

IMPROVEMENT OF METACOGNITION SKILLS WITHIN
HIGH SCHOOL GENERAL CHEMISTRY

by

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ABSTRACT

Within my science classroom at Germantown High School, students seem to lack the ability, or desire, to evaluate their own understanding of material. These underdeveloped metacognitive skills negatively affect both their grade as well as, their participation in class and their overall attitude towards science. Research has shown the importance of metacognition, or thinking about your own thinking, in students, and especially in chemistry students. Many students lack the knowledge and experience to conduct this type of thinking. Within this study, I used specific lessons and techniques that focus on modeling and practicing techniques to develop metacognitive skills.

No quantitative changes were found within student use of the metacognitive techniques or their grades, but significant changes were seen in students' ability to accurately understand their own skill level.

INTRODUCTION AND BACKGROUND

I currently teach at Germantown High School (GHS), a suburban to rural high school located in Germantown, Wisconsin, population 19,749. I teach both biology and chemistry at GHS. The average general chemistry class has 20-24 students from both 10th and 11th grades. GHS student population consists of approximately 1,420 students in grades 9-12. Students of ethnic origin other than white constitute approximately 11.5% of the school's population; Asian 3%, Black 3.7%, Hispanic 2.7% and American Indian .2%. Meanwhile, students identified as economically disadvantaged reflect 13.5% of the population and students with disabilities constitute approximately 10.3% of our clientele.

I have taught in secondary schools for the last six years. I am currently teaching one section of Biology (sophomores and freshmen) and four sections of Chemistry (sophomores, juniors and seniors). I have taught many subjects including anatomy & physiology, geology, meteorology, astronomy, physical science and fresh water biology. More of my background will be discussed in the methodology section of this paper.

Within my science classroom at GHS, students lack the ability, or desire, to evaluate their own understanding of material. This can be seen in their general apathetic attitude towards chemistry, lack of participation in class discussions and belief that the teacher controls their grade in the class. This inability negatively affects both their grade and their participation in class. I want to improve the students' metacognition skills, and encourage their use, within my general chemistry class. I plan to teach, demonstrate and encourage the use, of several metacognition techniques to two of my general chemistry classes. The existing content will remain the same during my study; the only change will

be the introduction of metacognition techniques. These techniques will be described in detail in the methodology section.

Through the use of these techniques, my goal is to improve student test scores and class discussion participation. I will investigate the following focus question and three sub questions: *How do my student's metacognition skills and techniques impact their learning?*

1. What are the current metacognition levels and techniques used by my students?
2. How are my students' grades impacted by instruction of and the use of metacognition techniques?
3. How do the attitudes of my students towards their chemistry learning change after the use of metacognition techniques?

CONCEPTUAL FRAMEWORK

With this literature review, first metacognition will be defined and explained. An explanation of constructivism in education will follow and a discussion of the need for such techniques in the chemistry classroom. Following this discussion, general techniques will be explored.

Research and classroom experience show that metacognition plays a key role in the learning of all students. The actual definition of metacognition can differ slightly between researchers, but most agree with Flavell (1976), a pioneer researcher in the field writes, "Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear" (p 232). It is an internal process of monitoring,

understanding and knowledge of material (Rickey & Stacy, 2000). This process of monitoring is a normal occurrence in advanced students, but not often seen in lower achieving students (Van Velzen, 2012). For this reason, I chose to focus my study on metacognition strategies.

Metacognition and Chemistry

Metacognition is especially necessary in a chemistry classroom (Thomas & Anderson, 2013; Thomas & Campbell, 2012). Chemistry is a complex subject that brings together not only science concepts but math as well, in ways some other sciences don't. Topics range from abstract concepts to the study of atoms and their parts, to the interaction of atoms with other atoms, to more tangible topics of input-output chemical equations. Therefore, "students' own monitoring of their developing understanding of new concepts is essential for effective learning." (Rickey and Stacy, p 915).

At most universities and colleges across the country, chemistry is required as an entry level course for many science, technology, engineering, and mathematics, (STEM) degree programs (Cool, Kennedy, & McGuire, 2013). Most of these chemistry students have taken chemistry in high school, but those courses have not adequately prepared them for the rigor of the college level course. Consequently, entry-level undergraduate chemistry classes have a high attrition rate, some as much as 70% (Chambers, 2005), though the average rate is approximately 25% (Cooper, Pearson 2012). One can imagine how difficult it is to have a large number of students graduating with STEM degrees with this high attrition rate. In order to deal with this attrition, it is crucial to improve performance of students in introductory courses, such as general chemistry. (Cook,

Kennedy, & McGuire, 2013). At Louisiana State University, General Chemistry is taken primarily by first year college students. These students are mostly 18-19 year olds, just three months beyond high school. In 2010 and 2011 Cook, Kennedy and McGuire performed an intervention on these students that consisted of a simple 50-minute intervention involving the presentation of metacognition techniques geared towards replacing or supplementing the techniques they learned and used in high school along with a commitment to use these tools (Cook, Kennedy, & McGuire, 2013). In 2010, 595 students and 668 students in 2011, took General Chemistry I. Of those 1263 students, 901 students took part in the intervention and 362 that did not. The students that took part achieved an entire grade higher than those who did not attend the intervention or commit to using the tools presented (81.5% to 72.6% in 2010 and 81.6% to 70.4% in 2010). Though these studies focused on college level courses, ideas and attitudes about subjects are often formed in high school. The material in introductory college level chemistry is, by in large, the same as that presented in high school general chemistry. By providing students a chance to acquire and practice skills that they will use in college courses, such as chemistry, the chances of success in these courses, dramatically increases. According to Tai, Bruce Ward, & Sadler (2006), there are direct positive correlations between experiences students have in high school chemistry class and their grades in college courses.

The level of student metacognitive skills is linked to those taught and modeled by their teachers (van Velzen, 2012). Within a study van Velzen (2012) conducted, six teachers from various subjects were given a questionnaire that was developed to obtain

quantitative and qualitative data regarding their level of experience in teaching metacognition skills. These teachers had various levels of experience in teaching, but all had taught secondary level students (van Velzen, 2012). Many of these teachers expressed concerns that students do not see a value in metacognition skills because high schools are more answer driven (van Velzen, 2012). The teachers with higher levels of knowledge of metacognition skills discussed the need for metacognition skills in order for students to move beyond simple textbook learning (van Velzen, 2012). Teachers need to provide opportunities for students to develop metacognitive skills, but cannot do so without knowledge of metacognition and how to provide these opportunities. Teachers must educate themselves on a variety of methods in order to help their students learn and practice metacognition. (van Velzen, 2012)

The theory of constructivism in education is rooted in Piagetian beliefs of active learners, and further defined by Vygotsky's beliefs of the importance of a skilled tutor and scaffolding (Schaffer & Kipp, 2010). Though there are varying beliefs within the field exactly what constructivism actually means, the common thread is that "learning new knowledge implies the active involvement of the learner, for she/he has to construct this knowledge" (Bächtold, 2013). A constructivist teacher utilizes a students' previous knowledge to build new knowledge. They must also discover and correct any misconceptions within a students' prior knowledge. In order to learn, students need to learn the steps that lead up to that new knowledge (Bächtold, 2013). This thought process is metacognition. A constructivist views teaching science as an active, social process, of making sense of the world similar to that of actual practicing scientists.

(Bächtold, 2013) These authentic experiences are brought to the classroom often through Inquiry Based Learning.

Metacognition and Inquiry Based Learning.

One method discussed by Thomas and McRobbie involves the use of the Activity Theory [2012}. This is a process of allowing students to have guided experimentation to form content knowledge with the use of text materials to back this knowledge (Thomas & McRobbie, 2013). This methodology is very similar to inquiry based learning. Within an inquiry-based classroom, teachers should act more as facilitators verses leaders (Ramnarain, 2014). Real raw data that is either generated by the students or provided by the teachers should be used. The students use this data to guide the lesson and teachers should shift the instruction to match the students' interests or difficulties.

Communication and dialogue between students and the teacher is essential in this style of instruction. While there is no doubt that inquiry based learning promotes and develops metacognition, there are concerns of inability to create authentic inquiry learning within a science classroom in short term studies (Schraw, Crippen & Hartley, 2006). This difficulty in creating authentic inquiry learning is something that must constantly be combatted within a classroom. Opportunities for students to drive the learning in the classroom must be embraced if students are to learn and practice metacognitive skills.

Collaboration with students and with teachers is another method of inquiry-based learning that is used to help develop metacognition skills. These collaborations could include small tutor groups lead by "expert" peers, cooperative learning groups or teacher modeling (Schraw, Crippen & Hartley, 2006). By grouping with other students of similar

ability levels, students are able to easily and comfortably talk through a task together. This talking through of a task is the basis of metacognition. Using strategies such as the Thinking Aloud Together Program, a program that prompts students to say out loud what they are thinking as they solve a problem or complete a task. (Mercer & Littleton, 2007) This method of learning by explaining how a problem is solved as you solve it, is modeled by most teachers as a way to help students understand different strategies for problem solving.

Instruction of Metacognition Strategies

Yet another method for teaching students metacognition skills involves the instruction of strategies. This method is linked to the previous method of collaboration, but it is deserving of discussion on its own. There is much research and discussion about the value and need to teach not only content, but also problem-solving skills that can be applied outside of the science classroom. The latter requires metacognition development. The most effective problem-solving strategies involve three parts: acquiring expert knowledge from a teacher or peer and guided reflection; to utilize an appropriate general problem-solving strategy usually modeled by a teacher; and to use tools such as summary tables, flowcharts or causal diagrams to lessen the amount of material committed to memory (Schraw, Crippen & Hartley, 2006).

The PEAK (Performance Excellence for All Kids) Learning System highlights several metacognition techniques (Rogers, 2014). A method within this system, to help teach metacognitive techniques, is called Point Processing (Rogers, 2014). Throughout a class, the teacher will stop and ask the students to process what they have just been going

over. This processing can come in the form of turning and explaining to a neighbor the topic that is being covered, drawing a picture or model, rephrasing in a better way than what the teacher has said, or write a tweet about what was just covered. Another technique is called Interactive Notes (Rogers, 2014). The Student Note Sheet is divided into half. The left half, are version of guided notes where the bulk of or all the presented material is provided to all students. The right half is blank except for the heading process. The teacher proceeds through the notes as they normally would, with the exception that after every point, or every other point, they pause and have the students Point Process on their notes sheets.

Research has shown the need for, and benefits of, metacognition in a chemistry classroom. An effective way to teach these skills are through inquiry based learning and a constructivist style learning environment. These methods allow students to develop problem solving skills which are metacognitive skills. These ideas are the basis and rationale for the study that was completed in my classroom.

METHODOLOGY

I have taught within secondary schools for the last six years. The first year I was not a classroom instructor, I was an AmeriCorps worker. That first year, I worked in a low income, poor performing school. I worked with classroom instructors to incorporate more hands-on, experiential learning. The last five years I have worked in suburban schools as a classroom instructor of a variety of sciences. Prior to the last six years, I worked in several non-traditional educational environments, including both museums and a traditionally rigged sailing vessel. All of these experiences have provided me a solid

background and understanding of how people learn. I have seen the importance of metacognition first hand in a variety of settings. It is this background that led me to investigate the metacognition skills of my students.

Research has shown the importance of metacognition in students and especially chemistry students (Rickey & Stacy, 2000). Many students lack the knowledge and experience to conduct this type of thinking. Through specific lessons that focus on modeling, as well as, opportunities to practice what was modeled, students can dramatically improve not only their understanding but also their grades (Rickey & Stacy, 2000).

This project investigated the impact of students' metacognitive skills and techniques on their learning. In addition, impacts of these skills on their grades and attitudes towards chemistry were evaluated. The students' general level of metacognition skills will be measured before and after the treatment.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Table 1
Data Triangulation Matrix

Questions	Data Source		
Focus question: How do my students' metacognition skills and techniques impact their learning?	Pre-& Post-treatment survey	Classroom Observations	Student interviews
Sub question 1: What are the current metacognition levels and techniques used by my students and how does this change after the study?	Pre-treatment survey	Classroom Observations	Student interviews
Sub question 2: How are my students' grades impacted by instruction of and the use of metacognition techniques?	Weekly Study Survey Reflection	Grades of current students on Unit test and quizzes compared to grades of past students	Formative assessments in class.
Sub question 3: How do the attitudes of my students towards their chemistry learning change after the use of metacognition techniques?	Pre- & Post-treatment survey	Student Weekly Study Habit Survey	Student interviews

The treatment will be administered in three different chemistry classes. Each of these classes consist of between 16 and 24, 10th through 12th graders. My classes have a total of 80 students, 21 of which were part of the control group. The 21 students of the control group consisted of eight 10th graders, ten 11th graders and three 12th graders. This group was chosen to be the control because it was the first class of the day, which I had in a different classroom than all my other classes. There was also a two-hour gap from the first class to the remaining 3 classes. This spatial and temporal separation made for a natural separation for the control from the treatment group. The treatment group consisted of a total of 59 students; 24 10th graders, 33 11th graders and 2 12th graders. All

were informed of the study and that activities completed within would not affect their grade negatively.

Four students were chosen to be interviewed due to their ability to meet with the researcher outside of class time, but directly after the class (to help ensure that class activities were still fresh in their minds). They were a cross sectional representation of the treatment group. Two girls and two boys from the treatment group agreed to take part. They exhibited a variety of grades and involvement during class. They ranged from quiet with high grades to quiet with low grades, and high participation in discussion with high grades to high participation with low grades. They agreed to participate in both the pre- and post-interviews. This agreement facilitated data tracking and analysis. All of the students selected had a good rapport with the researcher which ensured honest responses.

The treatment included an explanation of metacognition, the introduction of metacognition techniques and the practice of those techniques. The students had little to no prior knowledge or experience with these techniques in chemistry class or any other class. Students were presented with a basic explanation of metacognition and its proven benefits in regard to understanding and grades. Specifically, the data and statistics presented in Cook, Kennedy and McGuire's paper were discussed, (Cook, Kennedy, & McGuire, 2013) including the need to preview material, learn material and then review the material often. This three-step model was used throughout the two units. From there, several methods to facilitate metacognition were presented. A brief video explaining the topic of metacognition was also shown.

The Interactive Notes method of note-taking was presented to the students (Rogers, 2014). An example of the note-taking sheet can be found in Appendix D. Students were given guided class notes that were divided into two sections, creating a left and right column. Most of the material presented for the class was preprinted for them on the left side. The right side was blank except for the heading of Processing. Notes were given in a manner that every few points, students were asked to process what was just explained. This processing was first guided, in that, students would turn to a neighbor and explain what was just presented, draw a picture that represented what was presented or make an analogy of what was presented. Students were asked to share what they had written. By reporting out to the class, it not only insured students understood the process, but also, allowed students that were unsure models to follow. Several other more traditional methods of metacognition were also presented and modeled including concept maps and planning problem solving (creation of data table from problems, the use of formulas and the use of units in equation before numbers are introduced).

Throughout this process, students were asked to complete the Student Weekly Study Habit Survey at the beginning of class every Friday (Appendix C). This survey asks the student to reflect on their participation in class and the metacognition process that week, again, using Likert-style questions. It also asked the student to list their weekly study activities. The results from this survey are not only used to evaluate the participation level of students and their resulting attitudes and grades, but were also used by the students to further reflect on the process. Students were given their weekly responses after the test for that unit had been administered and graded. Students were

asked to complete an end of the unit study survey using their own data to evaluate their studying against their grade.

Classroom observations were recorded throughout this entire process by daily reflections to assess the effectiveness of the treatment and any needed changes to the presentation or re-teaching of metacognition techniques. Formative quizzes, worksheets and discussions were also used to assess the effectiveness of strategies. An online program called Plickers was used to record and track data for individual students. This program assigns each student a unique QR code style symbol, Appendix E. Each of the four sides of the code is a different letter, A, B, C, and D. The direction this code is physically held was used by students to answer a multiple-choice question. The symbol, and its directionally indicated answer choice, is scanned by the teacher with a phone or tablet allowing collection of real time data for the entire class.

Data collection was in the form of student surveys, interviews, classroom observations and comparisons between grades of students in past years on similar unit assessments. The treatment was conducted over two units of the second semester.

Data collection began at the beginning of the second semester of study. The Metacognition Pre-Survey was administered to all students in order to assess the students' base line metacognition skills and attitudes (Appendix A). Questions were scored Likert style with answers ranging from 1-strongly disagree to 4-strongly agree or 1-not very important to 4-very important. A final open selection was given to assess the students' current study techniques. This final question also allowed for students to explain any additional methods they use. The Pre-Treatment survey results were

statistically compared to the Post-Treatment Survey results to illuminate changes in student behaviors and attitudes. The open response portion was evaluated to determine trends within students' study habits. The pre-treatment portion of the Student Interview Questions were also administered (Appendix B) to the same students after the study. Their responses were used to better understand students' thoughts, feelings and self-assessments on their current metacognitive skills. Prior to the treatment, these students were asked to describe their background regarding study skills that were taught to them prior to the treatment and to describe their most used study habit currently. As an additional response, students were asked if that preferred technique changes by subject. They were asked to articulate how they felt about their current study skill level. They were also asked to explain if there is a relationship between study skills and their attitude towards a class. These responses regarding study skills will be used to evaluate and compare their metacognitive abilities before and after the treatment.

The pre- and post-tests were given in consecutive 14 instructional days which also included weekly reflection surveys and end of unit reflections surveys. The data from these surveys was statistically analyzed and use with the pre- and post- student interviews. These results will be sorted into the following categories: Metacognition Levels and Techniques (qualitative), Impact on Grades (quantitative), and Impact on Attitude (qualitative).

DATA AND ANALYSIS

The treatment group consisted of three classes of general chemistry students (N=58) while the control group consisted of one class (N=21). The treatment was

conducted over two units which span the length of an entire quarter. The first unit covered basic reactions which included writing and balancing equations, recognition of the five basic types of equations (synthesis, decomposition, combustion, single replacement and double replacement) and the predication of products for these reactions. Special emphasis was placed on the double replacement reactions that produced precipitates. Prior to the beginning of the unit, the class read through the given objectives to foreshadow what will be learned. Students took notes using the processing style notes throughout the unit. Prior to the unit test, students were asked to create a concept map of the unit with a small group. These maps were then reviewed by all students and made available for use in studying via the class website. Each week, students took the Student Weekly Study Habits Survey (Appendix C) and the End of the Unit Survey (Appendix D) to reflect on their study habits. The treatment group was presented the same material, but visual representations and reflections were not stressed. They used traditional fill-in notes and were given just as many practice opportunities as the treatment group.

The second unit consisted of an introduction to the concept of the mole. The treatment group continued to use the process style notes where applicable. This unit was almost entirely math based which did not lend itself to the process style note, but instead, the unit calculation method was used. Prior to the beginning of the unit, the class read through the given objectives to foreshadow what will be learned. It proved to be more difficult to separate the method of instruction between the treatment and control groups during this unit. The control group was initially presented material in the traditional way (not processing or using the units in calculations prior to the input of numbers) but it was

found that material needed to be presented a second or third time due to students not understanding. This second or third method was unfortunately often the treatment style. The treatment group continued to complete the Student Weekly Study Habits Survey (Appendix C) and the End of the Unit Survey (Appendix D) to reflect on their study habits.

Metacognition Levels and Techniques

Through informal classroom observations and the Metacognition Pre-Survey, it was determined that most students were unfamiliar with most of the methods taught in the treatment including the concept of planning calculations by using the units in an equation prior to using any numbers. This method was practiced repeatedly throughout the classes via group think techniques and modeling. Through informal surveying, the initial number of students using the unit equation method was approximately >10%. By the end of the second unit, once again through informal surveying, the number had risen to approximately 70%. One student (low grade, high participation) stated, "...the step-by-step and slower," method was their favorite of the methods taught during the treatment. They liked, "how everyone helps each other out...I like how we take time."

The End of the Unit Study Survey (Appendix D) allowed students to reflect on their study habits through the unit (N=58). This survey asked some opened ended questions, but most questions were Likert-style questions that students answered on a scale of four, being strongly agree, to one, being strongly disagree. Each student in the treatment group was presented with a bar graph of their ratings of the questions for all Student Weekly Study Habits Survey and their graded test. The students generally

ranked their active participation in class high (average: 3.39, 3.48, 3.5 and 3.5) while ranking their outside activities lower (average: 2.29, 2.01, 2.31, and 1.93) (Figures 1 & 2). Many students used the response section of the survey to comment on their lack of study time outside the class. Most identified this as an area they were in need of improvement.

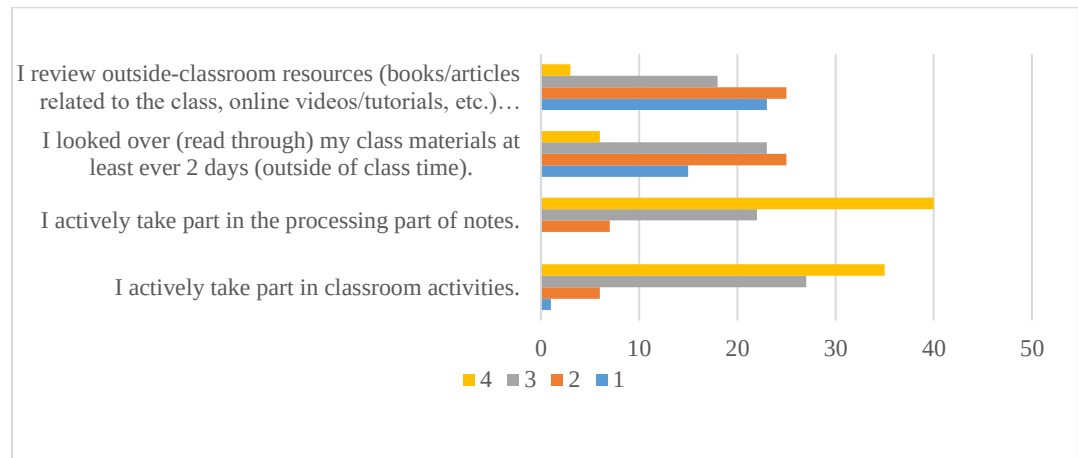


Figure 1. Unit 6 Student Self Reflection, (N=58)

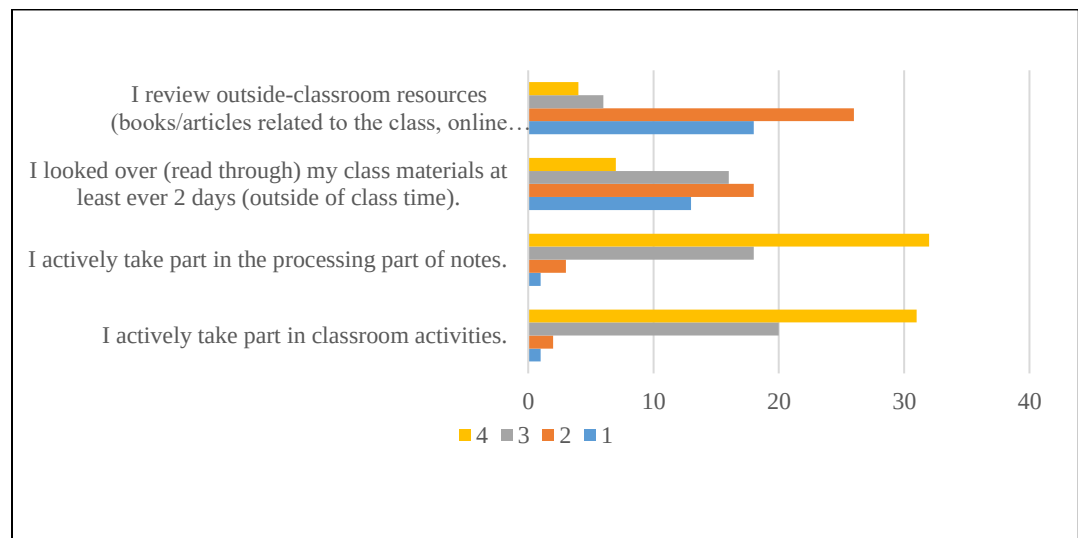


Figure 2. Unit 7 Student Self Reflection, (N= 58)

Of the students interviewed, only one of the student (low grade, low participation) reported adapting the treatment methods as their favorite or go to method of study

(Appendix A). They stated when studying a math style problem, they would, “I walk myself through how we did that,” which was one of the methods taught in the treatment. Three out of the four students felt that their study skills had improved over the course of the treatment. One student (low grade, high participation) went as far to say that they no longer simply “look over” their notes that they are now, “actually mentally participating, and thinking about it.” When asked which of the methods taught during the treatment they thought worked the best, three out of the four students stated the two-sided notes were their favorite. The high grade, low participation student liked the ability to draw a picture or write a joke to help them remember things (part of the two-sided note method); while the low scoring, low participation student thought this style was easy to read and more specific.

Impact on Grades

When the grades of the treatment (N=58), control (N=21) and previous year (N=104) groups are compared, the differences are unremarkable except when looking at the minimum scores. The previous year’s minimum scores in all three areas, Unit 6 test, Unit 7 test and 3rd quarter grades, were all decidedly lower than either the treatment or control group (Figure 3). While the figure appears to be data heavy, the trends can be seen by noting that the blue bars is the data collected from the control group, the red is from the treatment group and the green is from the group from the previous year. Though the trends are visible, using a one-way ANOVA test there were no significant results, alpha level 0.05.

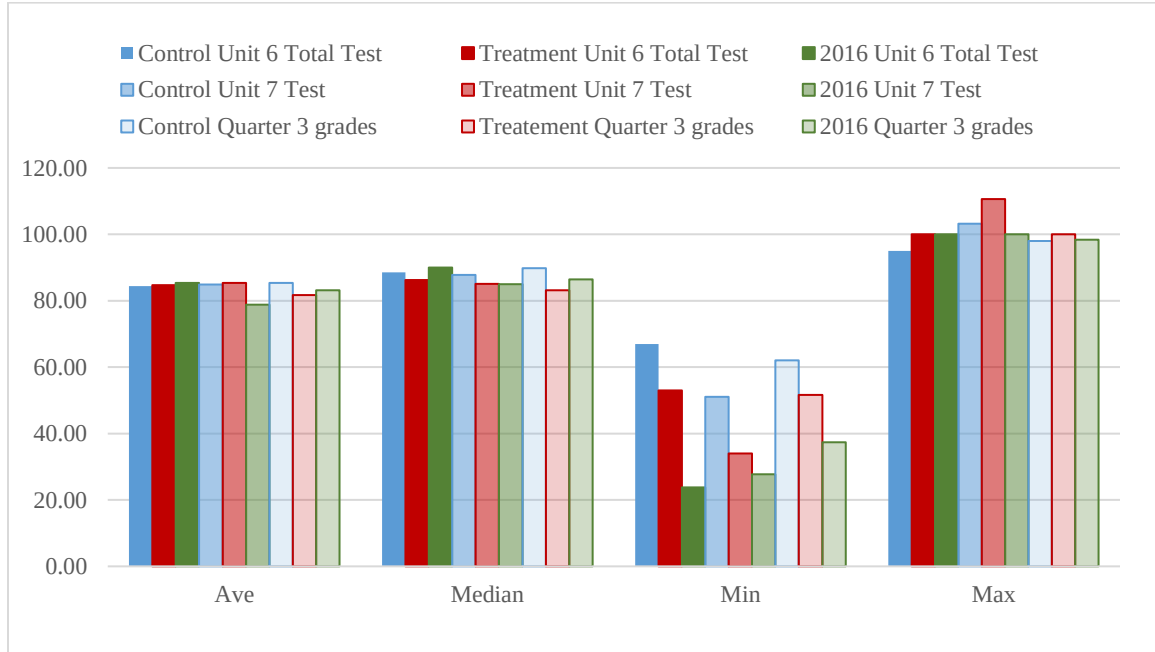


Figure 3. Summary of control, treatment and past years grades

When attention is paid to the Unit 7 Test, the introduction to the mole unit, the test averages for both the control and treatment groups are much higher than the previous year's. In Table 2, a comparison of these averages is shown. It should be noted that this unit was the unit that both groups, control and treatment, ended up getting much of the same teaching methods. Traditional methods of instruction were always used prior to the treatment methods. The level of and amount of questions from the control group, along with formative assessments (Pickers results and information observations during class), were used to determine the need to utilize the treatment method with the control group. Again, using a one-way ANOVA test there were no significant results, alpha level 0.05. This method was used as it is an effective way to determine statistical significance between three independent groups. A limitation to these results, that was not investigated, could be the effect of another year of teaching experience.

Table 2
Test Averages of Unit 7 (N=21, 58, 104)

	Control	Treatment	2016
Average	84.84	85.32	78.84

Impact on Attitude

All Students took the Metacognition Pre-Survey and Metacognition Post-Survey. The Metacognition Pre-Survey showed 86%(N=21) of the control group responded that studying was important (43%) or somewhat important (43%) to their learning. That differed from the treatment group where 76% (N=58) responded that studying was important (33%) or somewhat important (43%) to their learning. The Metacognition Post-Survey revealed little gains in both groups. The control group showed 90% (N=21) responding that studying was important (52%) or somewhat important (38%) to their learning, while the treatment group responded 81% (N=58) that studying was important (34%) or somewhat important (47%) to their learning. See Figure 4 for comparison of responses. Using a two-sample z-test of proportion (see Table 3), a small level of significance, $p=0.058$, was determined to be present between the pre- and post- responses of the control group. The sample size, $N=21$, hindered the level of significance. This style of statistical analysis was used to determine the level of similarity between two proportions.

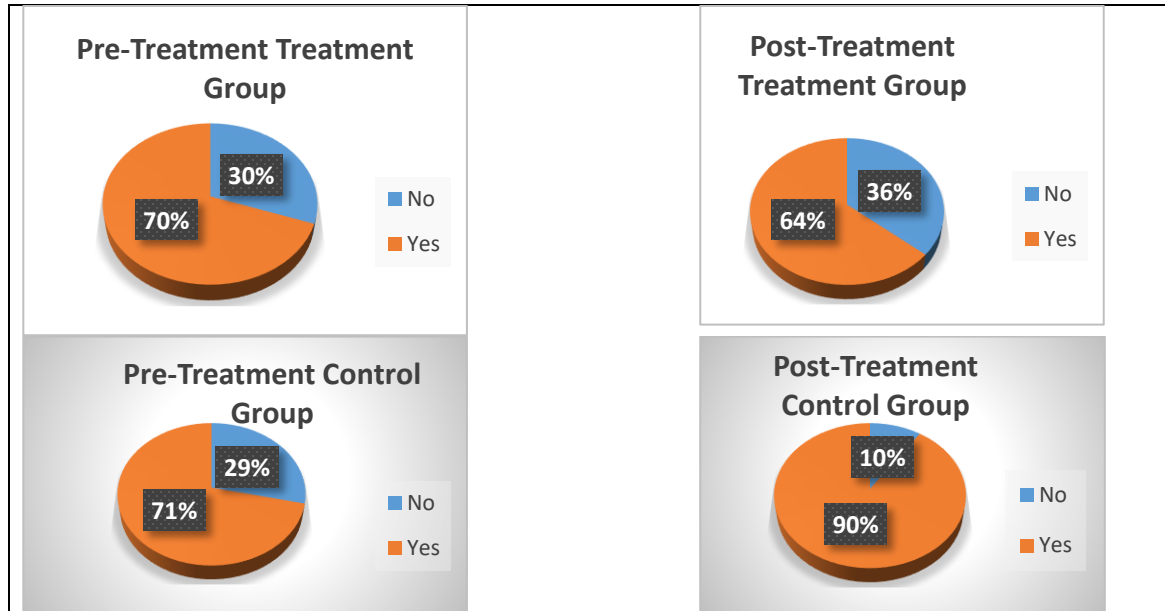


Figure 4. Pre- and post-correlation between grade and student attitude.
Student answers to “Does your grade in this class affect your attitude towards it?”

Table 3
Attitude Correlation

$N=21$ Hypothesis Test - Two population proportions: confidence level = 0.95 Samples of population 1 in C3 Pre-C Samples of population 2 in C4 Post-C Event = Yes			
	Number of Events	Number of trials	Proportion
Sample 1	15	21	0.714
Sample 2	19	21	0.905
Null hypothesis: $p_1 - p_2 = 0.0$ Alternative hypothesis: $p_1 - p_2 < 0.0$			
Significance Level	Critical Value	Test Statistic Z	p-Value
0.05	-1.645	-1.572	0.058

Prior to the treatment both groups were asked what their general attitude towards chemistry was on a scale of one, I have to take the class, to four I enjoy chemistry class and am interested in the subject. Prior to the treatment, the control group's average was 2.5 and the treatment group's average was 2.8. Both scores raised post treatment to 2.7 and 3.0 respectively. When asked prior to the treatment, specifically, if their grade affected their attitude towards chemistry class, 64% of treatment group responded yes, while 71% of the control group responded yes (Figure 1). When asked if their study skills affected their attitude, one student in the treatment group responded, "If I know something, I am confident and don't get nervous to be called on...if I don't I get frustrated. Usually if I'm frustrated, I'd don't want to learn it." The Metacognition Post-Survey revealed a stark difference between the two groups. Ninety-one percent of the

control group responded that their grade affected attitude towards chemistry while only 70% of the treatment group responded yes. This is a significant increase as the normalized gain for the treatment group is .7, which according to Hake a normalized gain score of $>.7$ is considered to be high.

INTERPRETATION AND CONCLUSION

The goal of this study was to investigate how students' metacognitive skills and techniques impact their learning. This was accomplished through the investigation of the current levels and techniques of metacognition used by the students, how the students' grades are impacted by the instruction of these techniques and how these techniques affect students' attitudes towards chemistry. The study had several difficulties which will be discussed further in this section.

Metacognition Levels and Techniques

The first portion of the investigation determined that students do not have a wide range of metacognitive skills, thus putting them at a low skill level. None of the students had ever evaluated their actions weekly, and then, looked back at those evaluations once a test had been taken. The reflection did allow students to put more ownership on their grades. This ownership is directly related to a change in attitude which will be discussed later. Most students recognized and admitted they needed to spend more time studying outside of class. This is something that they have heard teachers and adults tell them, but they now had actual data from themselves to support this need.

Impact on Grades

The second portion of the study focused on the impact metacognitive skills would

have on students' grades. Metacognitive skills were determined to directly relate to students' grades. This was most clearly shown in the second unit as traditional methods left the control group extremely confused and unsure of material. Once the treatment method was used, the control group quickly understood the material equal to or surpassing the treatment group. Both the treatment group and the control group's average score were higher than the previous year; 85.32%, 84.84%, and 78.84% respectively.

Impact on Attitude

The final portion of the study focused on changes in students' attitudes towards chemistry after learning metacognitive techniques. This was the area that provided the most intriguing data. Both groups began the study at almost the same percentage of students stating that their grade in chemistry did affect their attitude towards the class. The treatment group maintained virtually the same amount post treatment, but the control group jumped drastically to 91% stating their grade affected their attitude. Both groups, reported the same increase in general attitude towards chemistry. A correlation can be drawn between the level of metacognition skills and the ability to separate a grade from an attitude. The students in the treatment group took more ownership of their grade, as seen in the reflection surveys, and this ownership allowed them to separate their grade and their attitude. Though a dramatic increase in students' grades was not seen as Cook, Kennedy, & McGuire (2013) did in their introductory chemistry course, the lack of increase in linking their attitude in class to their grade is just as dramatic.

Study Limitations and Challenges

The methods used in the investigation are straight forward but do need more time

allotment than traditional teaching methods. It was difficult to run a control group and treatment group in parallel. While the data is the most accurate using this method, it was difficult. At one point, the control group was almost two days ahead of the treatment group. It was difficult to manage without giving the control group extra practice time, which would have affected the comparison to the treatment group. While more time is needed, the treatment group seemed to more deeply understand the material and therefore their ability to apply it to novel situations was much better. This deeper understanding can be seen in student comments such as, "I no longer just read my notes." The second unit, mathematically based, proved to be extremely difficult. The treatment method worked so much better for students that it wasn't possible ethically not to use it with the treatment group as they struggled. Rickey and Stacy's (2000) findings of the need for students to monitor their own learning in order for it to be effective was definitely supported with these findings. Based upon observations made of the control group prior to the re-teaching using the treatment methods, the students were not even realizing their own lack of understanding the material. Once the treatment methods were used, students knew the tools to use in order to evaluate their own thinking. This allowed them to ask better questions and increase their understanding.

Students truly seemed to benefit from the analysis of their own thinking and answers. As predicted, most had never physically linked their own evaluation of study habits to their test grades. This was evident in the Pre-Treatment survey responses. By enabling students a way to not only record their own evaluations of themselves, but also a method to review these evaluations, I believe students have begun to make needed

connections between their actions and outcomes within the classroom setting. This method of analysis needs to be refined for future use. It was extremely time consuming to compile the data for each individual student. A method to automate this process needs to be investigated.

The comparison of grades between groups also proved to be difficult. Without realizing it, the group that was randomly designated the control group, was a group of over half the class being extremely intelligent and above average work ethic, shown through their classroom participation and homework completion. This skewed the data, because even if they were presented material in a less effective manor, they would work twice as hard than my other classes.

Despite the stated difficulties this study proved to be beneficial to my students and myself. As the semester progressed I observed my students having more meaningful, content based discussions. They were able to assist each other using the techniques taught in class. A more efficient method of allowing students to record and evaluate their own data definitely needs to be determined, but this method proved to be extremely beneficial for student learning and growth.

VALUE

The results of this study indicated the students benefitted from learning and practicing metacognitive techniques. Though increases were slight quantitatively, the qualitative observations showed that students not only liked using the techniques, but also found value in them. Students would benefit from learning these techniques early in their scholastic careers and the continued practice throughout the tenure in high school. More

and more learning is being done on an individual level and pace, whether that be online or in the classroom. Students need to be taught how to evaluate their own thinking and skills because more and more often there is not an instructor immediately there to do it for them.

Once taught, these skills need to be practiced. The process of evaluating one's self understanding, and of looking back to compare those evaluations with grades, needs to become automatic and streamlined. In the study, this process was more of a novelty to students instead of a learned technique to be used in the future. This was evident by most students recognizing and stating that they needed to spend more time outside of class studying or review material on the first unit's reflection and then noting the same need on the second unit's survey.

If possible, a study that was expanded to an entire year would be advisable. Teaching students metacognitive techniques at the beginning of the year, and monitoring their practice and progress over a year would show more definitive correlations than this two unit study could. If possible, a study that would instruct students on techniques their freshman year and then reinforce those techniques throughout their high school careers would be the true ideal. This would allow students multiple science subjects to practice the techniques which allow students to apply techniques in novel situation, thus showing true mastery of these techniques. The time that would be required to teach and reinforce these techniques is a concession that must be made. Though this would take time away from teaching course specific content, the benefits to the students from learning these techniques outweigh the cost of the loss of content time. These techniques are life skills

that can help students throughout their scholastic lives and beyond.

I will be continuing the use and instruction of metacognition techniques in future years. I will be expanding my use of the process style notes. I will also continue to use the units plan method when teaching mathematical formulas and calculations. Students truly benefit from taking the time to plan where they are starting from and going to when doing calculations. This study has reinforced with me the need to foster understanding of a process rather than simply the use of a formula. I will also be continuing to use the group think method of doing math calculations. It is a wonderful technique that allows students to be given scaffolding without being singled out.

Teachers within my department have already taken noticed of the results seen throughout this study. The two column note method will be used in several other class this next fall due to the benefits seen during this study. As the methods for student data collection and analysis are refined, more classes can benefit from students reflecting on their own thoughts and feelings about their study habits. The techniques in this study, though they were used with the specific hope of helping chemistry students, are not content specific. This means the methods can be used in a wide variety of classes, benefiting an infinite number of students.

I am not completely satisfied with the results of this study, but I am grateful to have gone through the process. It has left me with more questions that need to be investigated and areas within my teaching I am still striving to improve.

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APPENDICES

APPENDIX A
STUDENT INTERVIEW QUESTIONS

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Pre-Treatment

Have you ever learned study skills before? If so where did you learn them and what were they?

What is your favorite/go to method to study?

How do you feel about your study skills?

Do you feel that study skills can affect your attitude in or about a class? Why or why not?

Do you study the same way for all your classes? Explain.

Post Treatment

What is your favorite/go to method to study?

How do you feel about your study skills?

Do you feel that study skills can affect your attitude in or about a class? Why or why not?

Do you feel that study skills can affect your attitude in or about a class? Why or why not?

Do you study the same way for all your classes? Explain.

What method of studying presented during this project did you find the most useful?

APPENDIX B

METACOGNITION PRE- & POST SURVEY

Metacognition

Thinking about your thinking.

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. I use graphic organizers (diagrams, ow-charts, etc.) to better understand problems. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

2. I plan out how to solve a problem before I actually start solving it. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

3. After a quiz or test, I make little or no effort to remember what I studied. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

4. If I do not know exactly how to solve a problem, I immediately try to guess the answer. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

5. How important is studying to your learning? *

1-not very important, 2-kind of important, 3-important, 4-Very important

Mark only one oval.

	1	2	3	4	
Not very important	☐	☐	☐	☐	Very important

6. **How do you feel study affects your understanding of the material presented in class ***

1-not very important, 2-kind of important, 3-important, 4-Very important

Mark only one oval.

	1	2	3	4	
Not very important	☐	☐	☐	☐	Very important

7. **How do you study? ***

Check all that apply.

Check all that apply.

- ☐ I read over my notes the night before a test or quiz.
- ☐ I read over my notes several times before a test or quiz.
- ☐ I have someone quiz me or I quiz myself
- ☐ I draw a picture of the material
- ☐ I create a graphic organizer that links concepts
- ☐ I create flash cards
- ☐ I study by doing the worksheets my teacher gives me
- ☐ I do the required assignments, but do not study beyond that
- ☐ I do none of these things

APPENDIX C

STUDENT WEEKLY STUDY HABIT SURVEY

Study Review

Thinking about your thinking.

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. I actively take part in classroom activities. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

2. I actively take part in the processing part of notes. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

3. I look over (read through) my class materials at least ever 2 days (outside of class time). *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

4. I review outside-classroom resources (books/articles related to the class, online videos/tutorials, etc.) to add to what I learn in class. *

1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree

Mark only one oval.

	1	2	3	4	
Strongly disagree	☐	☐	☐	☐	Strongly agree

5. This week I... *

Check all that apply.

Check all that apply.

- ☐ I read over my notes the night before a test or quiz.
- ☐ I read over my notes several times before a test or quiz.
- ☐ I had someone quiz me or I quiz myself
- ☐ I drew a picture of the material
- ☐ I created or used a graphic organizer that links concepts
- ☐ I created flash cards
- ☐ I did none of these things

APPENDIX D

UNIT REFLECTION SURVEY

Unit Reflection

Thinking about your thinking.

Today's Date Month, day, year

Use your bar graph of all your data from the past unit to reflect on the your learning.

Do you notice any trends in your answers? Please explain what you see. *

Do you feel that there is a relationship between how you study and your grade on the test? *

Yes

No

Is there an area of your study you feel you need to improve upon based on the data in your graphs? *

APPENDIX E
PLICKER CARD EXAMPLE

www.plickers.com

A

1

version 1

B

1

C

D

1

1

