other words, does the current high school science curriculum foster self-efficacy in science and math? Are collaborative peer study groups used in the high school setting? In the following chapter I will examine whether current science curricula promotes self-efficacy in math and science.

IV. Review of Self-Efficacy Building Science Curricula

Although there is clear need to have a larger and more diverse pool of workers trained for the STEM careers of the 21st century, much of the current high school math and science curriculum is not designed to help increase interest in STEM. Most high school math and science curricula are not designed to help raise students' scientific and mathematical self-efficacy. The vast majority of high school math and science curricular practices often lower self-efficacy about academic math and science particularly for less-prepared students (Bandura, 1997). The few curricula that recognize the importance of mastering rigorous content through social learning do not show teachers how to actualize this in the high school science classroom.

The Standards-based Curriculum Encourages Superficial Learning

Over the past several decades the science and math curriculum has grown with little restraint (AAAS, 1989). New discoveries and technological innovations have been added to the standards, but little has been taken out. Science and math teachers are asked to teach immense content loads with almost a complete absence of a support system (AAAS, 1989). A quick look at the National Biology Content Standards (NRC, 1996) shows the breadth of content that teachers are asked to cover in a typical year long class. The National Biology Content Standards have 10 sets of standards: Standard Set 1, Cell Biology; Standard Set 2, Genetics (Meiosis and Fertilization); Standard Set 3, Genetics (Mendelian); Standard Set 4, Molecular Biology; Standard Set 5, Biotechnology; Standard Set 6, Ecology; Standard Set 7, Evolution (Population Genetics); Standard Set 8, Evolution (Speciation); Standard Set 9, Physiology (Homeostasis); and Standard Set 10, Physiology (Infection and Immunity). Each standard set has 4-10 sub standards that students are required to know. These broad standards pressure teachers to cover a lot of material superficially, and ignore curriculum that requires in-depth study of any one subject. Most of the state standards suffer from the same problem that plagues the national standards. Forty nine of the fifty states have now developed their own systems of standards for teachers and students (Zemelman, Daniels, & Hyde, 2005). The California State Biology/Life Sciences Standards, for example, has 10 standard sets, each with several sub-standards that covers topics as diverse as biotechnology and human physiology (California State Board of Education, 1998).

The No Child Left Behind (NCLB) Act of 2001 has added pressure on teachers to follow the immense standards. NCLB uses high stakes test scores to determine if schools are making progress towards reducing their achievement gaps of students of various subgroups (U.S. Congress, 2002). Currently NCLB requires states to administer standardized tests in mathematics and language arts that are used to determine a schools' Adequate Yearly Progress (AYP), the measure of a school's progress toward achieving the legislation's goal of "academic proficiency" for every student by 2014.

Beginning in the 2007-2008 school year, NCLB required states to measure students' progress in science at least once in each of three grade spans (3-5, 6-9, 10-12) each year and use the science test results to determine each school's AYP. Although the goal of NCLB, to reduce achievement gaps between various subgroups by 2014, (U.S. Congress, 2002) is noble, NCLB has placed added pressure on teachers to teach the ever-widening standards (Aronson & Miller, 2007). As a result teachers may inadvertently avoid instructional practices that foster student's interest in the subject matter (Aronson & Miller, 2007). In a study of 376 elementary and secondary teachers in New Jersey, teachers indicated that they tended to teach to the test, often neglected individual students' needs because of the stringent focus on high-stakes testing, had little time to teach creatively, and bored themselves and their students with practice problems as they prepared for standardized testing (Centolanza, 2004).

The standards-based approach to teaching math and science fosters breadth over depth learning and discourages social learning. This curricular approach fails to help students master rigorous content through social learning experiences. What's worse is that the standards-based approach also promotes teaching practices like lockstep sequencing, tracking, and socially competitive grading practices, which have been correlated with decreases in self-efficacy for students, particularly for students who are less prepared (Bandura, 1997). Consequently, the standards-based instruction may lower, rather than raise students' self-efficacy particularly for disadvantaged, low skilled, low self-efficacious students.

The AAAS Recommends In-Depth Learning

The American Association for the Advancement of Science (AAAS) was critical of the science and math curriculum that failed to teach most American students to be scientifically literate (AAAS, 1989). The AAAS attributed much of the problem to the sheer amount of material being covered in modern science and math classes (AAAS, 1989; 1993). Consequently, AAAS researched the best methods for improving science teaching and learning. AAAS used their findings to create a plan for comprehensive science and math education reform named Project 2061. In a widely publicized publication, *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology* (1989), the AAAS whittled the science curriculum standards down to four major topics: the nature of science, mathematics and technology; basic scientific knowledge about the world; great episodes in the history of the scientific endeavor; and the habits of mind essential for scientific literacy. Building on their former publications, the AAAS published two volumes of the *Atlas of Science Literacy* (2001; 2007) which took the benchmarks and wove them into a web of interconnected ideas. The *Atlas* illustrates these connections through "strand maps" that connect concepts and thinking skills.

Unfortunately, AAAS teaching practices are not aligned with the kinds of learning that will be assessed by the high stakes assessments mandated by NCLB (Aronson & Miller, 2007). NCLB could cause students to fragment their knowledge into isolated, unrelated concepts instead of helping students understand and appreciate the unifying themes in science that AAAS promotes (Aronson & Miller, 2007). With the pressures of NCLB, few teachers are implementing the models that AAAS supports (Zemelman, Daniels, & Hyde, 2005). The vast majority of math and science teachers continue to teach math and science by superficially covering many topics through direct instructional methods. For example, Wood reported in her 2002 survey of 5,720 science and mathematics teachers that 86 percent of biology teachers said that their students listened to a lecture by the teacher and took notes at least once a week. Wood found that other high school science classes used lecture in similar frequencies. time to lecture/discussion than any other activity. Wood also found that 45% of biology teachers used 75-100% of the textbook in their class (with the most common textbooks used containing over 1000 pages).

CES Teaches In-depth but Fails to Provide Strategies for Mastery

Although the method of teaching science and math through shallow and expansive curriculum is prevalent, there are several schools around the country that have resisted the pressure created by NCLB (Zemelman, Daniels, & Hyde, 2005). These schools recognize the need to break away from expansive and shallow curriculum, lock-step sequencing, and tracking practices. Many of these schools are affiliated with The Coalition of Essential Schools, a network of diverse schools that share a common vision.

The Coalition of Essential Schools (CES) was founded in 1984 by Ted Sizer who after a five year study of American High Schools concluded that despite their difference in location and demography, they were woefully inadequate (CES, 2006). As a result, Sizer developed a set of ten common principles from which a school could fashion itself in ways that made sense to their community (See Figure 4).

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10 Common Principles of CES
1. Learning to use one's mind well
2. Less is more, depth over coverage
3. Goals apply to all students
4. Personalization
5. Student-as-worker, teacher-as-coach
6. Demonstration of mastery
7. A tone of decency and trust
8. Commitment to the entire school
9. Resources dedicated to teaching and learning
10. Democracy and equity

Figure 4: The Ten Common Principles of the Coalition of Essential Schools (CES, 2006).

In 1984, a group of 11 schools in six states agreed to redesign themselves on the basis of Sizer's ideas and to form the Coalition (CES, 2006). Since then hundreds of likeminded schools have joined the Coalition.

Several of the principles of CES could be used to raise self-efficacy beliefs. For example, principles one, two, and six (learning to use one's mind well, less is more, depth over coverage, and mastery learning) advocate that students master rigorous content. Mastering rigorous content increases self-efficacy (Bandura, 1997). Principle seven, student-as-worker and teacher-as-coach, supports social learning experiences. Social learning experiences can increase self-efficacy (Bandura, 1997, Schunk, Hanson & Cox, 1987, Zimmerman and Ringle, 1981). Principle three, that goals apply to all students, and principle ten, democracy and equity, advocate for learning for all students, even the low skilled, low self-efficacious, and disadvantaged. Although the Coalition of Essential schools has created goals that are designed to increase self-efficacy, sometimes these goals are not realized in actual instructional practices.

I work at a charter school that is a member of the Coalition of Essential Schools. Even though my school sets goals which could increase self-efficacy beliefs of disadvantaged students, often these goals are not realized. One reason that these goals are not realized is that teachers and administrators do not know how to actualize these goals. The teachers need procedures and curriculum for helping their students master rigorous curriculum in social learning environments.

AVID Strategies for Mastering Rigorous Content Lack Directions for Teacher

One curricular approach that includes strategies for increasing academic selfefficacy is the Advancement Via Individual Determination (AVID) program. This program was designed to increase access to higher education and career opportunities for underserved students (AVID, 2006). The AVID program targets academic middle students, B, C, and D students, who are capable of completing rigorous work, but are falling short of their potential (AVID, 2006). Typically, AVID students are the first in their families to attend college, and many are from low-income or minority families (AVID, 2006).

AVID is implemented in traditional public schools in the fourth through twelfth grades. AVID helps underserved students attend college by pulling these students out of their unchallenging courses and putting them on the college track: acceleration instead of remediation (AVID, 2006). AVID students are enrolled in their school's toughest classes, such as honors and Advanced Placement, and also in the AVID elective (AVID, 2006).

The purpose of the AVID elective is to support student learning by teaching students strategies that help understand rigorous content. In the AVID elective class students learn note taking skills, organizational skills, writing skills, problem-solving skills, and study skills (Weiss et al., 1998a). College tutors help guide students through these skill building exercises. The college tutors are trained on the strategies taught in the elective class. A review of the strategies that are taught to tutors can be found in the following AVID texts: *The Tutorial Path: A Guide for Teachers* (Weiss et al., 1998a); and *The Tutorial Path: A Guide for Tutors* (Weiss et al., 1998b).

Although the Tutorial Path curriculum encourages tutors to group students and to have students teach each other, the tutorial path curriculum does not provide any structures that help teachers and tutors create effective collaborative peer study groups.

In addition to the Tutorial Path texts, AVID tutors may also use subjectspecific AVID curriculum in their elective classes (AVID, 2006). This subject specific curriculum is driven by writing, inquiry, collaboration, and reading, the WICR method (AVID, 2006). AVID publishes two math curriculums (*The Write Path: A College Preparatory Reading and Writing Program Teacher Guide/Student Guide Mathematics* (Swanson & Dooley, 2001), and *The Write Path II: An Advanced College Preparatory Reading and Writing Program Mathematics Teacher Guide* (Ching, 2004) and two science curriculums (*The Write Path: A College Preparatory Reading and Writing Program Teacher Guide/Student Guide* (AVID, 2004), and two science curriculums (*The Write Path: A College Preparatory Reading and Writing Program Teacher Guide/Student Guide* Science (AVID, 2001), and *The Write Path II: An Advanced College Preparatory Reading and Writing Program for High Schools Life and Physical Science Teacher Guide* (Hays & Molloy, 2004). While these curricular programs provide many strategies for helping students develop their writing, reading, and inquiry skills, they provide few strategies for helping students to work together collaboratively. In addition to The Write Path curriculum guides, AVID also publishes *The Student Success Path for High School: An Embedded Sequential Academic Skills Program for Refining AVID Strategies in a Non-Elective, Multi-Subject Classroom Teacher Guide* (Sundly et al., 2006). The Student Success Path includes several classroom activities to help students learn organizational skills, student success skills, writing skills, and collaboration skills. Although the Student Success Path does not include detailed directions for helping students learn rigorous material from their peers.

AVID encourages students to master difficult content and provides them with strategies to do so such as organizational skills, reading skills, writing skills, and inquiry skills. Unfortunately, AVID does not provide teachers with adequate structures that help students master the curriculum through social learning. AVID does advocate that students work together in tutoring sessions, but leaves teachers with little direction on how to facilitate collaborative peer study groups.

College Mathematics Workshop Program uses Collaborative Peer Study Groups

Treisman's Math Workshop Program (MWP) offers a format for students to master rigorous curriculum through social learning. In Treisman's MWP, undergraduate freshman who are interested in a career requiring mathematics, master calculus through their work in collaborative peer study groups (Fullilove & Treisman, 1990).

The MWP is advertised as an honors program that recruits students of all races but typically enrolls 80% African American and Hispanic students (Fullilove & Treisman, 1990). MWP organizes the students into groups of 5-7 who study work together for approximately two hours, twice a week, on worksheets containing carefully constructed, usually difficult problems (Fullilove & Treisman, 1990). The students are encouraged to discuss the problems with each other and teach each other how solutions and proofs are derived (Fullilove & Treisman, 1990). There are no rules on how students work in the group; students are free to spend part of each session working alone. The students must, however, be willing to share their ideas and critique the work of their peers at some point during the workshop session (Fullilove & Treisman, 1990). A graduate student workshop leader typically observes the functioning of these small groups as they work on the worksheets (Fullilove & Treisman, 1990). The leader of the workshop monitors the discussions of the students and assists students with hints that can help them to work their way through difficulties that they encounter (Fullilove & Treisman, 1990).

Treisman's MWP asks students to do challenging work with peers. Mastering rigorous curriculum and working socially with peers can help improve self-efficacy in math. Unfortunately, the MWP relies on carefully constructed math worksheets. When these math worksheets are unavailable, students may not be able to master the material. Another problem with Treisman's MWP curriculum is that it is geared for students who are already interested in STEM and probably see themselves as at least

somewhat self-efficacious. Treisman's MWP curriculum needs to be modified for high school science and math classes, where students have less skills, and/or are less self-efficacious.

Collaborative Peer Study Group Curriculum

After examining existing curricula, it is evident that students are expected to master rigorous math and science content without being taught strategies for doing so. The few curricula that do teach strategies for mastering the content, such as AVID, do not provide sufficient strategies for helping students learn from their peers. Although Treisman's Math Workshop Model provides a structure in which students can master rigorous content in a collaborative peer study group, it is geared toward college students and relies heavily on supplementary material provided by the instructor. The Collaborative Peer Study Group Curriculum (CPSG) is designed to help any high school science teacher increase student self-efficacy in science and math. The Collaborative Peer Study Group Curriculum provides teachers with explicit, practical strategies for developing collaborative groups where students master rigorous curriculum through social interactions and metacognition. CPSG includes handouts that can be tailored to any science subject matter that help students create individual and group learning goals, and rotate teaching and learning. CPSG gives teachers tips on how to choose rigorous curriculum, from effective study groups, set-up the classroom for optimal learning, and gradually give students autonomy over their study groups.

V. Collaborative Peer Study Group Curriculum

I designed the Collaborative Peer Study Group Curriculum (CPSG) to help students to master rigorous science and math content in collaborative peer study groups by raising their self-efficacy. In the Collaborative Peer Study Group Curriculum students set individual and group goals for learning. Then students fulfill roles as both teachers and learners in order to gain deeper understanding of science and math topics that they have been taught previously. As teachers, students use vocabulary and images to explain difficult math and science content. As learners, students ask questions and take notes. Students rotate teaching and learning in their groups every time they meet, until they have mastered the unit covered in class. Students meet in their collaborative groups for roughly 60 minutes one or two times per week for a duration of no more than six weeks, before groups are switched.

Goal: To Increase Self-efficacy in Science and Math

The primary goal of the Collaborative Peer Study Group Curriculum is to increase student self-efficacy by providing students with the experience of mastering rigorous science and math content. If students are better able to master rigorous content, they will improve their performance on academic assessments in their math and science classes, which should further improve their self-efficacy about science and math courses as a whole (Bandura, 1997: Bandura & Schunk, 1981). Because students' self-efficacy about science and math courses in general will improve, their motivation to participate fully in these classes will also improve. This participation will likely increase their success in the classes and increase their self-efficacy and self-

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motivation for these classes even more, creating an upward spiral of success (see Figure 5).



Figure 5: The goal of CPSG is to increase self-efficacy by mastery.

Self-efficacy is a difficult construct to observe. However, because selfefficacy increases motivation (Deci, 1995), teachers can use observations of student self-motivation to measure self-efficacy. Self-motivation, also termed intrinsic motivation, leads a person to do an activity for no apparent reward except the activity itself or the feelings that result from the activity (Deci, 1995). There are several signs that students are intrinsically motivated to learn. Students who are intrinsically motivated do not race through the activities to complete them and get a grade. Instead they care about their own learning. They ask questions to better understand the material. By measuring the number and nature of questions, teachers can measure self-motivation and gauge self-efficacy. Students who are intrinsically motivated to learn will try to learn the material outside of class time. Teachers can gauge selfefficacy if students are engaging in learning activities outside of class time. *Ideal Classroom Context for Collaborative Peer Study Groups*

The Collaborative Peer Study Group Curriculum helps students gain a deeper understanding of rigorous material. When using CPSG, students master rigorous material by setting individual goals for learning and by working with peers to achieve these goals. Because working with peers is an important aspect of the Collaborative Peer Study Group Curriculum, I suggest that teachers set up optimal classroom conditions for working in groups. I recommend that teachers carefully select rigorous content, choose student groups and arrange their classroom so that the students in each group can easily collaborate.

Choosing rigorous content. The Collaborative Peer Study Group Curriculum helps students to master difficult content. Mastering difficult material causes students to improve their self-efficacy (Bandura, 1997). Although *rigorous material* is defined differently by different educational researchers, most researchers believe that rigorous curriculum offers in-depth immersion in a complex subject (Lundsgaard, April 2004; Strong, Silver & Perini, 2001; Washor & Mojkowski, December 2006-January 2007). I define "rigorous content" as content that is both new to students and requires students to understand several small discrete pieces of knowledge (and the connections between them) in order to understand the big idea. Examples of big ideas in science are evolution, how DNA codes for traits, or how plants get energy. These ideas may be the subject of a teaching unit.

Before using the Collaborative Peer Study Group Curriculum, teachers decide on the rigorous content that they would like the students to master. Teachers first decide on a big idea. For example, a teacher could decide to use CPSG to help students better understand how plants get energy. Once the teacher decides on a big idea, he or she must break up that big idea into smaller chunks and clusters of information. For example the idea of how plants get energy could be broken down into smaller chunks like the light reactions of photosynthesis, the dark reactions of photosynthesis (The Calvin Cycle), glycolysis, the Kreb's Cycle, and the electron transport chain. Smaller chunks are usually the subjects of individual lessons.

Teachers may use the Collaborative Peer Study Group Curriculum after they have introduced the rigorous material by using various teaching methods such as lecture, labs, projects, demonstrations, videos, reading or discussions. CPSG is not designed to introduce new ideas, but instead designed to help students better understand ideas that have already been presented.

Group formation. After teachers choose the rigorous content that they would like their students to master through study groups, then they must decide how to divide the class into groups. The research on collaborative group dynamics suggests that teachers carefully form the groups so that they can maximize self-efficacy and student learning (See Figure 6). Most researchers agree that student groups function best when they are selected by the teacher and are heterogeneous (Kagen, 1994;

Johnson & Johnson, 2008). When students pick their own groups, the results are not always beneficial. Student-selected groups can lead to off-task behavior and the reinforcement of status hierarchies in the class (Kagen, 1994; Johnson & Johnson, 2008). The students who are left to group together often do not communicate or function well (Kagen, 1994; Johnson & Johnson, 2008).

The heterogeneous groups should contain a mix of abilities, gender, race, ethnicity, backgrounds and confidence. Kagen (1994) believes groups should be composed of one low, two medium, and one high ability student. It is also important to consider the self-efficacy of the students in the group. Although high ability students often have high self-efficacy and low ability students have low self-efficacy, they do not always follow this pattern. High self-efficacy students can help students with lower self-efficacy increase their perceived competence. Peer models who express confidence in the face of difficulties encourage a higher sense of efficacy and perseverance in others than do models who begin to doubt themselves as they encounter problems (Zimmerman & Ringle, 1981).

Teachers, however, should be careful not to place a low student with only high students, who have already mastered the material. If students are paired with students that they believe have skills that are far above their own, they may withdraw from the study group (Meyer, 1987). Cooperative groups where low skilled students learn academic skills from coping peers (peers who are familiar with the skill, but not yet proficient), can help raise the self-efficacy for the low skilled (Schunk, Hanson & Cox, 1987).

Alternately, teachers may decide to group students randomly. Although this group formation method is quick and easy (and can be done without knowing the status of the students), one disadvantage is that you can form "loser" teams, teams where the four lowest achievers are grouped on the same team (Kagen 1994). Another disadvantage is that students may be grouped with classmates that they do not work well with.

Do

- Create small groups of 3-5 students.
- Group students of different gender and race together.
- Put students of low, middle, and high ability in the same group.
- Put students of low, middle, and high confidence levels in the same group.

Don't

- Create groups that are larger than 5 students.
- Group one student of low ability in a group with all high ability students
- Group a low confidence student with all high confidence students.
- Put students who have personal conflicts with each other in the same group
- Put students who distract each other in the same group.
- Put more than one student who has difficulty interacting with their peers in the same group.

Figure 6: Guidelines for forming collaborative peer groups.

Teachers should divide their classes into heterogeneous groups of four students

each. In cases where classes can not be evenly divided into groups of four, teachers

can create groups of three or five. Kagen (1994) advocates groups of four students for

cooperative learning experiences and suggests that students form groups of three or

five when the class does not divide evenly. Once the teacher forms the student groups,

students should meet in these groups every time the teacher uses CPSG to understand a big idea taught in class. Teachers should keep students in the same groups until they master the overarching topic (unless it extends beyond six weeks). I recommend changing groups every five to six weeks or for every big idea, or whichever comes first. Kagen (1994) suggests keeping students in groups for four to six weeks so that they stay together long enough to feel interdependence, but are able to transfer their group collaboration skills to a new group. Carefully grouping students can help maximize the effectiveness of CPSG.

Setting up the classroom. For optimal results from the Collaborative Peer Study Group Curriculum, teachers should set up their classrooms so students can easily collaborate in their small groups. In an ideal classroom context, students in each study group sit in a square or rectangle and face each other (see Figure 7).



Figure 7: Ideal Collaborative Peer Study Group seating arrangement.

When using the Collaborative Peer Study Group Curriculum students teach each other by speaking, drawing and writing. Therefore, each group will need a large vertical or horizontal surface area (4' x 4' or larger) to draw or write on. Two tables pushed together work best, but whiteboards, chalkboards, easels or windows also work. Students can either draw directly on the surface area with dry erase markers (or chalk), or students can draw on large sheets of butcher paper. In my experience, having students write and draw directly on the tables with dry erase markers works best. Students like drawing on the tables and students can easily see what their peers draw. The tables easily clean with window cleaner and paper towels.



Figure 8: Students teach study group members by drawing and writing on tables.

After creating space for each group, set aside materials for each group. Each group needs least two different colored markers to use when explaining concepts. If using dry erase markers, provide each group with window cleaner and paper towels. If using regular markers, provide ample butcher paper for each group. Identify each study group workstation so that when the students walk into the classroom, they can find the table that they will be working at, and sit down with the other students in their groups. Teachers can identify workstations by placing put nametags with the names of each student in the group on the workstation. Carefully setting up the classroom, choosing student groups, and selecting rigorous material will maximize the effectiveness of the CPSG.

Description of the Collaborative Peer Study Group Curriculum

The Collaborative Peer Study Group Curriculum is divided into three parts (see Figure 9). First students complete the individual goal setting activity entitled "What

are your Individual Goals?" After completing the individual goal setting activity, students discuss their group goals in the "Table Talk: Group Goal Setting" activity. Last students begin a cycle of teaching and learning using the Protocol for Working in a Peer Study Group. Students rotate teaching and learning for as many cycles as possible in the allotted time. These three activities are designed to be completed in 60 minutes. The goal of the Collaborative Peer Study Group Curriculum is to increase student self-efficacy in the content (math or science) after several 60 minute sessions.



Figure 9: Flowchart of the Collaborative Peer Study Group Curriculum.

The Collaborative Peer Study Group Curriculum increases self-efficacy by promoting metacognition and collaborative learning (see Table 1). All three of the activities in the curriculum ask students to be metacognitive about their own learning. In the individual goal setting activity called "What are your Learning Goals", students
identify their prior knowledge, create their own learning goals, and identify any questions that they have. In this activity students also prioritize what they want to teach or learn first. In the "Table Talk: Group Goal Setting" activity, students also create goals and set priorities. During the teaching and learning activity, "Procedure for Working in a Peer Study Group", students finalize their group goals, identify and organize their materials and resources, and brainstorm any questions they may have. In the teaching and learning activity, students explain the science or math ideas while others listen, ask questions and give feedback. When students explain the rigorous ideas, ask questions, and answer questions, they evaluate their own understanding and the understanding of others. In the Collaborative Peer Study Group Curriculum students think metacognitively by identifying prior knowledge, setting goals, prioritizing learning activities, evaluating their understanding, and by selecting resources that can help them answer their questions. Metacognition can build self-efficacy (Bandura, 1997).

Peer interactions also influence self-efficacy. Students determine their selfefficacy based on comparisons to their peers and peer feedback (Bandura, 1997). For this reason, students using the Collaborative Peer Study Group Curriculum mostly work in small collaborative peer groups. The students work in these small groups for the group goal setting activity and the teaching and learning activity. In these groups students learn from peer models, get feedback from their peers, and compare themselves to their peers. All of these social experiences can increase self-efficacy (Bandura, 1977; Schunk, Hanson & Cox, 1987; Zimmerman & Ringle, 1981). In collaborative study groups students teach and learn by verbalizing their thoughts to their peers. When students verbalize their thought processes they can increase their self-efficacy (Bandura, 1997; Schunk & Rice, 2002, Schunk, 1982). Talking about what they are learning helps the students master the rigorous content (Schunk, 1982; Johnson, Johnson, Roy & Zaidman, 1984). When students master difficult tasks their self-efficacy increases (Bandura 1997). The Collaborative Peer Study Group Curriculum is designed to increase self efficacy by helping students master rigorous math and science and think metacognitively about that learning process through collaborative learning.

Activity	Constructs		
	Metacognition	Collaborative	Self-
		learning	efficacy
What are your Individual Goals?	Х		Х
Table Talk: Group Goal Setting	Х	Х	Х
Procedure for Working in a Peer Study Group	Х	Х	Х

 Table 1: CPSG Activities and Corresponding Educational Constructs

Individual Goal Setting. Teachers begin the Collaborative Peer Study Group Curriculum with the individual goal setting activity. In this activity, students spend roughly five minutes silently completing the "What are your Individual Goals?" worksheet. In this worksheet students write as much as they can about the topics that the teacher has provided. After students write down as much as they can about the topics, they also write down any questions they might have about these topics. Finally, the students circle the topics that they are most interested in understanding better. An example worksheet is found below (Figure 10) and blank worksheets are found in the Appendix.

What are your individual goals?			
Without box below	looking at any notes or texts, write (or draw) as much as you can about the following topics in the w		
•	Transcription and Translation		
•	RNA processing		
•	Mutations		
Write as	much as you can about the topics above here		
	· · ·		
What ar	a you still uncloar about? List any quartienes that you have about these tonics below:		
what al	e you suit unclear about: List any questions that you have about these topics below.		
Now cire	ale which of the three tenics above you want to understand better		
•	Transcription and Translation		
•	RNA processing		
•	Mutations		

Figure 10: Example of the individual goal setting worksheet.

Before the teacher passes out this activity he or she selects a few ideas that have already introduced to the students by lecture, lab, activity and other instructional methods. The teacher then bullets the ideas on the "What are your Individual Goals?" worksheet. These ideas will be what students strive to teach and learn during the peer study groups. The ideas should be new, challenging, and support the big idea being taught in the unit. In the sample above, the teacher selected the following ideas: transcription, translation, RNA processing and mutations. These ideas support the larger idea taught during the unit of how DNA codes for traits.

Group Goal Setting. After each student completes the individual goal setting activity, students discuss what they want to teach and learn in their study group. Teachers pass out one "Table Talk: Group Goal Setting Worksheet" (see Appendix) to each group. The worksheet instructs students to discuss the following questions in their groups:

1. What concepts/ideas have you found most difficult?

2. Which of these ideas do you find particularly interesting? Why?

3. What are each of you interested in teaching and learning with each other?

Instructions on the worksheet ask students start their discussion with question one, then question two, and finish with question three and make sure that each person in the group shares his or her ideas for each question. The teacher reads the directions for the Table Talk out loud and asks one student from each group to take notes in the space provided. The teacher also passes out an extra set of questions, "Table Talk: Group Goal Setting Questions" (see Appendix), so that every student has access to the discussion questions.

When students are finished (after about five minutes), the teacher collects the individual goal setting worksheets and any extra "Table Talk: Group Goal Setting Questions". The teacher leaves the completed "Table Talk: Group Goal Setting Worksheet" with each group, so the study group can reference it. The teacher can use the individual goal setting handouts to gauge what the students know and what they

don't know. If the teacher would like more information on student's prior knowledge, he or she can collect the group goal setting worksheet at the end of class.

Teaching and learning. After the students discuss their group goals, students begin the teaching and learning portion of the Collaborative Peer Study Group Curriculum. First teachers pass out three copies of the "Procedure for Working in a Peer Study Group" per student, one copy for each time a different student teaches a new in-depth idea. Teachers also pass out drawing supplies (e.g. two dry erase markers, one bottle of window cleaner, and one roll of paper towels per group). The teacher tells the class that they will be teaching and learning in groups, then asks the students to follow the directions on the "Procedure for Working in a Peer Study Group." The teacher reminds the students what they will do in each step of the procedure (See Figure 11). A full size copy of the "Procedure for Working in a Peer Study Group" can be found in the Appendix.



Figure 11: "The Procedure for Working in a Peer Study Group."

In Step 1 of the procedure the group decides on the one topic that they want to master first. In Step 2 the students decide who will teach this topic to the group. In Step 3 students gather relevant notes or texts and reread them. The student who assumes the role of teacher can use this time look up any questions he or she may have in a text or online, or ask the teacher for help. Meanwhile student learners formulate questions for the student teacher. This step should last five minutes or less. In Step 5 the student teacher teaches the topic. He or she uses the markers to write down appropriate vocabulary or images that help explain the topic. During this time the student learners can ask the student teacher questions and take notes on the "Procedure for Working in a Peer Study Group" handout. This step should last 10 minutes or less. After the teaching/learning (Step 6) students "reach out" to other resources to get

answers to questions. Students can look up information online or in text books, ask adult instructors for help, or write their questions down so they can ask their teacher later. When students are finished, they can repeat this process with a new topic and a new student teacher.

During the entire teaching and learning part of the Collaborative Peer Study Group Curriculum, the teacher walks around the classroom and helps groups if they ask for help. The teacher also monitors each group to make sure that students are not teaching each other misinformation or misconceptions. If the students are teaching each other misinformation, the teacher intervenes and corrects the mistakes.

During the "Procedure for Working in a Peer Study Group" students rotate teaching and learning roles. When students are in the teaching role, they have a responsibility to help their peers better understand the material. To motivate students to tackle difficult material, CPSG makes students responsible to their peers.

When students teach the topics, they actively engage in the material. They rehearse the material by reciting the material out loud and drawing images to reflect what they know. As the students explain the math and science, they gain a greater understanding of the material and increase their self-efficacy (Bandura, 1997; Schunk & Rice, 2002, Schunk, 1982). As they explain the math and science and respond to questions from their peers, they uncover any holes in their understanding. These metacognitive processes also help students raise self-efficacy (Johnson & Johnson, 2001).

Students who are learning from peer teachers benefit from watching their peers struggle through the difficult material (Schunk, Hanson & Cox, 1987). If the students

see their peers struggle through the material and ultimately succeed, they think that they can also be successful with this rigorous material. Peer modeling can increase student self-efficacy (Schunk, Hanson & Cox, 1987; Zimmerman & Ringle, 1981). Positive feedback from peers in the collaborative peer study groups can also increase self-efficacy (Bandura, 1977).

The goal of the Collaborative Peer Study Group Curriculum is to increase selfefficacy in science and math. In order to increase student self-efficacy in science and math, students participate in three activities: an individual goal setting activity, a group goal setting activity, and a peer teaching activity. These activities encourage students to think about their learning processes and master difficult material by collaborating with their peers. I implemented the Collaborative Peer Study Group Curriculum in a high school science class and measured how the curriculum affected student's self-efficacy in science.

VI. Collaborative Peer Study Group Implementation

I implemented the Collaborative Peer Study Group Curriculum (CPSG) in three untracked 11th grade Biology classes in an innovative charter high school in Southern California. Classes were 60 minutes long and contained 19-20 students. I employed the curriculum once per week, for five weeks. I used the activities in the curriculum to help students understand rigorous biological content during an interdisciplinary forensics unit. Although I used the Collaborative Peer Study Group Curriculum to help students learn forensic science, the curriculum can be used to help students master rigorous content from any science field.

The School Context

I implemented the Collaborative Peer Study Group Curriculum at a small innovative charter school with a diverse student body. I will refer to this school as Central High, a pseudonym. Central High serves roughly 530 students in grades nine through twelve. Enrollment at Central High is non-selective. Central High does not consider grades or recommendations when admitting students. Instead Central High uses a lottery system to admit students to the school. The lottery is based on the zip code of the student, which ensures a diverse student body. There is no tracking at Central High. As a consequence, each class is extremely diverse and closely mirrors the population of the city in which this school is situated. The enrollment breakdown is as follows: 43 % White, 28% Hispanic, 11 % Black, 9 % Asian, 8% Filipino, 1% American Indian, and 1% Pacific Islander. Just over half (53 %) of the student population is male. Almost a quarter of the student body (24%) participates in the

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federal free and reduced lunch program. Ten percent of the student population qualifies for Special Education services.

Three design principles that guide the educational philosophy of Central High are: personalization, adult-world connection, and common intellectual mission. The school provides personalization in several ways. Central High has small class sizes of no more than 25 students per class. Core teachers (math, science, and humanities teachers) teach 2-3 classes of students per year (so they teach a maximum of 75 students per year). Teachers work together on interdisciplinary teaching teams. Although the teachers on teaching teams don't teach students at the same time, the teaching teams share the same group of students for the entire year. Teachers on the teaching teams have common preparation time that they use to design interdisciplinary projects and to support their small number of students. In this way students have a few teachers who know them well. Students also have a faculty member who serves as their advisor for the entire length of their stay at the school. Students with special needs are fully included in the classroom, and receive individual attention that they need. Much of the curriculum taught at this school is authentic in that it has an application outside the classroom. Students often work on interdisciplinary projects that benefit the community, such as the student researched and written field guide for a local waterway which is now published. This school prepares students for the adult world by combining "technical training" and "college preparatory" coursework, a strategy Central High refers to as their *common intellectual mission*. In other words, students have "hands-on" technical experiences and are taught the theoretical and historical background information that supports these experiences.

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One of the main goals of Central High is to increase the number of educationally disadvantaged students who succeed in high school and post-secondary math and engineering education. In order to meet this goal, this charter school's graduation requirements are the course requirements for admission to the University of California, also known as the University of California A-G requirements. Students take English, a laboratory science, and math every year. In addition to these classes, students take a variety of technical and engineering classes. Students take a multimedia class, a graphic design class, a programming class, and an electrical or mechanical engineering class. Students are also encouraged to take entrance exams and apply for college. In 2006-2007, 100% of graduating seniors at this charter school took the SAT and/or the ACT and applied to a four year university. Approximately 74% of the graduating seniors attended four-year programs, and 26% attended twoyear colleges. Of the 2006-2007 seniors, 30% were first-generation college students.

Not only does Central High have high college admittance rates, but it also has high rankings compared to other high schools. Central High scored an 807 on its 2006-2007 Academic Performance Index rankings (API) and was ranked 9/9 on the API comparisons to schools Statewide/and Similar Schools. The small charter school where I implemented my curriculum is considered successful, diverse, and innovative. This school is committed to helping disadvantaged students succeed in high school and post-secondary science, math and engineering education. Despite these lofty goals and impressive statistics, Central High still has difficult convincing underrepresented students to enter the science, technology, engineering, and math (STEM) education. Perhaps implementing curriculum designed to raise student's elfefficacy in science would increase interest in STEM fields.

The Classroom

I used the Collaborative Peer Study Group Curriculum in three of my 11th grade Biology classes during an interdisciplinary forensics project. The students in my Biology classes shared the same math, humanities, and Core (a class designed to augment the class work in Biology, Math, and Humanities) classes. The teachers of each of these classes collaborated to create an interdisciplinary forensics project. At the beginning of this unit, students saw a fake crime scene that was roped off by caution tape. The crime scene included a fake dead body, simulated blood drips, blood spatter, and several pieces of metal. My team teachers and I grouped the students into investigative teams and asked them to solve the crime. The students were given roughly one hour a day during their Core class to work with their groups on solving the crime. They learned forensic science techniques in their Math III and Biology classes and they learned about civil rights and the justice system in their Humanities class. Students attended each of these classes for approximately 60 minutes-70 minutes, depending on the day of the week.

During this forensics unit students learned about DNA, DNA replication, transcription, RNA splicing, translation, and mutation in Biology class. They also learned how to amplify DNA (found at the crime scene) using polymerase chain reaction (PCR) and how to analyze it using gel electrophoresis. I used a wide variety of teaching strategies to teach these topics including, but not limited to, direct instruction, hands-on activities, labs, class discussions, small group discussions, quick writes, and jigsaws.

The classes were untracked and heterogeneous. Each class contained a approximate bell-shaped distribution of high skilled, middle skilled, and low skilled students. The classroom demographics mirrored those of the charter school in which the class was situated in. I used CPSG in diverse 11th grade Biology classes to help students learn the science behind forensics and therefore to increase their self-efficacy in science. Although I used the Collaborative Peer Study Group Curriculum to help my students master forensic biology, the curriculum can be used to help students master any rigorous science or math content.

Why Biology?

I decided to implement the curriculum in a biology classroom for two reasons: 1) because Biology is my area of expertise and my passion and 2) because more high school students take Biology than any other science in high school according to the High School Transcript Study (HSTS) (NCES, 2002). The HSTS examined the actual coursework completed by a representative sample of those finishing high school in 2000. This analysis showed that 99.5% of the high school graduates in 2000 took a science class before they graduated. Biology was the dominant science class; 91% of the high school graduates in 2000 took biology. The next most commonly taken subject was chemistry, however, a mere 62% of the high school graduates in 2000 took chemistry. Because more high school students take biology than any other science class, biology is a class where teachers have the ability to impact the most students. The biology classroom presents an opportunity to change how students perceive their ability in science, and possibly influence underrepresented students to enter the STEM fields.

Pilot Study

I began piloting the Collaborative Peer Study Group Curriculum the first week of the Forensics Project. My goal was to increase my students' self-efficacy in science. I wanted to accomplish my goal by encouraging the students to think metacognitively about learning science and by helping the students to master rigorous material through social interactions in a small group of their peers. During the first day of my pilot study, I had the students set individual goals and group goals on two separate worksheets. Then I had students rotate teaching and learning through an elaborate protocol. I noticed that my goal setting activities did not accomplish my goals as a teacher. The students struggled to complete the individual goal setting activity. Many of the students left sections blank or answered questions with one or two word sentences. I realized that my original individual goal setting activity did not sufficiently activate my student's prior knowledge. Also the group goal setting activity that I used for my pilot study did not foster dialogue between the members of the groups. Students had short conversations and not all members of the group participated in the conversations. Many groups created goals without the input of all the group members, other groups did not even set group goals. I made changes to both the individual goal setting activity and the group goal setting activity after the first day of the pilot study. I changed my individual goal setting sheet so that it asked questions that activated prior knowledge, like "write as much as you can about the bulleted topics without using notes." This got the students ready to participate in the teaching

and learning activity. Then I changed the group goals activity so that it would facilitate group discussion better. Instead of handing each student a group goal setting worksheet to fill out, I handed each student a set of group goal setting questions which they were asked to discuss at their table and had one student record the group's conversation on the "Table Talk: Group Goal Setting" worksheet.

Twelve days later I piloted my curriculum again. This time the individual and group goal setting activities worked much better. The students wrote continuously for about five minutes, brainstorming what they knew. Then they wrote down what they were still unclear about. They then quickly decided what they wanted to learn more about. Next the students brought their individual goals to the group. They easily discussed their individual goals with group. As a result, the groups were able to quickly able to prioritize what they wanted to learn and who would teach first. Unfortunately, the students got stuck on the teaching and learning activity. My procedure for rotating teaching and learning was too cumbersome. It had too many steps and rules. The students became bogged down in the procedure. The student conversations about the content were slow and were often interrupted by the rules. After each class of the day, I asked the students to give me some feedback on how I could make the procedure better. The students told me that they did not like all of the steps and rules. They suggested that I allow them to interact more naturally during the teaching and learning segment. They suggested that the teaching and questioning steps be combined. The students suggested that student learners ask questions as soon as they arise. They also suggested that there be space on the procedure where student

learners could take notes. The changes that the students suggested are reflected in the final curriculum, which can be found in the Appendix.

During the pilot study of the Collaborative Peer Study Group Curriculum, I used several different grouping formations. I realized that some grouping formations were not as productive as others. For example, when I placed three shy students together, none of the students did anything. I also realized that one of the groups that I had made was dysfunctional because two friends were paired together and they had difficulty staying on task. A different group didn't work well together because a student was grouped with a student who she had a personal conflict with.

My experience piloting CPSG showed me that there were several small yet crucial changes that I needed to make to my curriculum so that it would be more effective. I altered my initial study group formations. I changed my individual goal setting sheet so that it asked questions that activated prior knowledge. I modified the group goals activity so that it would facilitate group discussion better. I also revised the teaching and learning activity so there were less procedural steps. I made changes to each of the activities before implementing the Collaborative Peer Study Group Curriculum.

The Classroom Context for Collaborative Peer Study Groups

Not only did I revise my curriculum prior to implementation, but I also made classroom and curricular preparations before I implemented the Collaborative Peer Study Group Curriculum. I carefully chose the rigorous material that students would master by using CPSG, sorted students into study groups, and arranged my classroom so that the students in each group could easily collaborate.

Choosing Rigorous Content

Before I used the Collaborative Peer Study Group Curriculum, I carefully chose rigorous curriculum that the students would master using CPSG. I decided to use the curriculum to help my students better understand one of the biggest ideas in biology, how DNA determines your traits. This idea is often referred to as the "central dogma of molecular biology" a phrase first coined by Francis Crick (1958), the codiscoverer of the structure of DNA. I taught the central dogma of molecular biology during an interdisciplinary forensics unit. So, in addition to teaching how DNA codes for proteins, I also taught these students DNA analysis techniques, polymerase chain reaction (PCR) and gel electrophoresis. Both the forensic techniques and the process by which DNA codes for proteins are complicated molecular processes.

When I created my unit plan, I separated important information about how DNA determines your traits into discrete chunks and clusters. Then I taught the students these chunks of information on separate days. I started by teaching my students about the structure of DNA and DNA replication. Next I taught polymerase chain reaction (PCR), gel electrophoresis, and short tandem repeats (STRs). Finally I taught transcription, RNA processing, translation, and mutations. Each time that I taught new chunks and clusters of material, I used CPSG to help students better understand the complicated molecular processes in these chunks of information, and to see the connections between each of these chunks of information. By seeing the connections between each of these chunks of information, I hoped that the students would better understand the big idea, how DNA determines your traits. I hoped that the Collaborative Peer Study Group Curriculum would help my students master the rigorous science content, and therefore increase their self-efficacy in science.

Group Formation

After selecting the rigorous material that I would use during implementation of the Collaborative Peer Study Group Curriculum, I created student study groups. I carefully divided the students from each of my classes into study groups of four students. The students met in these same groups whenever we used CPSG, unless several students in their group were absent (in these situations, I merged groups).

Before I created the study groups, I determined the students' self-efficacy in math and science by giving them a self-efficacy survey (this survey is explained in more detail in Chapter VII and a copy of the scale appears in the Appendix). I used the students' mean self-efficacy scores to form study groups with students of different self-efficacy levels. To create the heterogeneous groups, I first ranked the students from highest self-efficacy to lowest self efficacy. Then I created three groups of students, a group with low self-efficacy (with self-efficacy scores below 70), a group with medium self-efficacy (with self-efficacy scores of 70-89) and a group with high self-efficacy (with self-efficacy scores of 90-100). I made an effort to put one student from each self-efficacy level into the groups of four. If there were not enough students to make groups of four, I made a few groups of three. When I created the study groups I made sure that each student in the group had a student who could serve as a coping peer model. A coping peer model is a student who struggles through the material, but perseveres. In other words, I made sure that a student presenting a low

self-efficacy in science and math was grouped with another student with low-medium self-efficacy, and not three students with high self-efficacy in science and math.

Self-efficacy was not the only factor I considered when I created the study groups. I tried to make the study groups mixed gender (preferably half female and half male), and racially diverse. I did not place students in groups with students who they worked with previously. I avoided placing students in a group with a student who they had personal conflicts with or a friend. I also refrained from teaming all the introverted or extroverted students together.

I decided not to let the students choose their own teams, because the research literature indicates that this method does not work well (Kagen, 1994). When students pick their own teams, they often group with students who are like them (same sex, race, ability) and the students who are left to group together do not communicate or function well (Kagen, 1994). Research shows that students can raise their selfefficacy when they are paired with a coping peer, a peer who they see as like them who perseveres when learning difficult material (Schunk, Hanson, & Cox, 1987). During my pilot study, I tried different group formations. This helped me decide which students I should avoid grouping together when I began the implementation. *Classroom Set-up*

The final preparation that I made for the Collaborative Peer Study Group Curriculum was setting up my classroom so that it was conducive to collaborative group work. I pushed tables together so that four students could sit easily around a large square table (see Figure 12). I also set up my materials ahead of time. I gathered enough dry erase markers for each group to have two, each a different color. I also gathered a few rolls of paper towels and bottles of window cleaner (one of each for every group). I kept the markers, window cleaner and paper towels on a separate table, until later in the activity. On each table I put nametags with the names of each student in the group so that when the students walked into the classroom, they could find the table that they would be working at, and sit down with the other students in their group. After choosing rigorous curriculum, creating study groups, and preparing my classroom, I implemented the Collaborative Peer Study Group Curriculum.



Figure 12: How I changed my table arrangement for CPSG. The left side of the figure shows how I configured my tables for lectures and teacher directed-lessons. The right side of the figure shows how I moved the tables together for the Collaborative Peer Study Group Curriculum.

Implementation

I began implementing the Collaborative Peer Study Group Curriculum ten days

after beginning the interdisciplinary forensics unit. I implemented the curriculum

once a week for five weeks. On each day that I implemented the curriculum, students participated in three activities: the individual goal setting activity, the group goal setting activity, and the peer teaching activity. The students completed the three activities during the 60 minute period.

Individual Goal Setting

I began the Collaborative Peer Study Group Curriculum with an individual goal setting activity. First I asked my students to clear their desks and take out a pen or pencil. Then I passed out the "What are your Individual Goals?" worksheet. I instructed the students to spend roughly five minutes silently writing as much as they could about the bulleted topics that I had chosen. I chose topics that I had recently taught by lecture, lab, activity and other instructional methods. I selected three topics for each CPSG session. These topics included DNA structure, DNA replication, PCR, STRs, gel electrophoresis, transcription, RNA processing, translation, mutations, gene regulation, and genetic engineering.

After students wrote as much as they could about the topics, they wrote any questions they might have about these topics. Finally, the students circled the topics that they were most interested in understanding. Figure 13 is a sample of student work.



Figure 13: Example of student work for the individual goal setting activity.

I noticed that at the beginning of my implementation that the students worked on these individual goal setting sheets diligently. They also wrote interesting questions and comments. For example, on the student sample that appears in Figure 13, the student wrote that she wanted to get a "deeper understanding of the material to feel more confident." This student was motivated to learn and part of that motivation was to increase her confidence.

As students became more proficient at the Collaborative Peer Study Group Curriculum, they spent less time on goal setting. Several students stated, "I already know what I want to learn" (Field Notes on March 10, 2008) In response to their feedback, I eliminated the individual goal setting activity during the last two times I used CPSG.

Group Goal Setting

After all of the students completed the "What are your Individual Goals?" worksheet, they decided on the topics they wanted to teach and learn in their group. First I passed out one "Table Talk: Group Goal Setting Worksheet" and one extra set of "Table Talk: Group Goal Setting Questions" per group (see Appendix for copies of the handouts). Next I asked the students to discuss the group goal setting questions that appeared on each handout:

- 1. What concepts/ideas have you found most difficult?
- 2. Which of these ideas do you find particularly interesting? Why?
- 3. What are each of you interested in teaching and learning with each other?

I asked the students start their discussion with question one, then question two, and finish with question three. I also requested that each person in the group share his or her ideas for each question. I assigned one student in the group to take notes on the discussion for the group. An example of one study groups' notes on their group goal setting discussion is shown below (Figure 14). The names of students are crossed out to protect their anonymity.

Table Talk: Group Goals

Discuss the following questions in your group at your table. Start with question 1, then question 2, and finish with question 3. Make sure that each person in your group shares his or her ideas for each question.

1. What concepts/ideas have you found most difficult?

- 2. What are each of you interested in teaching and learning with each other?
- 3. Which of these ideas do you find particularly interesting? Why?

NOTES ON CONVERSATION:



Figure 14: Example of student notes on a group goal setting discussion.

During the group goal setting discussion students share their individual goals and prioritize what they want to learn as a group. On the student sample in Figure 14 above, a student wrote that "PCR is difficult to remember. We'd like to teach and learn that." This student also wrote down some of the other goals of the individual group members. After the group goal setting discussion, the group had a plan for what they wanted to teach and learn.

After the students discussed their group goals for five minutes, I collected their individual goal setting and group goal setting worksheets. Then I passed out three copies of the "Procedure for Working in a Peer Study Group" per student. I also

passed out two dry erase markers per group and one bottle of window cleaner and one roll of paper towels for every two groups.

I noticed that at the beginning of my implementation that students took notes on their group conversations and wrote down their group goals. At the end of my curriculum implementation, however, the students resisted writing down their group goals. They wanted to quickly discuss their priorities so they could begin the teaching and learning portion of the curriculum sooner. In response to their verbal feedback, I eliminated the group goal setting activity during the last two times I used the Collaborative Peer Study Group Curriculum.

Teaching and Learning

During the first few times I implemented the Collaborative Peer Study Group Curriculum, I gave very explicit instructions on how to do the teaching and learning activity. I instructed the students to follow the "Procedure for Working in a Peer Study Group". I reminded the students that they would first decide on one topic to teach and learn in the group (Step 1), then decide who would teach this topic to the group (Step 2), and finally decide on a facilitator (Step 4). I also reminded the students that during Step 4 all members of the group should gather relevant notes or texts and review them and write down any pertinent questions. I also told the students who assumed the role as teachers to use the dry erase markers during the teaching section (Step 5) for the students who assumed the role of learners to take notes in the note taking section of the study group procedure handout. Finally I reminded the students to "reach out" to other resources to get answers to questions during Step 6. Students usually completed two cycles of teaching and learning per class period. Figure 15 shows examples student work for this teaching and learning activity.

Take notes on the lesson in the box below Procedure for Working in a Collaborative Peer Study Group PNA STEP 1: Decide on what you are going to teach and learn as a group PNA Knocenn Transcription RNA will teach the group firs (Splicing occurs will learn first _ Intron RNA Enzymeswipe EH th massi awa STEP 3: The group selects one learner to be the facilitator _____ The facilitator _____ The facilitator keeps the group on task and makes sure that the group $d\phi d$ limit. in 7 Exon o over the time the Exons EDED reconnect STEP 4: Review Materials (5 minutes) tyether the teaching questions about the material, they ask instructors for help The learning students review the material as well. The learning students each think of two Dest How does the polymerase work eodes? PLOCENS he get to called RNA How epoch does it Re-MRNA processin 1911 RNA STEP 6: Reach Out (2 minutes) STEP 5: Teachers Teach/ Learners Learn (10 minutes) The student in the teaching role teaches the other group members. The student teacher draws important terms and images for everyone in their group to see. The student learners ask Ask for help from other classmates, look information up online or in text books, ask your adult instructor for help, or write your questions down so you can ask your teacher later auestions CHANGE ROLES AND TOPICS AND REPEAT THE PROCESS

Figure 15: Example of student notes during the Collaborative Peer Study Group

It usually took the groups a few minutes to decide on a teacher for the teaching and learning segment and a few minutes to review the material. After the students in the teaching role had reviewed the material, they were more likely to ask the teacher questions because the students felt a responsibility to teach their group. For example, one student in the teaching role, who had previously been hesitant to ask questions in class, asked several clarifying questions about PCR before he had to teach his group (Audio Recordings on March 10, 2008). The liveliest part of the Collaborative Peer Study Group Curriculum occurred during the teaching and learning part of the procedure. The students in the study groups were very engaged in teaching and learning. The student learners asked many questions about the material. They were more comfortable asking questions in the small group. Even students with low self-efficacy, who were normally quiet in class, asked questions. For example, when learning about the 0.5% of DNA that is different between humans, one student with a very low self-efficacy score asked, "Where does this 0.5% come from?" (Audio Recordings on March 10, 2008). Another quiet student who was learning about PCR identified an area of confusion when he said, "I get confused about the temperatures" (Audio Recordings on March 10, 2008). Even a student who previously told me that she didn't care about learning biology and that she only cared about her grade, asked several questions that helped her gain a better understanding of PCR (Field Notes on March 10, 2008).

When the students taught the rigorous material, they had to try to clarify the material so that their peers would understand it. Students drew pictures, told stories, and made analogies in an effort to explain the concepts to their peers. Figure 16 shows a photograph of a student teaching her study group about PCR.

Figure 16: Photograph of a drawing that a student made while teaching the study group about polymerase chain reaction (PCR).

Students in the teaching roles also had to answer their peer's questions. These

questions often made students realize that they didn't understand the material as well

as they thought they did. One student said:

I think it [teaching] is a good gauge for knowledge. As long as one person knows whatever they are teaching, they can usually explain it well enough that everyone will understand it too. But if no one understands it, then it becomes very apparent very quickly. And so everyone knows we should probably go to the teachers or someone else to teach us (Student Interview on May 5, 2008).

When the students realized that they lacked understanding, they would often ask me or another teacher for help. Students also asked peers in other groups for help or attempted to answer their own questions by using text books or the internet. Students usually grabbed a textbook off my book shelf or accessed the internet at least once a class period.

The last two weeks that I used CPSG, I did not pass out the "Procedure for Working in the Collaborative Peer Study Group". I felt that the students had internalized the process because a few students requested to study in groups without the procedure worksheet and because other students, who initiated their own study groups (without my prompting), did not use the procedure worksheet. Instead of using the procedure worksheet, I gave the students brief oral directions. I told the students that they would be using "peer study groups to really understand the biology." I would then write the three to four rigorous biology ideas on the board for the students to teach and learn from each other. Then I would select a person from each group to teach first. For example, I told the students to "decide which person in the group had the shortest pinky finger." Then I told the students that the person with the shortest pinky finger would teach first and that person got to pick what they wanted to teach the group. Next I told the students that after that person taught, the student sitting next to him or her, moving in a clock-wise direction, would teach a topic until all students in the group had taught a topic and the group felt like they had a deep understanding of the rigorous material.

Without the procedure, the students continued to teach and learn from each other. They continued to ask lots of questions and continued to be engaged in the process. In fact, on several occasions students initiated their own collaborative peer study groups. For example, when I gave students a study guide for an exam a student, said, "Do you guys want to dedicate time where we study all of the drawings?" The students sitting next to her replied, "Yes." Then they made group goals for their study group. Later I found the students writing on the desks and explaining the material to one another. I also found the students forming study groups in their math class when they had free time to work on problems.

As my 11th grade biology students quickly realized, the Collaborative Peer Study Group Curriculum can not only help students learn forensic science, but can also help high school students master any rigorous high school math and science content. My preliminary observations suggested that my students were engaged in learning the material, thought about their understanding, and took ownership of their own learning. However, in order to truly understand the effects of CPSG on student self efficacy, I carefully monitored the implementation of the curriculum using a variety evaluation methods. Ultimately, I gathered data to explore how social collaboration with peers, goal setting, and teaching and learning activities effected self-efficacy in science. VII. Evaluation of the Collaborative Peer Study Group Curriculum

The Collaborative Peer Study Group Curriculum (CPSG) is designed to increase self-efficacy by helping students master rigorous math and science through activities that foster metacognition and collaborative learning. I evaluated the Collaborative Peer Study Group Curriculum to see if the curriculum increased student self-efficacy in science. After careful analysis of the data, I could not show any statistically significant change in student self-efficacy. However, I did find that CPSG increased student understanding of the rigorous science content presented in the Forensics Unit, fostered metacognition, and motivated students to learn. All these factors are associated with self-efficacy (Bandura, 1997). I also found that students internalized the structures of the Collaborative Peer Study Group Curriculum and often initiated their own peer study groups even after the CPSG scaffolds were removed.

Evaluation Methods

I evaluated the affects of the Collaborative Peer Study Group Curriculum on student's self-efficacy in science using several different methods. I administered selfefficacy surveys to measure changes in self-efficacy. These self-efficacy surveys were based on Bandura's self-efficacy measures (Bandura, 2006). I also measured changes in self-efficacy indirectly by measuring depth of understanding of the rigorous science content, metacognition, and motivation because these are all indicators of increases in self-efficacy. Mastering a difficult task and thinking metacognitively can improve self-efficacy (Bandura, 1997). Self-efficacy influences academic motivation (Bandura, 1997; Zimmerman & Cleary, 2006). I analyzed audio-recordings of peer

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study groups, field notes taken during the implementation, and post implementation interviews with students for depth of understanding of the science content, metacognition, and motivation.

Self-efficacy Surveys

All students completed a self-efficacy survey entitled "Student Self-efficacy Scale" three times during implementation (see Appendix). The survey asked students to rate their degree of confidence on their ability to do science and math. Students rated themselves on a scale from 0-100 on twelve different measures of science and math. The survey was based on self-efficacy measures by Bandura (2006). Students took the Student Self-efficacy Scale before implementation of the CPSG curriculum, halfway through the implementation, and at the end of the implementation period. I measured changes in self-efficacy between all of the students and sub groups (gender, race, and students with low medium and high self-efficacy).

Audio-recordings of the Collaborative Peer Study Groups

I audio recorded three groups of students during the implementation of the Collaborative Peer Study Groups. I chose these groups because they were representative of the classroom. The demographics of the groups reflected the demographics of the classroom. All groups were composed of males and females. Two of the groups had two males and two females. One group had three females and one male. All of the groups were racially diverse and had a mix of high, medium and low achieving students. Each group contained one student who had a high mean selfefficacy score, two students with a medium mean self-efficacy score, and one student with a low self-efficacy score. I transcribed the audio tapes and analyzed the transcriptions for signs of deep understanding of the science content, metacognition, and motivation to learn. I measured the depth of understanding by first counting the number of content questions asked during the teaching and learning portion of the Collaborative Peer Study Group Curriculum. Then I analyzed all of the content questions that students in the study groups asked for depth of understanding as described by Costa (2001). Costa divided questions into three levels (see Table 2). Level one questions are factual recall questions that show the most superficial level of thinking. Level two questions involve a synthesis of ideas. Often level two questions involve connection making and analogies. Level three questions show the deepest level of thinking and involve applying knowledge to new contexts. I categorized each question, or a level three question.

I considered questions that a student asked to try to make sure that they understood another student's meaning clarifying questions. Examples of clarifying questions are "What is the green dot you drew there?" and "Did you say this is a protein?" Clarifying questions are not part of Costa's scale and do not represent depth of understanding because they are used to "clarify" what another student attempts to communicate. However, clarifying questions do show metacognition and motivation because these questions represent self-monitoring of understanding and a desire to learn the content. Clarifying questions are entry questions that help students understand enough so that they can ask deeper questions and gain a greater understanding.

Level	Cognitive	Costa's Example Questions for Each Level
	Behavior	
	Define	Ex. What does the word "haggard" mean? (define)
	describe	
	identify	Ex. How does the Gettysburg Address begin?
	list	(recite)
	match	
Level 1	name	Ex. Which states seceded from the Union to form the
	observe	Confederacy? (identification)
	recite	
	scan	Ex. Which states bound California? (name)
	select	
	scan	
	count	
	complete	
	analyze	Ex. What data are we going to need to solve this
	compare	problem? (analysis)
	contrast	
	group	Ex. In what ways are pine needles different from
	infer	redwood needles? (contrast)
Level 2	sequence	
	synthesize	Ex. What other machines can you think of that work
	explain	in the same way? (make an analogy)
	classify	
	make an analogy	Ex. How does the formula for the volume of the cone
	experiment	compare with the volume of a pyramid? (compare)
	distinguish	
	Apply	Ex. Drawing on what you know about how heat
	evaluate	affects the speed of molecules, what do you predict
	hypothesize	will happen when we put the liquid in the
	imagine	refrigerator? (predict)
	judge	
	predict	Ex. From what we have learned about its
Level 3	speculate	characteristics, what other examples of romantic
	model building	music can you cite? (apply a principle)
	generalize	
	extrapolate	Ex. What do you think might happen if we placed the
	forecast	saltwater fish in the tank of freshwater?
	transfer	(hypothesize)
		Ex. What are some ways to use this bimetal strip to
		make a fire alarm? (apply)

 Table 2: Costa's Model of Intellectual Functioning in Three Levels (Costa, 2001, p. 362-363)

I also analyzed the audio recordings of the student groups for signs that students were thinking metacognitively about their own learning. I looked for markers of metacognitive thinking such as setting and prioritizing learning goals, and identifying what they knew and what they didn't know (see Table 3). I particularly looked at whether students would create learning goals without the scaffolding of the individual goal setting worksheet, the group goal setting discussion guide, and the teaching and learning notes.

Metacognitive Process	Terms that Identify Metacognition in Student
	Speech
Students set and prioritize	What do you want to learn?
learning goals	I want to learn
	What do you want to learn first?
	What do you want to learn next?
Students identified what they	I already know
know and don't know.	I don't know
	I don't understand
	I don't get
	I get
	I thought I knew
	Ask for help
	Ask teacher
	Ask student
	Search on the internet
	Look in notes
	Look up in a book

Table 3: Operationalization of Metacognition in the Audio Recordings of the Peer Study Groups

Field Notes

I took field notes during the implementation of all of the CPSG structured activities and when I allowed students to have more autonomy over the CPSG curriculum. I also took field notes when I noticed students creating their own collaborative peer study groups without any direction from the teacher or class time devoted to the process. I noted examples of deep understanding, metacognition, and motivation during these observations. I analyzed student quotes from my field notes using the same categories as the audio recordings analysis of the collaborative peer study groups.

Post-Implementation Interviews with Student Participants

I interviewed two groups of students after the implementation of the Collaborative Peer Study Groups. As noted above, I chose these groups because they were representative of the students in my classes. I interviewed both groups of students simultaneously. In the interviews, I asked students to tell me about how they felt about the collaborative peer study groups and if they felt more or less able to learn science after peer teaching. I also asked them how they felt about being in the teaching and learning roles. I analyzed the student responses for examples of selfefficacy, deep understanding, and metacognition. I looked for markers of understanding such as when students said the words *learn, understand*, and *know*. When I found these trigger words, I did a closer analysis of those responses. I also analyzed the interviews for markers of metacognition as shown in Table 3.

The Findings

Data from the student self-efficacy surveys showed no statistically significant change in student's self-efficacy scores before and after implementation. Although a few students showed small increases in math and science self-efficacy between the pre and post self-efficacy surveys, overall there were no significant increases in selfefficacy in math and science. There are a few reasons why there was no statistically
significant change in the pre and post self-efficacy surveys. The questions may not have been sensitive enough to pick up small changes in self-efficacy. Self-efficacy is difficult to measure because it is task and context specific, and depends on the mastery criterion (Zimmerman, 2000). Another possible reason for lack of statistically significant change in self-efficacy scores is that the five week implementation duration was too short to see any movement in self-efficacy.

Although the Collaborative Peer Study Group Curriculum did not increase self efficacy survey scores, qualitative data did show gains in some of the indicators of increased self-efficacy. In the student interviews when I asked, "Do you feel more or less able to learn science after peer teaching?" all of the students responded that the curriculum helped them feel better about their learning. For example a female student, Katie, who scored low on the self-efficacy surveys said, "I was able to teach almost all of the things that we did [in class]. It taught me that I actually did know a lot and if I study more with people, I grasp it better" (Student Interview on June 10, 2008). This student explained that she felt better about learning science as a result of the Collaborative Peer Study Group Curriculum. Another student, Dave, responded "I felt like peer teaching has helped me more because I noticed that I know a lot more about science now" (Student Interview on June, 10, 2008). Dave felt more confident in his science knowledge. David's classmate, Aaron, said, "I felt not as stressed after the peer teaching session yesterday because I knew the content better. I was not completely knowledgeable on the content before." The student interviews indicated that students felt more confident about learning science after using the CPSG

curriculum even though there was not a statistically significant change in self-efficacy according to the self-efficacy surveys.

The qualitative data from the student interviews contradicts the quantitative data from the student self-efficacy surveys. This contradiction may arise because the students interviews may show early signs of self-efficacy change, which could not be measured in the self-efficacy surveys. Other data suggests that the students may have begun to raise their self-efficacy beliefs about learning science.

Data from the student interviews, audio recordings of peer study groups, and field notes also showed that the Collaborative Peer Study Group Curriculum helped students understand rigorous science, promoted metacognition, and motivated them to learn science. Mastery and metacognition can increase self-efficacy (Bandura, 1997). When people are more self-efficacious about something, they are more motivated to engage in the task (Bandura, 1997). Therefore, increases in understanding of rigorous science, metacognition, and motivation suggest gains in self-efficacy.

Finding One: The Collaborative Peer Study Group Curriculum Increases

Understanding

There were several indications that students increased their understanding of rigorous science content as a result of participating in the Collaborative Peer Study Group Curriculum. Students claimed that their understanding increased as a result of the CPSG Curriculum both during and after implementation. I recorded student statements about their increased learning in my field notes and audio recorded interview. In the student interviews, all but one of the seven students interviewed said they learned more from the peers study groups than from teacher lectures. Students also showed deep understanding during the peer study groups when asking and responding to questions about the content. The number and nature of student generated content questions and student statements about learning suggest that the CPSG curriculum increased student understanding of the forensic science content.

Students reported that the Collaborative Peer Study Group Curriculum helped them learn during implementation of the curriculum. One quote that illustrates increased student understanding was from a Hispanic female student with a medium self-efficacy score that I will call Alejandra. After a Collaborative Peer Study Group session she said, "Can I copy this [sic. notes from the study session]? Because I didn't understand nothing until today (Field Notes on February 25, 2008)."

The students that I interviewed after the implementation of the curriculum also reported that they had a much better understanding of the rigorous material after participating in the Collaborative Peer Study Group Curriculum. All but one of the seven students that I interviewed said that they learned more from the study groups than lecture based lessons. Dave, a Mexican-American student, best summed up the sentiments of the interviewees when he said,

I think I learn more from peer teaching because the teaching was slower and it wasn't as fast paced. And so I got to learn more and I remembered more. Because I felt like when it goes fast, I don't really remember everything; I only learned certain parts of the lesson (Student Interview on May 5, 2008).

Dave later added, "Another thing is that this helped me to remember more about what I learned, translation and transcription, because I had to memorize it and learn it to teach it." Several agreed that teaching helped them learn the rigorous material.

The students also thought that the Collaborative Peer Study Group Curriculum helped them learn by encouraging them to ask questions. All of the students that I interviewed liked how the curriculum allowed them to ask more questions. One White female student said, "It was such a small intimate group you felt free to ask questions whenever you need. That's really helpful because you are not really nervous within a big classroom because they don't want to look stupid and stuff (Student Interview on May 5, 2008)." Another student added, "When you are teaching your peers and they have a question, you feel more obligated to answer the question since you are the teacher. So it makes you think more in depth of the topic to answer the question (Student Interview on May 5, 2008)." The students thought that asking more questions helped them to gain a deeper understanding.

My analysis of audio recordings of the peer study groups showed that students did ask a lot of questions during the collaborative peer study groups. The students in the three study group sessions that I recorded asked about one content question *per minute* in their respective study groups (see Table 4). I audio recorded these same groups on a different occasion when students discussed different subject matter. Each group yielded similar question rates as shown in Table 4. Individual students in study groups are able to ask many more questions than they could in a whole class lesson. This observation is supported by Graessner and Person (1994), whose research with adolescent and college-age students found that students asked students asked an average of 1.7 questions *per hour* in a traditional classroom setting. In addition, Graessner and Person analyzed previous research on student questions, finding that estimated frequencies of student questions *per hour* have ranged from 1.3 to 4.0 in

traditional classroom settings. Individual students in collaborative peer study groups asked approximately nine times as many content questions as students in a typical classroom setting. The number of minutes in the collaborative peer study groups recorded was approximately 45 minutes and the typical 50 minute lecture-based class. Therefore it is appropriate to compare the number of questions student generated during a CPSG lesson to the number of questions generated in a typical lecture-based classroom. Students asked approximately nine times as many content questions as they would in lecture-based class.

Tuble 1. Humber of Content Questions Students Hisked in Each Group				
Study Group	Date	Number of Questions per Minute		
Group 1	April 3, 2008	0.89 questions/minute		
Group 2	April 3, 2008	0.96 questions/minute		
Group 3	April 3, 2008	1.59 questions/minute		

Table 4: Number of Content Questions Students Asked in Each Group

Not only did students ask a lot of questions during the collaborative peer study groups, but they also asked a number of higher level thinking questions (see Figure 17). I found that over one third of the content questions that students asked were level two or level three questions. An example of a level two question that a student asked was, "Are they [primers] kind of like flags?" (Audio Recording on March 10, 2008). I considered this question a level two question because the student asked if flags are analogous to primers. Another example of a level two question that a student asked was "They are both [the bacterial genome and the plasmid] DNA, aren't they?" (Audio Recording on April 3, 2008). I considered this question a level two questions differed from level two questions because students had to apply their knowledge in a

new or novel way. For example, in one study group the students related the concept of gene regulation to an experiment they had heard about in which scientists genetically engineered an emu to have scales. One student asked a level three question relating gene regulation and the emu experiment, "And so the scale genotype is still in the emu? And so they genetically engineered it so the scale gene would be expressed?" (Audio Recording on April 3, 2008). In this question the student realized that the emu still had this gene for scales, and the scientists devised a way for the scale gene to be expressed.

In the student interviews one student said that the reason she felt that she learned more from the CPSG curriculum was because she asked higher thinking questions in the study groups. She contrasts this with learning from a teacher's lecture:

When the teacher lectures you are just given the general idea. But when you are doing peer teaching, there are a lot more specific details you can go over because you can ask a lot more questions than you normally would...[In the lecture] we were taught that histamines cause a chemical alarm, but we never really asked why before. The *whys* really help a lot when you do peer teaching (Student Interview on June 10, 2008)

This student explained that the higher thinking questions helped her understand the material better because she was not just "absorbing the information" by passively listening to a lecture. Instead she was interacting with the information.

Students asked many content questions during the Collaborative Peer Study Group Curriculum, approximately one question per minute as shown in Table 4, and over a third of the questions were higher order thinking questions. The number of questions and type of questions that that students asked during the Collaborative Peer Study Group Curriculum not only suggests increased understanding of the rigorous content, but also suggests increased metacognition.



Figure 17: The percentage of content questions asked by category for Groups 1 and 2 on different implementation days.

Student statements during and after the Collaborative Peer Study Group Curriculum and the large number of student content questions that students asked, many of which were deep thinking content questions, indicates that the curriculum helped students understand the rigorous biology content. The large number of content questions asked by students also suggests that students were thinking about their learning.

Finding Two: The Collaborative Peer Study Group Curriculum Fosters Metacognition

There were several indications that the Collaborative Peer Study Group Curriculum fostered metacognition. After students used the Collaborative Peer Study Group Curriculum a few times, they were able to set and prioritize learning goals without the formal structures of the collaborative peer study group. Students also verbalized what they knew and didn't know during the study groups. When students needed help, they turned to peers, teachers, and outside resources.

At the beginning of the implementation of the Collaborative Peer Study Group Curriculum, students set individual and group goals with the help of the What Are Your Individual Goals worksheet and the Table Talk: Group Goal Setting activity. After a few days of curriculum implementation, however, the students resisted the individual goal setting and group goal setting activities. They wanted to go immediately into the teaching and learning portion of the curriculum. One student said, "Why are we doing this? Can't we just start teaching and learning? I already know what I want to learn (Field Notes on March 10, 2008)." Students wanted to skip the individual goal setting and group goal setting activities because they believed that they could quickly mentally set goals; the students felt that the writing portion wasted their time. Field notes supported that belief. When I eliminated the goal setting activities, students still decided as a group what they wanted to learn first. I overheard students say, "Okay what are we learning first" or "Okay so what do you guys want to learn first" (Audio Recordings and Field Notes on April 3, 2008)? I think that the students had gradually internalized the goal setting process and were able to do it without any structures or outside support.

Students also evaluated what they knew and didn't know throughout the collaborative peer study groups. During each study group that I audio recorded, I students explicitly verbalized what they knew and what they didn't know (see Figure 18). Students verbalized evaluations of their knowledge on average once every four minutes.

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Student Statements About Their Knowledge

- "I thought I knew, but I didn't know."
- "I thought I had an idea what PCR was, but I was totally off. I didn't know."
- "That is the part that I am unclear about too."
- "Oh. Okay. I get it."
- "I didn't understand any of it."
- "I don't get the gene regulation and the lac operon stuff."
- "We don't know either."
- "I think I get it now"
- "I don't know. I need to look at my notes."
- "I don't really know how this one works."
- "Well I know that part."
- "I don't know why..."
- "I don't understand what it does from the blunt ends."

Figure 18: Examples of metacognitive statements that students made during the peer study groups (Audio Recordings and Field Notes on April 3, 2008).

When students articulate what they know and don't know, they are better able

to get the help that they need. Katie summed this up when she said,

It feels really good when you do know something, but when I don't know something it just shows what I can improve on... it made me study those things [that I had trouble understanding] as opposed to the other things that I actually really knew. And it gave me more confidence because knowing everything showed me that maybe I am going to do really good at quizzes...It just gives me more confidence on that (Student Interview on June 10, 2008).

Katie explains that the Collaborative Peer Study Groups helped her identify what she

didn't understand, so she could study those ideas more.

When students found that they didn't know something, they often asked for

help from their peers, the teacher, or sought the answer elsewhere. As stated earlier,

students asked approximately one content question per minute in their study groups.

One student, Eric, explained the benefit of the questions,

A good thing about the questions was that a lot of times that you asked them, the person you were asking a lot of the time would say 'that's interesting, I don't really know.' And then you would ask another group, ask Bryan [the student teacher], ask the teacher, look it up in a book. And so you get to expose, not misconceptions, but missing pieces (Student Interview on May 5, 2008).

Eric explains how all the questions that students are encouraged to ask in the study groups made him realize that he didn't fully understand the material. In order to understand the material, he needed to reach out to his peers, teachers, or other resources. As I observed in the field notes and audio recordings, the students did just that.

When I used the Collaborative Peer Study Group Curriculum in my classes, I was asked many content questions. I had to make an effort to circulate the room, so all students would get a chance to get help from the teacher. This was a change from previous lessons, where students asked significantly fewer questions. On several occasions, I saw students look up a question on the internet or grab text books off of my book shelf to answer their own questions. I observed, as noted in my field notes, that students looked up their own answers to their questions with greater frequency during the collaborative peer study groups.

The evaluation of the field notes, audio recordings, and student interviews showed that the Collaborative Peer Study Group Curriculum fostered metacognition. When using the CPSG curriculum, students set learning goals, decided what they knew and didn't know, and asked questions or looked in other resources when they felt like they didn't fully understand the rigorous content. When students took steps to find the answers to their own questions during the CPSG curriculum, they not only showed metacognitive behaviors, but also showed motivation to learn.

Finding Three: The Collaborative Peer Study Group Curriculum Motivates Students to Learn Science

There were several indicators that the Collaborative Peer Study Group Curriculum motivated students to learn science. Students were engaged in the teaching and learning activity and even initiated their own study groups. I noticed an increased level of student engagement during the implementation of the Collaborative Peer Study Group Curriculum compared to teacher-centered lessons. The number of content questions that students asked during the activity shows how engaged students were. Students who had not been interested in learning science were now engaged in the learning process. For example one female student had told me at the beginning of the year that she "didn't care about learning biology" and that she only cared about her grade. I witnessed that same student asking many questions during the peer study group (Field Notes on February 5, 2008). Many of these questions were deep thinking Level 2 and Level 3 questions that helped her better understand the material. She seemed to be motivated to learn the material and not just find the right answer for the grade. Student engagement in the peer study groups was not the only indicator that students learned in the collaborative peer study group.

Students initiating their own study groups also indicated that the Collaborative Peer Study Group Curriculum motivated students to learn. I recorded in my field notebook (see Table 5) when students initiated their own collaborative peer study groups. I considered instances when students initiated their *own* study groups when students formed groups for the express purpose of better understanding rigorous content without my direction to form groups, nor my directions to study specific topics. Several of the students that participated were students with low-medium selfefficacy scores in science. Prior to the CPSG curriculum, I had never seen my students exhibiting this behavior.

Date and Period	Instances When Students Initiate Collaborative Peer	
	Study Groups	
March 3, 2008 Period: 3	Today in class when working on the study guide, Margaret took the pens and started writing on the desk and explaining how <i>DNA</i> , <i>genes</i> , and <i>chromosomes</i> were connected.	
March 5, 2008 Period: 5	Today in class when working on the study guide, Marion said, "Do you guys want to dedicate time where we study all of the drawings?" The students sitting next to her replied, "Yes." Austin replied, "Do you understand the drawing?Okay because I do too." Then Jon said, "Chares, It's your turn to draw us a diagram."	
	markers.	
March 6, 2008 Math Class	Heather, Ariel, and John wrote math problems on the tables with Expo markers.	
March 12, 2008 Math Class	Students studying in the math teacher's room together when I was not there they were writing on the tables and the boards everywhere.	
April 24, 2008: Period: 1	Lionel takes a dry erase pen and explains transformation to his tablemate, RA, who is having difficulty with his lab write-up.	

 Table 5: Instances When Students Initiated their Own Collaborative Peer Study

 Groups (Field Notes)

Students showed engagement during the collaborative peer study groups as evidenced by the number of content questions asked during the study groups. The students also were motivated to create their own study groups. In end of the year presentations, several students cited that learning to study in a group was one of the most important things that they learned all year. Two of these students said that they planned to use study groups in college. One student said, "In college I can create these study groups and teach each other" (Field Notes on June, 17, 2008). This student stated that she would take on the leadership role of creating her own study groups in college in two years.

Summary

As shown in the data analysis of the Collaborative Peer Study Group Curriculum, the curriculum influenced students' motivation, metacognition, and understanding of rigorous science content. Although the analysis the self-efficacy survey scores showed no statistically significant change in student self-efficacy in science, qualitative data suggests that student's self-efficacy in science increased as a result of the Collaborative Peer Study Group Curriculum as evidenced by their own statements about themselves as learners. Interviews with students indicated that The Collaborative Peer Study Group Curriculum improved self-efficacy. Other qualitative data showed that the Collaborative Peer Study Group Curriculum improved self-efficacy. Other qualitative data showed that the Collaborative Peer Study Group Curriculum improved student understanding, fostered metacognition and motivated students to learn science. Mastery of rigorous content and thinking about one's learning increase self efficacy (Bandura, 1997). When students are more self-efficacious about learning science, they are more motivated to learn science. Therefore the increase in student understanding, the increased motivation and metacognitive activities suggest that the Collaborative Peer Study Group may increase self-efficacy. However, the students may need to be exposed to the curriculum over a longer period of time to see any statistically significant change in self-efficacy.

VIII. Conclusion

The evaluation of the Collaborative Peer Study Group Curriculum (CPSG) shows that students benefit from the curriculum in many ways. Students increase their understanding, think about their own learning and are more motivated to learn. The Collaborative Peer Study Group curriculum may increase self-efficacy but a longer term study is needed to reach any conclusive results. My suspicion is that CPSG does increase self-efficacy, especially for students who are not very self-efficacious, but students need to engage in the curriculum over a longer period of time. If CPSG does increase self-efficacy, then the curriculum could help increase interest and access to science, technology, engineering, and math (STEM) education and careers.

Implications

If the Collaborative Peer Study Group Curriculum does increases self-efficacy, then the curriculum could help increase interest and access to STEM education and careers (see Figure 19). High self-efficacy in math and science increases motivation and interest in academic mathematics and science (Bandura & Schunk, 1981; Deci, 1995). When people are motivated to engage in academic math and science, they will devote more time to learning it and will persevere when they hit setbacks (Bransford et al., 2000). When students devote more time to learning and persevere when they hit setbacks, they are more likely to be academically successful (Bandura & Schunk, 1981), which increases their self-efficacy, creating an upward spiral of success. When a person is highly self-efficacious in a subject, they are more likely to choose to pursue education and careers in that subject (Lent et al., 2005). High self-efficacy and high motivation in math and science can increase students' interests in STEM careers. Success in high school science and math, fueled by increasing self-efficacy and motivation, can increase access to STEM education and careers. Therefore CPSG, by increasing self-efficacy in science and math, could help increase interest and access to STEM education and careers.

The Collaborative Peer Study Group Curriculum may have lasting effects on students who have been exposed to the curriculum. Students may transfer the collaborative peer study group strategy when learning math and science in other contexts. Students may create their own study groups when not prompted by the teacher, or when studying for other high school math and science classes, as many students did after using CPSG in my classroom. Students may also transfer the collaborative study group strategies to their future college math and science courses. College science and math courses are largely based on lecture and tests. If students can transfer their group study skills to these college science and math courses, they could increase their self-efficacy, motivation and academic success in these classes, which will likely increase their interest and retention in STEM majors.



Figure 19: Increasing self-efficacy in science and math may effect participation in STEM

Lessons Learned and Future Plans

I would like to use the Collaborative Peer Study Group Curriculum for eight months next year and evaluate the effects on self-efficacy and interest in STEM. There are, however, a few changes that I would like to make to CPSG based on what I have learned through my implementation and my evaluation experiences.

Before implementing CPSG again, I will tell the students about the importance of providing positive feedback to their peers and the importance of realizing that you don't know something. I think that encouraging students to give their peers positive feedback will help increase the self-efficacy of the participants. Not only will I tell the students to give each other positive feedback, but I will also tell the students that, "at some point during CPSG you will realize that you don't know something and this realization is a benefit of collaborative peer study groups." A few students in my interviews expressed anxiety when they were in the teacher role and realized that they didn't know something. I think if I told the students at the beginning of the CPSG implementation, that "not knowing is positive because then you can ask questions and use your resources to learn what knowledge you were lacking," then it would ease anxiety.

Before implementing CPSG next year, I will also change the "Procedure for Working in a Study Group." I would like to change the procedure for rotating teaching and learning roles so that the first student in the teaching role is decided at random, and after that student has taught, each student in the study group must take his or her turn teaching. When I used the "Procedure for Working in a Study Group", I noticed that the same students (usually the high skilled and high self-efficacious) in each group would always assume the teaching role first, and after they taught other students, who were less efficacious, would resist teaching after them, fearing that they would be less proficient. Often the last student to be in the teaching role would not get a chance to teach. I think that changing this part of the procedure would ensure that students had a more equal opportunity to be in the teaching role. It would also take the pressure of the student in the teaching role, because all students would have to be in that role during the study group.

I have learned a lot through the process of researching, creating, implementing and evaluating the Collaborative Peer Study Group Curriculum. I have learned about an incredible approach to learning-collaborative peer study groups-and the implications for using this type of curriculum to increase interest and access to STEM education and careers for underrepresented student groups. This research process has made me a better teacher, not only because I have added collaborative peer study groups to my curriculum repertoire, but also because I now critically examine all of my curriculum to see if it fosters self-efficacy, metacognition, motivation, and deep understanding. Appendix

The Collaborative Peer Study Group Curriculum

Jesse Wade

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Dear Fellow Educator,

If you are a teacher who wants to improve your teaching, who is open to change, who wants a more student centered classroom, who is comfortable with students working in groups, who is open to student dialogue in the classroom, who is knowledgeable in your content area, and who is comfortable learning with your students, then I am glad that you are a member of the teaching profession. If this description does not fit you, then the following is not for you. Ask yourself the following questions:

- Would you like to do more than direct instruction but not completely get rid of it?
- Would you like your classroom to become more student and learning centered but you don't have the time to create these types of lessons for every topic?
- Do you want students to gradually take more ownership of their own learning?
- Do you want your students gain a deeper understanding of your content area?
- Do you want a curriculum that helps improve the process of teaching and learning in your classroom?

If you answered yes to any of the above questions, then I may have a solution for you. The Collaborative Peer Study Group Curriculum shows you how to create, manage, and facilitate study groups in the high school classroom setting. It also shows you how to help students become more autonomous learners.

Although the following activities were successful in my own high school science classroom, they may need to be modified slightly to fit the needs of your lessons and your students.

Good luck and have fun teaching and learning from each other.

Sincerely, Jesse Wade

Introduction to the Collaborative Peer Study Group Curriculum

Collaborative Peer Study Group Curriculum is designed to help high school students master rigorous content in collaborative peer study groups. It is not designed to teach new concepts, but rather designed to help students have a deeper understanding of concepts that they have already been introduced to. In Collaborative Peer Study Group Curriculum students set individual and group goals for learning. Then students take turns being teachers and learners in order to gain deeper understanding of science and math topics. When students take on the role of teachers they use vocabulary and images to explain difficult math and science content. As learners, students ask questions and take notes. Students rotate teaching and learning in their groups every time they meet, until they have mastered the unit covered in class. Students meet in their collaborative groups for approximately 60 minutes one to two times per week for a duration of no more than six weeks, before groups are switched.

Teaching Strategy- Collaborative Peer Groups

The intent of this curriculum is to help teachers create a more student and learner centered classroom. Teachers will learn how to empower students to create their own learning goals and to teach each other. Students will learn how to create individual learning goals, create group goals, and work with peers to better understand complex material. Teachers will learn how to transition from a position where they are the sole transmitters of knowledge to a position where they help the students teach the information.

This curriculum moves away from traditional science teaching, which includes that memorization of many facts and covering many subject areas. This curriculum asks students to learn rigorous content in depth. In collaborative peer study groups students externalize their learning. This externalization allows the students to regulate their own learning and the learning of their peers. The process of teaching and learning from peers encourages the students to ask questions. Students expose their misunderstandings and learn from their peers. In the dialogue of peer study groups, students share their unique perspectives on what they are learning. Because each student shares his or her unique perspective on the material to the group, students are exposed to new ways of looking at the material and make new connections. Teaching and learning in collaborative peer study groups emphasizes learning and deemphasizes external rewards such as grades. As a result, students are more intrinsically motivated to learn.

Teacher's Quick Guide to the Collaborative Peer Study Group

Teacher's Advance Preparation (3 hours)

1. Decide on the rigorous material that you would like your students to master using the Collaborative Peer Study Group Curriculum.

2. Divide your students into heterogeneous groups of four (see Tips for Grouping Students).

3. Set-up the classroom for optimal collaboration. Configure your classroom, gather material, and create workstations.

Collaborative Peer Study Groups (60 minutes)

1. Individual Goal Setting Activity (5 minutes). Pass out the What are your Individual Goals? worksheet. Ask students to write as much as they can about the given topics.

2. Group Goal Setting Activity (5 minutes). Pass out one Table Talk: Group Goal Setting Worksheet and one extra set of Table Talk Questions. Ask the students to discuss the questions in their group and have one student write down their answers.

3. Students Rotate Teaching and Learning (50 minutes). Pass out copies of the Procedure for the Working in a Peer Study Group, dry erase markers, window cleaner, and paper towels to each workstation. Ask students to decide what they will learn first and who will teach it. Then have the students review their materials. Remind students to ask for help from the teacher. Circulate while students teach and learn to make sure that students are not propagating misunderstandings. E.g. How Plants Get Energy

- Photosynthesis
- Cellular Respiration





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Choosing Rigorous Curriculum

Definition of *Rigorous Content*

Rigorous content is both new to students and requires students to understand several small discrete pieces of knowledge (and the connections between them) in order to understand the big idea. Examples of big ideas in science are evolution, how DNA codes for traits, or how plants get energy. These ideas may be the subject of a teaching unit.

Selecting Rigorous Content

Before using the Collaborative Peer Study Group Curriculum, decide on the rigorous content that they would like the students to master. The following steps will help you choose rigorous content that you can help students understand by using the Collaborative Peer Study Group Curriculum.

Step 1: Decide on a big idea that connects several small ideas. An example of a big idea is how plants get energy.

Step 2: Break up that big idea into smaller chunks and clusters of information. For example, the idea of how plants get energy could be broken down into smaller chunks like the light reactions of photosynthesis, the dark reactions of photosynthesis (The Calvin Cycle), glycolysis, the Kreb's Cycle, and the electron transport chain. Smaller chunks are usually the subjects of individual lessons.

Step 3: Brainstorm different contexts that will help students to see the connections between each of the small pieces of knowledge. For example, if you want teach students about how plants get energy, you could have the students observe plants growing in sealed jars in the light and in the dark. This

would give students a context for understanding the photosynthesis and cellular respiration.

Introduce the Students to the Rigorous Content

Introduce the rigorous material by first activating students' prior knowledge. You can discover students' prior knowledge in a variety of ways. For example, you can ask students to answer open-ended questions based on their home experiences in free-writing exercises or in small group conversations. Once you have discovered what students already know about the topic, connect their prior knowledge to new ideas by using scaffolds such as mini-lectures, demonstrations, videos, reading, discussions, labs or projects. After students have been introduced to the new material, then use The Collaborative Peer Study Group to help students better understand ideas that have already been presented.

Use the Collaborative Peer Study Group Curriculum

Once you have introduced the rigorous content, use the Collaborative Peer Study Group Curriculum to help to help students understand the rigorous content. Use the curriculum every time you introduce several small pieces of information. The Collaborative Peer Study Group Curriculum will help students see the connections between these small ideas and how these small ideas help them understand the big idea. Write down these ideas that you will be using on the What are Your Individual Goals? worksheet.



Use the Collaborative Peer Study Group Curriculum as frequently as twice a week.

Tips for Grouping Students

Effective Study Groups

Collaborative peer study groups are most effective when they are heterogeneous. Each group member can bring a unique perspective to the group. Although random grouping can often create heterogeneous groups in a hurry, this can result in ineffective groups. Teachers can avoid *problem groups* by carefully selecting students for each group. Below is a list of tips for grouping students.

Do

- Create small groups of 3-5 students (4 students is ideal).
- Group students of different gender and race together.
- Put students of low, middle, and high ability in the same group.
- Put students of low, middle, and high confidence levels in the same group.

Don't

- Create groups that are larger than 5 students.
- Group one student of low ability in a group with all high ability students
- Group a low confidence student with all high confidence students.
- Put students who have personal conflicts with each other in the same group
- Put students who distract each other in the same group.
- Put more than one student who has difficulty interacting with their peers in the same group.



Setting-Up the Classroom

Configure your Classroom

For optimal results from the Collaborative Peer Study Group Curriculum, set-up your classroom so students can easily collaborate in their small groups. In an ideal classroom context, students in each study group sit in a square or rectangle and face each other.



Set up your classroom so that study groups can easily communicate with each other both orally and graphically. Each group will need a large vertical or horizontal surface area (4' x 4' or larger) to draw or write on. Two tables pushed together work best, but whiteboards, chalkboards, easels or windows also work. Students can either draw directly on the surface area with dry erase markers (or chalk), or students can draw on large sheets of butcher paper.



Having students write and draw directly on the tables with dry erase markers works best because students like drawing on the tables and students can easily see what their peers draw. The tables easily clean with window cleaner and paper.

Gather Materials

After creating seating for each group, set aside materials for each group. Each group needs at least two different colored markers to use when explaining concepts. If using dry erase markers, provide each group with window cleaner and paper towels. If using regular markers, provide ample butcher paper for each group. Create nametags for each workstation, so that students can find the table that they will be working at, and sit down with the other students in their groups. Make copies of the What are your Individual Goals?, Table Talk: Group Goal Setting, and The Procedure for Working in a Peer Study Group.

Quantity
2+ per group
1 per group
1 per group
1 per student
1 per student
1 per group
1 per group
3 per student

*These materials are unnecessary if using butcher paper and regular markers



Set-Up Workstations

Place the nametags on each workstation. Then place the copies of the What are your Individual Goals? worksheet on the table. Keep the following materials in a separate location for later distribution:

- Table Talk: Group Goal Setting Worksheet
- Table Talk: Group Goal Setting Questions
- Dry-erase markers
- Window cleaner
- Paper towels
- The Procedure for Working in a Peer Study Group

Tips for Giving Students More Autonomy over Their Study Groups

Start with the Activities

The first few times that you use collaborative peer study groups, provide your students with sufficient scaffolding. Give the students the What are Your Individual Goals? worksheet and then use the Table Talk to help students create their group goals. Ask students to follow all of the steps on the Procedure for Collaborative Peer Study Groups.

Eliminate the Goal Setting Worksheets

After students are familiar with the process of Collaborative Peer Study Groups, ask your students if they would prefer to quickly create their personal and group learning goals. If your students would like to begin teaching and learning sooner, have the students meet in their designated study groups, but do not use the What are Your Individual Goals? worksheet and the Table Talk: Group Goal Setting worksheet. Instead, tell students that they will need to decide on their group learning goals by considering every person's individual learning goals to master the material. Tell the students what rigorous material that you would like students to master and write down these ideas on the board. Then tell the students that they can begin teaching and learning by using The Procedure for Working in a Peer Study Group as soon as they are ready.

Eliminate the Procedure for Working in a Peer Study Group

Ask students if they feel ready to organize their own teaching and learning sessions. If the students respond favorably, do not use The Procedure for Working in a Peer Study Groups. Instead, have the students meet in their designated study groups and tell the students what rigorous material that you would like students to master and write down these ideas on the board. Then choose by a random process which student will teach first in each group. There are several ways that you can randomly choose a student to teach first. For example, you can have each student put their pinky finger in the middle of the table and tell the students in each group to decide who has the longest pinky finger. Once they decide on a student with the longest pinky finger, you can tell the students that this person will go first. Alternately, you can tell students to share their birthdays with the group, then tell the students that "the person with the birthday closest to today" teaches first. Regardless of which way you decide who will teach first, have the students that teach first choose what they want to teach the group. Then tell the students that each person in the group will teach traveling in a clockwise direction.



Encourage Informal Peer Study Groups

Once students have used the Collaborative Peer Study Group Curriculum in their classes several times, encourage the students to create their own informal study groups. You can do this by suggesting that students create study groups before a test or other assessment. Offer the use of your classroom at lunch or after school for study groups. Lend students dry erase markers and cleaning supplies for their study groups.

What Are Your Individual Goals?

Without looking at any notes or texts, write (or draw) as much as you can about the following topics in the box below

- 1. Transcription
- 2. Translation
- 3. RNA processing

Write as much as you can about the topics above here

What are you still unclear about? *List any questions that you have about these topics below:*

Now circle which of the three topics above you want to understand better

- 1. Transcription
- 2. Translation
- 3. RNA processing

What Are Your Individual Goals?

Without looking at any notes or texts, write (or draw) as much as you can about the following topics in the box below

1.

2.

3.

Write as much as you can about the topics above here

What are you still unclear about? *List any questions that you have about these topics below:*

Now circle which of the three topics above you want to understand better

- 1.
- 2.
- 3.

Table Talk: Group Goal Setting Worksheet

Discuss the following questions in your group at your table. Start with question 1, then question 2, and finish with question 3. Make sure that each person in your group shares his or her ideas for each question.

- 1. What concepts/ideas have you found most difficult?
- 2. Which of these ideas do you find particularly interesting? Why?
- 3. What are each of you interested in teaching and learning with each other?

NOTES ON CONVERSATION:
Table Talk: Group Goal Setting Questions

Discuss the following questions in your group at your table. Start with question 1, then question 2, and finish with question 3. Make sure that each person in your group shares his or her ideas for each question.

- 1. What concepts/ideas have you found most difficult?
- 2. Which of these ideas do you find particularly interesting? Why?
- 3. What are each of you interested in teaching and learning with each other?

Procedure for Working in a Peer Study Group

STEP 1: Decide on what you are going to teach and learn as a group

STEP 2: Decide who will teach the group _____

And who will learn _____

STEP 3: The group selects one learner to be the facilitator

The facilitator keeps the group on task and makes sure that the group does not go over the time limit.

STEP 4: Review Materials (5 minutes)

The teaching student reviews any notes or texts that they have on the idea. If the teaching student has questions about the material, they ask instructors for help.

The learning students review the material as well. The learning students each think of two questions about the topic and write them in the space below

1	 	 	
2			

STEP 5: Teachers Teach/ Learners Learn (10 minutes)

The student in the teaching role teaches the other group members. *The student teacher draws important terms and images for everyone in their group to see. The student learners ask questions.*

STEP 6: Reach Out (2 minutes)

Ask for help from other classmates, look information up online or in text books, ask your adult instructor for help, or write your questions down so you can ask your teacher later.

CHANGE ROLES AND TOPICS AND REPEAT THE PROCESS

Name:

Date: _____

Student Self-efficacy Scale

This questionnaire is designed to get a better understanding of the kinds of things that are difficult for you. Please rate how certain you are that you can do the kinds of things described below by writing the appropriate number. Your answers will be kept strictly confidential and will not be identified by name.

Rate your degree of confidence by recording a number from 0 to 100 by using the scale given below:

Get an A on a math test

Get an A in Biology Class this year

0	10	20	30	40	50	60	70	80	90	100	
Cannot do at all	Moderately can do							Highly certain can do			
Self-efficacy for Academic Achievement							Confidence (0-100)				
Learn scie	nce										
Learn biol	ogy										
Learn mat	h										
Learn biot	echnolo	gy									
Learn scie	ntific vo	ocabular	У								
Learn mol	ecular p	rocesses	5								
Learn lab	protocol	ls									
Learn fore	ensic sci	ence									
Execute pr	roper lat	o technic	ques								
Get an A o	on a scie	ence tests	8								

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