EVALUATING THE EFFECTS OF A MODIFIED THAYER METHOD APPROACH ON
ASSESSMENT SCORES IN HIGH SCHOOL CHEMISTRY CLASSES

by

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In presenting this professional paper in partial fulfillment of the requirements for a master’s degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

Stacey L. Rhodes

July 2013
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ABSTRACT

Traditionally, students are taught using a teacher centered model. Teachers lecture the class and disperse information to all students at one time. The Thayer Method is an alternative learning model that has been used for over a century at West Point. A modified version of the Thayer Method was implemented in three Chemistry I Honors classes at Meade County High School. Students were given all notes and assignments prior to the beginning of the unit and were expected to prepare and practice the work prior to attending class. Assessment scores were compared between the three treatment classes and two non-treatment classes. In the treatment classes scores were at least nine percentage points lower on all assessments. However, student engagement increased during the implementation of this unit. The implementation of a longer study would be expected to yield more comprehensive results and I would expect, after an initial adjustment period, that assessment scores would increase.
INTRODUCTION AND BACKGROUND

Peer teaching and independent learning are ideas that have been around for decades. Both have been used in many educational settings with mixed results. Peer teaching is a technique where students become the teacher and the teacher acts as a guide for the students rather than the primary information source. One setting that has used peer teaching that fosters students who are responsible for their own learning for well over a century is at the United States Military Academy at West Point. Students in math and select science courses are primarily responsible for their own learning while their professors act as guides to their learning. Students are responsible for preparation on the topic before coming to class and are then asked to brief (present) their work to the professor and the class. All students are encouraged to ask questions of one another, as well as their professor. This description of peer teaching became my inspiration for this research project.

The Thayer Method of instruction has been used for over 200 years and began with the implementation by West Point Superintendent Colonel Sylvanus Thayer. The method was created because “A professor can deliver lectures to many more than he can thoroughly teach” (S. Thayer, October 10, 1828). Thayer saw the problem well over a century ago and desired a way to improve student learning through student participation. The solution to the aforementioned problem was to have students become responsible for their own learning and to come to class prepared to discuss and present their work to fellow classmates. Students were asked to come to class prepared, demonstrate solutions to peers and be prepared to answer questions posed by their professors (S. Thayer,
October 10, 1828). This is the way that classes are still taught at West Point today. I used the ThayerMethod as my starting point for the development of this project.

I taught at Meade County High School in Brandenburg, Kentucky. My classes were Chemistry I Honors classes that consist of 20% sophomores, 74% juniors and 6% seniors. The majority of the students are taking this class because they are college bound and have taken or were currently taking Algebra 2. Meade County High School has a population of 1671 students and is populated from all the towns that make up Meade County, Kentucky. Meade County had 26,501 people in 2009 (Meade County Demographics, 2009). Of that population, 83% of the families were rural and 17% of the families were urban. Meade County is not racially diverse, with 91% of the population being white, non-Hispanic.

Despite the fact that the majority of Meade County is rural, MCHS was ranked in the 81st percentile for the 2011-2012 school year within Kentucky. Meade County Schools were ranked in the 91st percentile within the Commonwealth of Kentucky for the same time period (Unbridled Education, 2012). Therefore, simply taking demographics into account does not provide an accurate academic picture of the school and district within which I taught. Many times the assumption is that a mainly rural school will be ranked low academically, but that was not the case with MCHS.

Assessment scores are analyzed throughout the year, with the school year divided into six chunks of instruction. At the beginning of each chunk, students are given a pre-test to assess their current knowledge base. Students are given the same test as a post-test at the end of the six-week chunk to assess learning. These scores are monitored by the
teachers, departments and administration throughout the year and are used as predictors for performance on standardized tests students will take at various points throughout their high school career. The basis for my project was to see how learning can be improved within one six-week chunk by implementing peer teaching and semi-independent learning. Students in three Chemistry I Honors classes were asked to utilize an independent study packet for each unit during the six weeks. Assessment scores were compared between three treatment classes and two non-treatment classes.

The purpose of my study was to evaluate the effectiveness of student-led activities and independent study on assessment scores. My focus questions were as follows:

1. What effect does student-led lab activities or student-led problem solving have on assessment scores?
2. What effect does independent study have on whole class engagement?
3. Do student-led activities and independent study lead to greater interest in the topic?

CONCEPTUAL FRAMEWORK

The teaching method used in math and physical science classes at the United States Military Academy at West Point is an informative example of students taking charge of their learning within a student centered classroom. The Thayer Method of instruction has been used for over 200 years and began with the implementation by Academy Superintendent Colonel Sylvanus Thayer (Sylvanus Thayer to James Monroe,
1828). The method was created because lecture is not an effective way to teach a large group of students. The solution to the aforementioned problem was to have students become responsible for their own learning and to come to class prepared to discuss and present their work to fellow classmates. Students were expected to prepare before attending class and be ready to work problems out at the blackboard to demonstrate learning and teach their peers (Sylvanus Thayer to James Monroe, 1828). This is the way that classes are still taught at West Point today.

Learning has traditionally been a passive, teacher-centered activity. While lecture can be an effective way to teach, it is not the most efficient method for engaging students and for promoting learning. Teachers have long looked for ways to encourage students to be active learners in their classrooms. Student-led discussion groups and peer-teaching are two methods teachers have used to engage students and have them begin to take responsibility for their own learning (Bloxom, et al, 1975).

The Thayer Method is one specific method that has been used with success for over two centuries. Amy E. Shell (2007) describes the Thayer Method and her experience with it, while teaching mathematics at West Point:

The philosophy of the Thayer method is that cadets are responsible for their own learning. They study the material prior to attending class. The learning is then reinforced in class through a combination of group learning and active learning exercises done primarily at the blackboards. (p. 27-28)

Professors are not expected to lecture. Students learn primarily through completing the work on their own, briefing their work to their classmates and asking questions of the
instructor. Shell describes her experiences as positive. Problems are assigned to students that will encourage discussion and collaboration to help them gain their own insight and intuition in math. Time is spent with each student, asking them questions and allowing them to question their professor. If multiple students have issues with the same topic she will give a mini-lecture to the class and if a student has an interesting perspective on a problem she will direct the class’ attention to that student’s work (Shell, 2007).

Benefits have been seen in the use of the Thayer Method. Students take more ownership of their work when they have to work it out before coming to class. Students get practice with public speaking, which is a valuable skill for anyone to have. Students are also actively engaged in their learning (Shell, 2007). These benefits can easily translate into a classroom of any age and the method can easily be adapted for use in a science classroom.

Gibson (2007), another professor at West Point, adapted the Thayer Method to his English classes with success. He found the same benefits in his use of this method, and he found that students that were struggling writers became more confident in their abilities after learning through this method (Gibson, 2007). In a biochemistry course at West Point, Steifel and Blackmann (1994) found that after using the Thayer Method, students retained more important concepts and showed more enjoyment in the class.

Organic chemistry instructors at Georgia Gwinnett College sought to improve student attitude and engagement in a course where students typically struggle with the material. Students’ learning should take place outside as well as within the classroom according to Paredes, Pennington, Pursell, Sloop and Tsoi (2010). To do this, they
employed the Thayer Method to discussion groups of less than 30 students. Students were responsible for learning the content through pre-prepared lectures, flash cards and frequent assessments. The initial results were that students had a positive attitude towards learning organic chemistry concepts and their use of the Thayer Method. Over a three year period it “has proven very successful particularly with respect to increasing student engagement and activity in the classroom” (Parades, et al., 2010, p. 193).

Peer-led collaborative group learning is yet another variation on peer teaching. Students at a tribal community college were assigned to small groups and peer leaders were assigned with specific tasks to undertake for each group discussion. Course completion rates were raised by 15% with the implementation of peer teaching. Student responses demonstrated that they felt their grades benefited when they worked with a group they could relate to. Some even stated that they had a better understanding of the material when they had to explain it to their group. Perseverance rates increased 7% throughout the course of the study, meaning that students were 7% less likely to quit or withdraw from classes. Students felt a responsibility towards group members and did not want to let them down (Hooker, 2010).

The effects of student-led demonstrations on retention rates of AP Biology students as compared to teacher-led demonstrations were evaluated in Conner’s study (2011). The results were similar to the already mentioned benefits of peer teaching. The benefits she found were that students were actively engaged in their learning and students retained knowledge for the long term and could apply it better later. However, she found that if she did not proof the student demonstrations there was incorrect information
occasionally presented to the class. This method may create more work for the teacher but allows students to take more ownership of their learning (Conner, 2011).

Student attitude has been measured and observed within active learning experiences in a high school classroom. Active learning experiences were defined as collaborative lab activities. Teachers found that these types of activities, carefully designed by teachers, led to “increased use of student-centered instructional practices as well as enhanced content knowledge and process learning for students” (Taraban, Box, Myers, Pollard, & Bowen 2007, p. 960). Test data showed that there was a significant advantage of active learning over traditional instruction. Students scored an average of 5% higher after active learning sessions. Students also preferred active learning (mean=3.61 rating) to traditional learning (mean=3.37 rating). Additionally, students had more to say about their learning after active learning was implemented than traditional learning. Students were more likely to state a lab method as something learned, as well (Taraban, et al., 2007).

A study in an undergraduate physiology course took the class and split it into six discussion groups. Three of the groups were student-led while the other three were instructor-led. Quizzes were given after each discussion section. After the implementation of three quizzes, scores in the student-led sections were significantly higher than those in the instructor-led sections. This was attributed to an increase in student mediation as well as an increase in student responses within discussion groups (Clement, 1971).
Time and again, researchers, teachers and professors have found that engaging students in their learning and allowing them to take responsibility for their learning has led to increases in student retention of knowledge, better performance on exams, more ownership of their own learning and more confidence in the classroom. Student-led assignments, classrooms and discussions can be beneficial to the students but may require more preparation by the teacher. Teachers may need to proof, clarify, correct or expand upon student presentations. The confidence and feeling of responsibility a student may feel supports that these methods are well worth the extra effort put in by their teachers.

METHODOLOGY

The treatment took place over the course of one six week chunk and five Honors Chemistry I classes. The school year at MCHS is divided into six chunks. Chunks are sections of academic content within which all teachers of a given subject teach the same units of content. At the beginning of each six-week chunk, students are given a pre-test to assess knowledge moving into the academic chunk. After the six weeks of instruction, students are given the same test as a post-test to assess learning throughout the six-week chunk. Treatment classes were my three Honors Chemistry I classes ($n = 79$). The non-treatment classes were two Honors Chemistry I classes taught by another chemistry teacher ($n=44$). All Honors Chemistry I teachers teach the same content each day and work cooperatively to ensure that all Honors Chemistry I classes are doing the same work at the same time. 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.

Students completed the Pre-Treatment Opinion Survey on learning from their peers, working semi-independently and student-led problem solving sessions (Appendix A). The survey utilized a Likert Scale of 1 = Not At All to 5 = Very Much. Students also indicated their typical grade average on a test or quiz and what they expected their grade average would be after this new unit using the following grading scale: F 0-64 D 65-74 C 75-84 B 85-93 A 94-100. Finally, students were asked to write their thoughts about the independent study packet and how it might affect their test scores.

Data from the Pre-Treatment Opinion Survey was averaged and the mean was reported graphically. The Post-Treatment Opinion Survey (Appendix I) was implemented at the conclusion of the study and was designed as a follow up for the Pre-Treatment Opinion Survey. The questions were similar in scope and were scored on the same Likert Scale. The averages for each question were compared at the conclusion of the study to determine any overall differences in student opinion about the independent study unit.

The non-treatment classes did not involve student led problem solving sessions or an independent study packet. The non-treatment classes were taught using traditional teacher lecture as the primary means of instruction. The treatment classes involved student led problem solving sessions in addition to the implementation of an independent study packet. The chunk was designed to be a modified version of the Thayer Method and applied to high school students.
The treatment classes were given the notes at the beginning of the unit and were instructed to come to class prepared to complete work with minimal teacher-centered instruction. The packet also included all worksheets and problems students were assigned to complete during the unit. As students completed each assignment, I checked answers with the students to ensure everyone was completing the work correctly. All student work was collected at the completion of the unit and was given a grade for completion. The non-treatment classes were given the same assignments, activities, quizzes and tests as the treatment classes.

During the chunk, there were two units, Chemical Reactions and Stoichiometry. I prepared a packet that included a timeline with due dates for every assignment, notes for every section and at least one practice sheet for each section. Each day I told the students what they were expected to read (pertinent notes or worksheet) and to come to class prepared. I did not lecture the full class during this unit, with the exception of two times when the majority of the class did not understand the concept. I utilized a modified Thayer Method where students were expected to come to class having read the notes and attempted the worksheet. Students then began working on the worksheet during class with a partner or small group of no more than four students. The groups were of the students’ individual choosing and stayed the same throughout the unit. Students were not required to present their work to the class.

I monitored learning through observation, answered individual questions and addressed the whole class if I noticed an issue that many students were having with the work. I kept track of these observations as part of my journal throughout the treatment.
Many times I would help one group and a student from that group would turn to a group nearby and help other students to understand the concept if there was confusion.

During the chemical reactions unit there were two group inquiry activities. Students were asked to read through the activity before class and when they came to class, they were assigned a random group of students to work with. Observations were made during this process and recorded in my journal. Students were expected to teach one another how to complete the activity and there was no introduction or lecture to accompany the activity. Student progress was monitored through my journaling and through the final product of each activity (poster, flow chart, instruction manual, or drawings). During the stoichiometry unit there was one lab activity: Stoichiometric Analysis of a Powder and Acid (Appendix F). Students began the lab with minimal instruction and were expected to work from the instructions provided. Students wrote lab reports summarizing the lab and data; scores were used as a piece of the quantitative data using Stoichiometric Analysis of a Powder and Acid Rubric (Appendix G). Student scores were compiled and averaged together to compare the treatment and non-treatment classes. Score percentages were recorded and reported in the data and analysis section.

The final piece of quantitative data that I used was test scores. I used these to determine overall learning and to compare non-treatment classes to treatment classes with quantitative data. Average scores were recorded for treatment and non-treatment classes and results were recorded as percentages. Interim Assessment 5 was given at the beginning of the chunk as a pre-test, with the same test being given as a post-test at the conclusion of the same chunk (Appendix H). Two quizzes were given as a part of the
chemical reactions unit: Balancing Quiz and Balancing and Identifying Quiz (Appendices B and C). A Chemical Reactions Test was given at the end of the Chemical Reactions unit as well (Appendix D). Student scores for all assessments were averaged into two groups and percentages were compared between the treatment and non-treatment classes using the following grading scale: F 0-64 D 65-74 C 75-84 B 85-93 A 94-100.

After the Chemical Reactions Test, I surveyed students in the treatment classes who were willing to participate in the Mid-Treatment Survey about their feelings during the unit (Appendix E). The Mid-Treatment Survey included only open-ended questions regarding student opinions. At the end of the chunk I had students in the treatment classes complete the Post-Treatment Survey about their opinions and attitudes towards their learning during the unit (Appendix I). I also had the students rate their engagement during the unit. The survey used the same Likert Scale from 1-5, where 1 = Not At All and 5 = Very Much. As a part of the Post-Treatment Survey, students were also asked to report their typical test and quiz average using the grading scale (F 0-64 D 65-74 C 75-84 B 85-93 A 94-100) and the grade average they expected to earn on the Interim Assessment 5. Students were also asked to write their thoughts on the past 6 weeks including opinions on the independent study packets and whether they would change anything about the unit. Data from individual surveys were collected and averaged together by question. This data was compared to the Pre-Treatment Opinion Survey data. All data is reported in the data and analysis section of this paper.

A teacher journal was kept during the unit to write down observations regarding engagement during classes and to write down student quotes about the unit, either
overheard or told directly to myself. Within the journal I kept notes regarding my thoughts on the treatment and student engagement. Much of the student engagement was noted during the journaling and student interviews. Data was collected according to the following Data Triangulation Matrix (Table 1).

Table 1

Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Source</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>What effect does student led lab activities or student led problem solving have on assessment scores?</td>
<td>Comparison of Pre- and Post-Interim Assessment Scores</td>
<td>Balancing Quiz, Identifying and Balancing Quiz, Chemical Reactions Test</td>
<td>Stoichiometric Analysis of a Powder and Acid Lab and Rubric</td>
<td></td>
</tr>
<tr>
<td>What effect does student led discussions/problem solving have on whole class engagement?</td>
<td>Teacher journals/notes</td>
<td>Mid-Treatment Opinion Survey</td>
<td>Pre- and Post-Treatment Opinion Surveys</td>
<td></td>
</tr>
<tr>
<td>Does this lead to greater interest in the topic?</td>
<td>Pre-Treatment Opinion Survey, Post-Treatment Opinion Survey</td>
<td>Mid-Treatment Opinion Survey</td>
<td>Teacher Journaling</td>
<td></td>
</tr>
</tbody>
</table>

DATA AND ANALYSIS

Prior to the start of the chunk, students were given the Pre-Treatment Opinion Survey (Appendix A) Student opinion was high (4.58/5, 5 = very much) regarding whether they would work with their classmates ($N = 72$). Overall, response was positive
to beginning the unit with independent study packets and working with other students to learn the material. Students felt their test scores would improve (3.08/5) and they showed that they liked the idea of the independent study packet (3.10/5) (Figure 1).

![Survey Topics](image)

*Figure 1.* Student opinion prior to implementation of independent study, \((N = 72)\). Likert Scale of 1 (Not At All) to 5 (Very Much).

Students were asked how they thought this independent study unit would affect their test scores (Figure 2). Students also indicated the same opinion in response to the open ended statement *Write your thoughts about the semi-independent study packet and how it might affect your test scores.* Student responses included statements such as “I like the packet. It requires responsibility and self-discipline,” “I believe it will help my test scores tremendously,” “Might help somewhat so I can actually learn the work,” and “I
will be able to learn the stuff before class.” There were students with reservations about
the new unit as well, “I am afraid my grade will decrease,” “I don’t think it will help,”
and “I don’t think I will like it, I probably won’t read notes beforehand.”

Student assessment averages were compared prior to treatment and after treatment.
On the Pre-Treatment Opinion Survey (Appendix A) students were asked to mark their
expected scores during the unit. The expected scores were compared to the scores prior to
and following the treatment unit. Students’ assessment averages increased after treatment,
60% of students completed the unit with either an A or a B, with the remaining 40% of
students earning a grade of C or lower. Prior to treatment, 49% of students were earning
an A or B on tests and quizzes (Figure 2).

![Figure 2. Student grades prior to and following treatment, (N = 70). Grading scale is A
(100-94) B (93-84) C (83-75) D (74-65) F (64-0).]
After the chemical reactions unit all test and quiz scores were averaged for treatment and non-treatment classes separately. Percentages were used to compare the two groups of classes. All assessment scores were lower in the treatment classes than in the non-treatment classes (Figure 3).

![Figure 3. Unit quiz and test scores, (N = 44 and N = 79).](image)

Students were asked to participate in the Mid-Treatment Survey (Appendix E). When asked *What do you think of learning with the independent study packet?* a student said, “I thought the packet was very useful and planned out very well.” Another student said, “It made me feel like I had to work a lot and it gave me a lot of practice on what we were working on.” When asked *How do you feel that working more independently will affect your test grade?* students tended to reply similarly to the following “I feel it will help because I was responsible for the work I did and what I learned.” When asked what learning method they preferred student responses varied greatly between, “The independent study packet, with our work and notes handed to us it makes it feel easier”
and “Traditional lecture, I learn better that way, getting to see it all worked out.” At the midway point in the treatment, response to the independent study packet was still very positive.

On the first day after the packet was handed out, only 9% of all students had read the assignment before they came to class. As the treatment progressed, I began to notice more and more students coming to class prepared, towards the end of treatment I polled one class and 71% of the students in class had prepared prior to coming to class. Some comments I heard during classes throughout the treatment were “I wasn’t sure about this, but I really like it” and “I’m actually doing really well. I’ve gotten As on my quizzes and normally I don’t.”

During the stoichiometry unit, students were given the Stoichiometric Analysis of a Powder and Acid (Appendix F) and completed the lab with minimal teacher instruction. Lab reports were graded using the Stoichiometric Analysis of a Powder and Acid Rubric (Appendix G). The treatment classes showed an average of 75% on their lab reports while the non-treatment classes had an average of 91% on their lab reports.

After the students took the Interim Assessment 5 (Appendix H), pre-test and post-test scores were compared. Both treatment and non-treatment classes showed similar pre-test score averages, 26% and 24%. However, the post-test scores showed a very different result, consistent with previously reported test scores. The treatment classes (N = 79) scored an average of 60% on the test, while the non-treatment classes (N = 44) scored an average of 70% on the test.
The quantitative data show clearly that the implementation of a modified Thayer Method in my Chemistry I classes was not successful as compared to the non-treatment class. Looking at Figure 2, scores for the treatment classes did increase after treatment, even though they were lower, overall, than the non-treatment classes. This leads to the conclusion that the non-treatment classes were potentially higher achieving classes than the treatment classes. The non-treatment classes were, on average, 10 students less per class than the treatment classes. The difference between a class of 21 students and a class of 29 could account for some difference in the assessment results.

The Mid-Treatment and Post-Treatment Opinion Surveys show that many students enjoyed learning with this non-traditional method and felt they would benefit from it, if the implementation were continued throughout the year. After the completion of the unit, one student commented to me, “I miss those packets. I really liked knowing what we were going to be working on and being able to work ahead or know what I missed without having to ask you.”

The modified Thayer Method that I implemented did lead to increased assessment scores for the treatment classes (Figure 2). However, compared to the non-treatment classes, the treatment classes had lower overall averages (Figure 3). Scores for each assessment were at least nine percentage points lower for the treatment classes versus the non-treatment classes. The results for Interim Assessment 5 were similar, with the difference being a 10% reduction between classes. This data demonstrates that
implementation of a modified Thayer Method for a short term (six week) unit did not increase assessment scores beyond traditionally taught classes. The decrease in assessment scores indicates that this modified Thayer Method is not useful for shortened units of instruction.

The quantitative data do not completely agree with the qualitative data and personal observations. I found this to be interesting. I overheard positive comments from students throughout the unit such as, “These packets are the best thing to happen in here. I love them.” This led me to believe that this method can be a successful method when implemented long term. Based upon the mostly positive responses from students, I believe that this trial was too short.

A study that took place in a college organic chemistry course over the course of three years found that using a similar method increased student engagement in the classroom (Parades, et al., 2010). In a similar study within a biochemistry course at West Point, students retained important concepts more readily (Steifel and Blackmann, 1994). In both cases, the method was implemented throughout the entire course, rather than one unit. Another study showed a 5% increase in test scores throughout a high school biology class when active learning (not teacher centered) was implemented (Taraban, et al., 2007).

Based upon the aforementioned studies, if this method were used for an entire school year, I believe that assessment scores would improve overall. There was a steep learning curve for students, at the beginning of this unit. Students are accustomed to being given all of the information they are expected to know from a teacher, through
lecture. Students would acclimate to the independent study method over time and improved assessment scores would result.

VALUE AND CLAIMS

This study was quite valuable to me because I saw more engagement in my chemistry classes throughout this unit. I also observed some students struggling to understand the work and I would take the time to explain to a small group or the whole class, when necessary. One of my favorite observations throughout this unit was watching the struggling students asking other students for help or watching the students who understood the content volunteering their help to struggling students. I observed more students working together in small groups learning the material together.

In moving forward, I would like to implement this as a long term study to take place for an entire school year. I would also utilize the textbook more. Currently in Chemistry I classes, the textbook is rarely referenced or used. I believe that having that reference for students to read, while learning this way, would be more valuable than teacher created notes. The combination of both resources would be much more useful for students.

I did observe some student growth throughout the unit and was very proud of the students I saw working together to solve problems. Students who typically would not have been engaged in my chemistry classes worked very hard and put in more effort than I had seen them do prior to this unit. I believe that these students became dependent upon
teachers giving out information, and they were no longer trying to discover it and understand it themselves. I have observed some positive changes in my classes since the implementation of this study.

I enjoyed watching students teach each other the material. That experience was invaluable to them and I believe that they work more effectively in cooperative groups. I believe the biggest issue with this study is the fact that it only lasted for six weeks. Had the study lasted longer, I believe students would have seen an improvement in their assessment scores and course grades overall.

Throughout this action research process I have learned how to reflect on my teaching practices and how to improve them. I now know that I should try new strategies to help my students learn and to improve their assessment scores. I can see that a longer trial period is more beneficial, overall, to determine if a new practice is going to be effective. I would like to carry out this action research over an entire school year, with a course designed around this project. Even though the results of this research were not what I was expecting or hoping for, I am not discouraged. I will continue working with my colleagues and trying new things to help my students.
REFERENCES CITED


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APPENDICES
APPENDIX A

PRE-TREATMENT OPINION SURVEY
This survey is about your thoughts on the new semi-independent study method we are using for the next two units. Your participation in this survey is voluntary.

<table>
<thead>
<tr>
<th>Question</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will you spend your time before class reading the notes in the packet?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>Will you attempt the worksheets before coming to class?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>Will you work with your classmates to complete the assignments?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How comfortable would you be teaching your classmates, in a small group, how to do an assignment?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How often do you think you’d pay attention to Mrs. Rhodes’ lecture if you’ve read the notes before class?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How much will having the notes and assignments beforehand help you?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
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<tr>
<td>How do you feel your test scores will improve after using this packet for an entire unit?</td>
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<td>Somewhat</td>
<td>Undecided</td>
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<td>How do you like the idea of using this semi-independent study packet to learn chemistry?</td>
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<td>Undecided</td>
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What grade average do you typically earn on your chemistry tests and quizzes?

F (0-64)  D (65-74)  C (75-84)  B (85-93)  A (94-100)

What grade average do you expect to earn on your chemistry tests and quizzes during this unit?
Write your thoughts about the semi-independent study packet and how it might affect your test scores:
APPENDIX B

BALANCING EQUATIONS QUIZ
Balancing Equations Quiz

1. _____ Li + _____ N₂ \rightarrow _____ Li₃N
2. _____ NH₃ + _____ H₂S \rightarrow _____ (NH₄)₂S
3. _____ P₇(NO₃)₂ + _____ Na₂CrO₄ \rightarrow _____ NaNO₃ + _____ PbCrO₄
4. _____ Fe + _____ H₂SO₄ \rightarrow _____ Fe₂(SO₄)₃ + _____ H₂
5. _____ Al₂(SO₄)₃ + _____ Ca(OH)₂ \rightarrow _____ Al(OH)₃ + _____ CaSO₄
6. _____ Al + _____ CuSO₄ \rightarrow _____ Al₂(SO₄)₃ + _____ Cu
7. _____ MnO₂ + _____ HCl \rightarrow _____ MnCl₂ + _____ H₂O + _____ Cl₂
8. _____ Cs₂ + _____ Cl₂ \rightarrow _____ CCl₄ + _____ S₂Cl₂
9. _____ H₂S + _____ PbCl₂ \rightarrow _____ HCl + _____ PbS
10. _____ Li + _____ N₂O \rightarrow _____ LiOH + _____ H₂
APPENDIX C

IDENTIFYING AND BALANCING EQUATIONS QUIZ
Balancing and Identifying Equations Quiz

1. When the equation $\text{KClO}_3 \rightarrow \text{KCl} + \text{O}_2$ is balanced, the coefficient of $\text{KClO}_3$ is ____.

2. The equation $\text{H}_3\text{PO}_4 + 3\text{KOH} \rightarrow \text{K}_3\text{PO}_4 + 3\text{H}_2\text{O}$ is an example of which type of reaction? _____________________________

3. What are the missing coefficients for the skeleton equation below?
$$\text{Al}_2(\text{SO}_4)_3 + \_\_ \text{KOH} \rightarrow \text{Al(OH)}_3 + \text{K}_2\text{SO}_4$$

4. What are the coefficients that will balance the skeleton equation below?
$$\_\_ \text{N}_2 + \_\_ \text{H}_2 \rightarrow \_\_ \text{NH}_3$$

5. The equation $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$ is an example of which type of reaction?
_________________________________

6. What are the missing coefficients for the skeleton equation below?
$$\_\_ \text{Cr} + \_\_ \text{Fe(NO}_3)_2 \rightarrow \_\_ \text{Fe} + \_\_ \text{Cr(NO}_3)_3$$

7. The equation $2\text{C}_3\text{H}_7\text{OH} + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 8\text{H}_2\text{O}$ is an example of which type of reaction? _____________________________

8. When the following equation is balanced, what is the coefficient for $\text{HCl}$? ____
$$\text{Mg} + \text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$$

9. When the equation $\text{Fe} + \text{Cl}_2 \rightarrow \text{FeCl}_3$ is balanced, what is the coefficient for $\text{Cl}_2$? ____
APPENDIX D

CHEMICAL REACTIONS TEST
Chemical Reactions Test

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. In the chemical equation $\text{H}_2\text{O}_2(aq) \rightarrow \text{H}_2\text{O}(l) + \text{O}_2(g)$, the $\text{O}_2$ is a ____.
   a. catalyst  
   b. solid  
   c. product  
   d. reactant

____ 2. Which of the following is the correct skeleton equation for the reaction that takes place when solid phosphorus combines with oxygen gas to form diphosphorus pentoxide?
   a. $\text{P}(s) + \text{O}_2(g) \rightarrow \text{PO}_2(g)$
   b. $\text{P}(s) + \text{O}(g) \rightarrow \text{P}_2\text{O}_2(g)$
   c. $\text{P}(s) + \text{O}_2(g) \rightarrow \text{P}_2\text{O}_5(s)$
   d. $\text{P}_2\text{O}_5(s) \rightarrow \text{P}_2(s) + \text{O}_2(g)$

____ 3. If you rewrite the following word equation as a balanced chemical equation, what will the coefficient and symbol for fluorine be?
   nitrogen trifluoride $\rightarrow$ nitrogen + fluorine
   a. $6\text{F}_2$  
   b. $\text{F}_3$  
   c. $6\text{F}$  
   d. $3\text{F}_2$

____ 4. What are the coefficients that will balance the skeleton equation below?
   $\text{AlCl}_3 + \text{NaOH} \rightarrow \text{Al(OH)}_3 + \text{NaCl}$
   a. 1, 3, 1, 3  
   b. 3, 1, 3, 1  
   c. 1, 1, 1, 3  
   d. 1, 3, 3, 1

____ 5. What are the coefficients that will balance the skeleton equation below?
   $\text{N}_2 + \text{H}_2 \rightarrow \text{NH}_3$
   a. 1, 1, 2  
   b. 1, 3, 3  
   c. 3, 1, 2  
   d. 1, 3, 2

____ 6. When the equation $\text{Fe} + \text{Cl}_2 \rightarrow \text{FeCl}_3$ is balanced, what is the coefficient for $\text{Cl}_2$?
   a. 1  
   b. 2  
   c. 3  
   d. 4

____ 7. When the following equation is balanced, what is the coefficient for $\text{HCl}$?
   $\text{Mg}(s) + \text{HCl}(aq) \rightarrow \text{MgCl}_2(aq) + \text{H}_2(g)$
   a. 6  
   b. 3  
   c. 1  
   d. 2

____ 8. Which of the following statements is NOT true about what happens in all chemical reactions?
   a. The ways in which atoms are joined together are changed.
   b. New atoms are formed as products.
c. The starting substances are called reactants.
d. The bonds of the reactants are broken and new bonds of the products are formed.

9. Chemical equations must be balanced to satisfy ____.
   a. the law of definite proportions    c. the law of conservation of mass
   b. the law of multiple proportions    d. Avogadro’s principle

10. When the equation $\text{KClO}_3(s) \rightarrow \text{KCl(s)} + \text{O}_2(g)$ is balanced, the coefficient of $\text{KClO}_3$ is ____.
   a. 1  c. 3
   b. 2  d. 4

11. What are the missing coefficients for the skeleton equation below?
   $\text{Cr(s)} + \text{Fe(NO}_3)_2(aq) \rightarrow \text{Fe(s)} + \text{Cr(NO}_3)_3(aq)$
   a. 4, 6, 6, 2  c. 2, 3, 3, 2
   b. 2, 3, 2, 3  d. 1, 3, 3, 1

12. What are the missing coefficients for the skeleton equation below?
   $\text{Al}_2(\text{SO}_4)_3(aq) + \text{KOH(aq)} \rightarrow \text{Al(OH)}_3(aq) + \text{K}_2\text{SO}_4(aq)$
   a. 1, 3, 2, 3  c. 4, 6, 2, 3
   b. 2, 12, 4, 6  d. 1, 6, 2, 3

13. When potassium hydroxide and barium chloride react, potassium chloride and barium hydroxide are formed. The balanced equation for this reaction is ____.
   a. $\text{KOH} + \text{BaCl} \rightarrow \text{KCl} + \text{BaOH}$  c. $2\text{KOH} + \text{BaCl}_2 \rightarrow 2\text{KCl} + \text{Ba(OH)}_2$
   b. $\text{KOH} + \text{BaCl} \rightarrow \text{KCl} + \text{BaOH}$  d. $\text{KOH} + \text{BaCl}_2 \rightarrow \text{KCl}_2 + \text{BaOH}$

14. In order for the reaction $2\text{Al} + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$ to occur, which of the following must be true?
   a. Al must be above Cl on the activity series.
   b. Al must be above H on the activity series.
   c. Heat must be supplied for the reaction.
   d. A precipitate must be formed.

15. In a combustion reaction, one of the reactants is ____.
   a. hydrogen  c. oxygen
   b. nitrogen  d. a metal

16. The type of reaction that takes place when one element reacts with a compound to form a new compound and a different element is a ____.
   a. synthesis reaction  c. single-replacement reaction
   b. decomposition reaction  d. double-replacement reaction
17. In a double-replacement reaction, the _____.
   a. products are always molecular
   b. reactants are two ionic compounds
   c. reactants are two elements
   d. products are a new element and a new compound

18. Which of the following is a balanced equation representing the decomposition of lead(IV) oxide?
   a. PbO₂ → Pb + 2O
   b. PbO₂ → Pb + O₂
   c. Pb₂O → 2Pb + O
   d. PbO → Pb + O₂

19. What are the correct formulas and coefficients for the products of the following double-replacement reaction?
   RbOH + H₃PO₄ →
   a. Rb(PO₄)₃ + H₂O
   b. RbPO₄ + 2H₂O
   c. Rb₃PO₄ + 3H₂O
   d. H₃Rb + PO₄OH

20. Which of the following statements is true about single-replacement reactions?
   a. They are restricted to metals.
   b. They involve a single product.
   c. Two reactants produce two products.
   d. Any metal replaces any other metal.

21. Use the activity series of metals to complete a balanced chemical equation for the following single replacement reaction.
   Ag(s) + KNO₃(aq) →
   a. AgNO₃ + K
   b. AgK + NO₃
   c. AgKNO₃
   d. No reaction takes place because silver is less reactive than potassium.

22. A double-replacement reaction takes place when aqueous Na₂CO₃ reacts with aqueous Sn(NO₃)₂. You would expect one of the products of this reaction to be _____.
   a. NaNO₃
   b. NaSn
   c. Sn(NO₃)₂
   d. CNO₃

23. The complete combustion of which of the following substances produces carbon dioxide and water?
   a. C₈H₁₈
   b. K₂CO₃
   c. CaHCO₃
   d. NO

24. The reaction 2Fe + 3Cl₂ → 2FeCl₃ is an example of which type of reaction?
   a. combustion reaction
   b. single-replacement reaction
   c. synthesis reaction
   d. decomposition reaction
25. The equation Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g) is an example of which type of reaction?
   a. synthesis reaction     c. decomposition reaction
   b. single-replacement reaction   d. double-replacement reaction

26. The equation H_3PO_4 + 3KOH \rightarrow K_3PO_4 + 3H_2O is an example of which type of reaction?
   a. double-replacement reaction   c. decomposition reaction
   b. synthesis reaction         d. single-replacement reaction

27. The equation 2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O is an example of which type of reaction?
   a. combustion reaction           c. double-replacement reaction
   b. single-replacement reaction       d. decomposition reaction

28. A double-replacement reaction takes place when aqueous cobalt(III) chloride reacts with aqueous lithium hydroxide. One of the products of this reaction is ____.
   a. Co(OH)_3     c. LiCo_3
   b. Co(OH)_2     d. LiCl_3

29. If a combination reaction takes place between rubidium and bromine, the chemical formula for the product is ____.
   a. RuBr     c. RbBr_2
   b. Rb_2Br   d. RbBr

30. What is the balanced chemical equation for the reaction that takes place between bromine and sodium iodide?
   a. Br_2 + NaI \rightarrow NaBr_2 + I   c. Br + NaI_2 \rightarrow NaBrI_2
   b. Br_2 + 2NaI \rightarrow 2NaBr + I_2     d. Br + NaI_2 \rightarrow NaBr + I_2
APPENDIX E

MID-TREATMENT OPINION SURVEY
Your participation in this survey is voluntary. Your responses will be kept anonymous and will not affect your grade in this class. Please answer with as much detail as you are comfortable sharing.

1. What do you think of learning with the independent study packet?

2. What would you do differently with another packet?

3. How do you feel that working more independently will affect your test grade?

4. Did you work with your peers more during this unit? Do you feel that it was helpful? Explain

5. Did you help your peers to understand the material? Did any of your peers help you?


7. Add any additional thoughts about this past unit (things you liked, things you would change, etc).
APPENDIX F

STOICHIOMETRIC ANALYSIS OF A POWDER AND ACID LAB
Stoichiometric Analysis of a Powder and an Acid

Introduction: We have all seen what happens when baking soda is mixed with vinegar… lots of fizzing and bubbling. What’s causing the bubbling? Can we measure the amount of gas produced? The equation below shows the chemicals that react when we mix baking soda and vinegar:

\[ \text{NaHCO}_3 (s) + \text{HC}_2\text{H}_3\text{O}_2 (l) \rightarrow \text{NaC}_2\text{H}_3\text{O}_2 (aq) + \text{H}_2\text{O} (l) + \text{CO}_2 (g) \]

Procedure:
1. Measure the mass of an empty cup and record in the data table (A).
2. Mass out between 1-3 grams of baking soda and record the exact mass in the data table (B).
3. Mass out between 20-50 grams of vinegar and record the exact mass in the data table (C).
4. Place your baking soda and vinegar in the cup and allow the reaction to proceed.
5. Once most of the bubbling has stopped, mass the cup and contents and record in the data table (D).
6. Calculate the mass of gas lost \( E = (A+B+C) - D \) and place it in the data table (E).
7. Send someone from the group up to the computer to input your mass of baking soda (B) and mass of gas lost (E) in the spreadsheet.
8. Record the class data.

Data Table

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<th>Mass of Empty Cup</th>
<th>Mass of Baking Soda</th>
<th>Mass of Vinegar</th>
<th>Mass of cup and contents</th>
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Analysis and Calculations
1. Make a best fit line graph of the mass of gas lost (y) and the mass of baking soda used (x) using the class data.
2. Mark your data point on the graph.
3. Was your data point good? Explain why or why not
4. If you used 3.5 g of powder, how many g of gas would be lost?
5. If you wanted 3.5 g of gas, how many g of solid should be used?
6. How many grams of gas should you have lost for your point to be perfect?
APPENDIX G

STOICHIOMETRIC ANALYSIS OF A POWDER AND ACID RUBRIC
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APPENDIX H

INTERIM ASSESSMENT 5
IA5: Reactions
Chemistry I Honors

1. At 25°C, germanium (II) chloride (GeCl₂), rapidly reacts with chlorine (Cl₂) to produce germanium (IV) chloride (GeCl₄).
   \[
   \text{GeCl}_2 + \text{Cl}_2 \rightarrow \text{GeCl}_4
   \]
   According to the law of conservation of mass, which statement correctly describes this reaction?
   a. The sum of the masses of GeCl₂ and Cl₂ equals the mass of GeCl₄.
   b. The sum of the masses of Cl₂ and GeCl₄ equals the mass of GeCl₂.
   c. The mass of GeCl₂ is greater than the mass of GeCl₄.
   d. The mass of Cl₂ is greater than the mass of GeCl₄.

2. Fluorine gas reacts with aqueous iron (II) iodide to produce aqueous iron (II) fluoride and iodine liquid. What is the balanced chemical equation for this reaction?
   a. \( \text{F}_2 (g) + \text{FeI}_2 (aq) \rightarrow \text{FeF}_2 (aq) + \text{I}_2 (l) \)
   b. \( \text{F}_2 (g) + 2 \text{FeI}_2 (aq) \rightarrow 2 \text{FeF}_2 (aq) + \text{I}_2 (l) \)
   c. \( 2 \text{F} (g) + \text{FeI}_2 (aq) \rightarrow \text{FeF}_2 (aq) + 2 \text{I} (l) \)
   d. \( \text{F} (g) + \text{FeI}_2 (aq) \rightarrow \text{FeF}_2 (aq) + \text{I} (l) \)

3. At high temperatures, nitrogen (N₂) reacts with magnesium (Mg) to produce magnesium nitride (Mg₃N₂).
   \[
   \text{N}_2 (g) + 3 \text{Mg} (s) \rightarrow \text{Mg}_3\text{N}_2 (s)
   \]
   Which statement accurately describes the information represented by this balanced chemical equation?
   a. 1 atom of N₂ reacts with 3 atoms of Mg to produce 1 atom of Mg₃N₂.
   b. 1 formula unit of N₂ reacts with 3 formula units of Mg to produce 1 formula unit of Mg₃N₂.
   c. 1 mole of N₂ reacts with 3 moles of Mg to produce 1 mole of Mg₃N₂.
   d. 1 molecule of N₂ reacts with 3 molecules of Mg to produce 1 molecule of Mg₃N₂.

4. At room temperature, sodium (Na) reacts with sulfur hexafluoride (SF₆) to produce sodium sulfide (Na₂S) with sodium fluoride (NaF).
   \[
   8 \text{Na} (s) + \text{SF}_6 (g) \rightarrow \text{Na}_2\text{S} (s) + 6 \text{NaF} (s)
   \]
   Which statement correctly describes the information provided by this balanced chemical equation?
   a. The products have a larger mass than the reactants.
   b. The products have a smaller mass than the reactants.
   c. The total number of moles of products is larger than the total number of moles of reactants.
   d. The total number of moles of products is smaller than the total number of moles of reactants.
5. At high temperatures, tin (IV) oxide (SnO₂) solid reacts with carbon (C) solid to produce tin (Sn) liquid and carbon monoxide (CO) gas. What is the correct balanced chemical equation for this reaction, including the appropriate symbols of state for each substance?
   a. SnO₂ (l) + C (s) \rightarrow Sn (s) + CO (g)
   b. SnO₂ (s) + C (s) \rightarrow Sn (l) + CO (g)
   c. SnO₂ (l) + 2 C (s) \rightarrow Sn (s) + 2 CO (g)
   d. SnO₂ (s) + 2 C (s) \rightarrow Sn (l) + 2 CO (g)

6. A certain chemical reaction has two steps.
   Step 1: NH₃ + C₂H₄O₂ \rightarrow NH₄C₂H₃O₂
   Step 2: NH₄C₂H₃O₂ \rightarrow C₂H₅NO + H₂O
   In Step 1, ammonia (NH₃) reacts with acetic acid (C₂H₄O₂) to produce ammonium acetate (NH₄C₂H₃O₂).
   In Step 2, at high temperatures, NH₄C₂H₃O₂ converts into acetamide (C₂H₅NO) and water (H₂O).
   Classify the chemical reactions in Step 1 and Step 2.
   a. Synthesis and decomposition
   b. Synthesis and single replacement
   c. Decomposition and single replacement
   d. Double replacement and single replacement

7. What balanced chemical equation is a single replacement reaction?
   a. 2 K (s) + Br₂ (l) \rightarrow 2 KBr (s)
   b. 2 HgO (s) \rightarrow 2 Hg (l) + O₂ (g)
   c. Zn (s) + CuSO₄ (aq) \rightarrow ZnSO₄ (aq) + Cu (s)
   d. NaCl (aq) + AgNO₃ (aq) \rightarrow NaNO₃ (aq) + AgCl (s)

8. Which balanced chemical equation contains the correct product(s) for the reaction of rubidium (Rb) solid with chlorine (Cl₂) gas?
   a. Rb (s) + Cl₂ (g) \rightarrow RbCl₂ (s)
   b. Rb (s) + Cl₂ (g) \rightarrow RbCl (s) + Cl (g)
   c. 2 Rb (s) + Cl₂ (g) \rightarrow 2 RbCl (s)
   d. 2 Rb (s) + 3 Cl₂ (g) \rightarrow 2 RbCl₂ (s) + 2 Cl (g)

9. What is the correct balanced chemical equation for the complete combustion of octane (C₈H₁₈)?
   a. C₈H₁₈ (l) + 4 O₂ (g) \rightarrow 8 CO (g) + 9 H₂ (g)
   b. C₈H₁₈ (l) + 8 O₂ (g) \rightarrow 8 CO₂ (g) + 9 H₂ (g)
   c. 2 C₈H₁₈ (l) + 17 O₂ (g) \rightarrow 16 CO (g) + 18 H₂O (g)
   d. 2 C₈H₁₈ (l) + 25 O₂ (g) \rightarrow 16 CO₂ (g) + 18 H₂O (g)
10. In water, ammonia (NH₃) reacts with nitric acid (HNO₃) to produce ammonium nitrate (NH₄NO₃).

\[ \text{NH}_3 \text{(aq)} + \text{HNO}_3 \text{(aq)} \rightarrow \text{NH}_4\text{NO}_3 \text{(aq)} \]

Dana carefully adds 0.550 mol of NH₃ to an excess of HNO₃. What is the maximum number of grams of NH₄NO₃ that this reaction can produce?

a. 44.0  
   b. 53.4  
   c. 115  
   d. 146

11. Under anhydrous (meaning no water) conditions, sodium peroxide (Na₂O₂) reacts with carbon dioxide (CO₂) to produce sodium carbonate (Na₂CO₃) and oxygen (O₂).

\[ 2 \text{Na}_2\text{O}_2 + 2 \text{CO}_2 \rightarrow 2 \text{Na}_2\text{CO}_3 + \text{O}_2 \]

What is the minimum number of grams of CO₂ required to produce 26.7 grams of O₂?

a. 73.4  
   b. 36.7  
   c. 18.4  
   d. 9.71

12. Caitlin adds 5.95 g of hydrochloric acid (HCl) to 4.56 g of magnesium (Mg). A reaction immediately occurs, and hydrogen gas (H₂) forms.

\[ \text{Mg} \text{(s)} + 2 \text{HCl} \text{(aq)} \rightarrow \text{MgCl}_2 \text{(aq)} + \text{H}_2 \text{(g)} \]

Assume the reaction goes to completion. What is the maximum number of grams of H₂ that the reaction can produce?

a. 0.165  
   b. 0.329  
   c. 0.378  
   d. 0.658

13. Which type of bond exists between two atoms having identical electronegativities?

   a. Covalent bond  
   b. Hydrogen bond  
   c. Ionic bond  
   d. Polar bond

14. Which property of ionic compounds can a chemist use to differentiate between ALL ionic and covalent compounds?

   a. They are insoluble in water.  
   b. They have low melting points.  
   c. They are solid at room temperature.  
   d. They conduct electricity when they melt.
15. For his term paper, Juan plans to write about the unique features of bonding in carbon (C) compounds. Which statement should Juan include in his paper to accurately describe the bonding in C compounds?
   a. C forms covalent bonds with sodium (Na) atoms.
   b. C forms ionic bonds with hydrogen (H) atoms.
   c. C forms single and double covalent bonds with oxygen (O) atoms.
   d. C forms single, double, and triple ionic bonds with other C atoms.

16. Which compound is the most polar?
   a. H₂O
   b. CO₂
   c. CH₄
   d. SiCl₄

17. Why do atoms share electrons in covalent bonds?
   a. To become ions and attract each other
   b. To attain a noble-gas configuration
   c. To become more polar
   d. To increase their atomic number
APPENDIX I

POST-TREATMENT OPINION SURVEY
This survey is about your thoughts on the semi-independent study method we used for the past two units. Your participation in this survey is voluntary.

<table>
<thead>
<tr>
<th>Question</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you spend your time before class reading the notes in the packet?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>Did you attempt the worksheets before coming to class?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>Did you work with your classmates to complete the assignments?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How comfortable did you feel with the material?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How confident do you feel about the material we learned (chemical reactions and stoichiometry)?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How much did having the notes and assignments beforehand help you?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How do you feel your test scores improved after using this packet for an entire unit?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
<tr>
<td>How did you like the idea of using this semi-independent study packet to learn chemistry?</td>
<td>Very Much</td>
<td>Somewhat</td>
<td>Undecided</td>
<td>Not Really</td>
<td>Not at all</td>
</tr>
</tbody>
</table>

What grade average did you typically earn on your chemistry tests and quizzes BEFORE this unit?

F (0-64)  D (65-74)  C (75-84)  B (85-93)  A (94-100)

What grade average do you expect to earn on your interim assessment (IA5) during this unit?

F (0-64)  D (65-74)  C (75-84)  B (85-93)  A (94-100)

Write your thoughts about the semi-independent study packet and how it might have affected your test scores. Would you change anything about the way it was done?