A Test of the Effectiveness of the Active Learning Technique Think-Pair-Share in a High School Science Classroom

Michael Francis Lowe

Louisiana State University and Agricultural and Mechanical College

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A TEST OF THE EFFECTIVENESS OF THE ACTIVE LEARNING TECHNIQUE THINK-PAIR-SHARE IN A HIGH SCHOOL SCIENCE CLASSROOM

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Natural Sciences

in

The Interdisciplinary Program in Natural Sciences

by

Michael Francis Lowe
B.S., Louisiana State University, 2000
August 2015
Acknowledgements

I would like to thank Dr. John Larkin, my committee chair and advisor for all the guidance and helpful advice. I would also like to thank my committee members Dr. William Wischusen and Dr. David Longstreth for their help. I also want to thank my wife Ashley, and my daughters, Katie and Abigail for their patience, love, and support throughout this process. This work was supported by NSF Grant 098847.
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Abstract

In this study, the active learning technique think-pair-share was tested in an independent high school non-honors chemistry classroom to see if it was more effective than teaching techniques already being used in the chemistry classes. Two classes of tenth grade chemistry students were combined as a test group and a third class of tenth grade chemistry students acted as the control. Learning gains for pre and post-tests from three different chemistry units were analyzed and no significant difference was found between the results of the control and test groups, indicating that think-pair-share was as effective as teaching methods already in place. Power analysis indicated that results had a low chance of showing a significant difference between the learning gains for the two groups. An attitude survey given after the study was over indicated that students felt more comfortable in the classroom when cooperative learning techniques were employed.
Introduction and Literature Review

A 2011 report by the National Science Foundation and the National Research Council on the state of STEM education in the U.S. points out that, when compared to international students, students from the U.S. perform significantly lower in science and math than their international counterparts. This is discouraging since a previous study by the NRC found that although scientists and engineers in the STEM fields make up only about 4% of the nation’s workforce, they are responsible for a majority of the jobs generated for the other 96% of the workforce. Employers are increasingly demanding that applicants possess the problem solving skills that STEM education is supposed to provide, and international students are filling elite positions in these fields at an increasing rate (National Research Council (US), 2011). In today’s competitive world, effective teaching methods in science are becoming increasingly important for students in the U.S.

In many modern-day science classrooms, information is disseminated most often through lecture, an ancient form of transmitting knowledge. In fact, lecture was the only efficient way to transmit knowledge until the middle of the nineteenth century when book printing became mechanized (Mazur, 1997). Even though today textbooks abound, both on paper and in digital form, lecture remains dominant in our classrooms. However, recent investigations show that another effective way to distribute information to students and ensure that they retain and better understand that information is through active learning techniques like peer instruction. Peer instruction involves simple cooperative learning exercises, or structures (Kagan, 1989), that promote student’s participation in class and interaction with other students as well as with the instructor (Rao et al., 2000).
In a typical 50 minute class period, the students’ level of concentration during a lecture tends to peak early in the class period, typically within the first 15 minutes (Rao et al., 2000). After this first brief period, their ability to concentrate falls sharply and students will often get lost in the stream of information. At that point students will resort to blind note-taking, often resolving to “think about it later and figure it out” (Rao et al., 2000). Ultimately, many students resort to an attempt at memorization of their notes rather than achieve an understanding of the concepts and bad habits set in (Mazur, 1997). Their ability to retain information drops sharply as well after this initial period. In fact, during a 45 minute period, only about 20% of the information distributed through lecture may be retained by the typical student (Rao et al., 2000).

To make matters worse, after the initial peak in concentration levels, students who find themselves falling behind are reluctant to ask questions for fear that they will disrupt or hold back the other students in the class. At this point, the distribution of information is only flowing in one direction, creating a very passive learning environment in which the instructor is the only person discussing information and many of the students are not engaged at all (Truong et al., 2002).

To promote retention, students must become “active learners” and actually participate in the process of learning. They have to discuss information with other students, write about it, relate it to past experiences, and somehow figure out how it applies to their own daily lives (Rao et al. 2000). Studies reveal that students retain more information when they are active participants in the process than when passively obtaining information. This could be explained by the fact that most students prefer active learning techniques to traditional lecture and that active learning enhances a student’s level of understanding and their ability to integrate and synthesize material (Rao et al., 2000).
Active learning promotes student involvement through a variety of techniques that involve brief lectures punctuated by short conceptual questions designed to check student understanding and, at the same time, attempt to correct misconceptions and keep students on track with the discussion and actively engaged throughout the lesson (Fagen et al., 2002). Also called cooperative learning, peer instruction usually involves putting students together in pairs or small groups that must cooperate in order to answer a question or series of questions. These questions may be designed to have a specific answer or to simply check or reinforce students’ understanding of a concept (Kagan, 1989). Researchers, like Robert DeHaan, argue that active learning strategies are essential to training science students to think creatively. A study by Cracolice et al. (2008) suggests that only about a quarter of U.S. college students possess the reasoning skills necessary to solve conceptual problems. In order to better prepare students, more instructors must become skilled themselves in implementing active learning strategies in their own classrooms that promote peer instruction and foster creativity (DeHaan, 2011).

Implementation of peer instruction involves the use of various structures as a way of organizing the interaction between students (Kagan, 1989). Examples of these structures include “Roundrobin”, a teambuilding structure in which students simply share ideas with teammates, or “Numbered Heads Together”, a structure designed to check for mastery in which teammates must discuss and agree on an answer to a question before one of the members provides the team’s answer to the rest of the class. A multifunctional structure, “inside-outside circle” involves a rapid question and answer session between students oriented in two circles, one inside the other, facing each other. Inside-outside circle can be used for review, to check for understanding, or even for tutoring (Kagan, 1989).
A study performed by a group from Harvard University reveals that the majority of instructors who use or have used peer instruction in their classrooms found it preferable to traditional lecture and planned to continue using it in the future (Fagen et al., 2002). The researchers invited over 2700 instructors to complete a survey regarding their experiences using peer instruction techniques. Of those that responded, 384 were identified as using peer instruction in one form or another. Of those 384, only 29 indicated they would probably not use peer instruction in the future (Fagen et al., 2002). Over 90% of those identified as using peer instruction in their classrooms indicated they would continue using it and in some cases even expand their usage in the future (Fagen et al., 2002).

In one popular peer instruction technique, think-pair-share (Butler et al., 2001), lecture remains the avenue for disseminating information, however at regular intervals throughout the lecture, students are required to answer a question to check their understanding of the concept that was just discussed. The students are given one minute to answer the question on their own and record their answer. This is the “think” part. Then, the students will turn to a partner (the “pair” part) and proceed to discuss their answer, again for one minute only, and their reasoning behind their answer which fulfills the final phase of the process, “share”. The point of this process is to reveal any misconceptions that a student may have regarding a particular lesson and through discussion with a partner offer the student an opportunity to correct that misconception prior to moving on with the lecture. In the “think-pair-share” method of peer instruction, students are required to take an active role in their learning, improving their understanding and long-term retention. Other variations of think-pair-share include think-pair-share-create in which pairs of students are required to discuss their response or reasoning with a partner and then must share responses with other groups, and think-aloud-pair-problem-solving, where one member is
the explainer and the other member is the questioner and together they must reason their way to a solution for a problem that has been proposed to the class. After solving the problem, different groups discuss ways that they arrived at their solutions (DeHaan, 2011).

A study that focused on the think-pair-share method of peer instruction at the Wayne State University School of Medicine illustrates the potential benefits for students. 256 first year medical students participated in the study which consisted of three or four short presentations spread over each 50 minute class period. At the end of each short presentation, the students were asked to answer a multiple choice question. Students were given one minute to think about and record their answers. Then, the students were allowed to discuss their answers with a partner and after one minute either keep their initial answer or change their answer based on what they learned in their discussion with their partner. The questions were arranged in three levels of increasing difficulty according to Bloom’s taxonomy. Questions from the first level tested simple recall of information. Questions from the second level tested intellectual skills and those from the third level tested synthesis and evaluation skills. In the results of the test, it was noted that prior to discussion, level one questions were answered correctly 94.3 ± 1.8% of the time, but after discussion that percentage increased to 99.4 ± 0.4%. Level two questions were answered correctly 82.5 ± 6.0% of the time prior to discussion and 99.1 ± 0.9% after discussion with a partner. The largest increase was seen in the level three questions, the most difficult of all. Prior to discussion, level three questions were answered correctly 73.1 ± 11.6% of the time, but after discussion the percentage of correct answers on level three questions rose to 99.8 ± 0.24% (Rao et al., 2000). Clearly think-pair-share helped to improve the student’s understanding of the material, but remarkably, the biggest gains were seen with regard to the questions that required the highest order thinking to answer correctly. As pointed out in a recent article published in
CBE-Life Sciences Education in 2014, there have been multiple studies that illustrate the effectiveness of active learning techniques like think-pair share in improving scores on test questions that require higher order thinking, including studies done in physics and chemistry classrooms (Linton et al., 2014).

A study performed by Kathleen Trent at East St. John High School, as part of a Masters of Natural Science thesis at Louisiana State University, tested the effectiveness of think-pair-share in a high school chemistry classroom (Trent, 2013). The results of the study did not show a significant difference between the test groups and the control group, but the study did highlight some of the challenges with performing a controlled experiment to test the effectiveness of think-pair-share in a high school setting as opposed to a collegiate setting. Small class sizes combined with absenteeism may have played a part in the absence of a detectable significant difference between the groups’ results. There was also an issue with students in the control group continuing to interact as if they were using Think-Pair-Share even though they were not instructed to. Prior to beginning the experiment, all of the students were taught to use think-pair-share, and once the study began, the students in the control group tended to continue using the technique even though they had not been instructed to do so. As if that was not enough, Hurricane Isaac flooded the East St. John campus in the middle of the study and forced Ms. Trent and her students to relocate their classroom. She was forced to use preliminary data which could have also contributed to a lack of difference in learning gains (Trent, 2013).

Although studies on this technique have been performed at the college level, relatively few have been performed at the high school level and I wanted to test the effectiveness of think-pair-share for promoting learning in a high school chemistry setting. Kathleen Trent’s study addressed some of the issues associated with performing this type of study in a high school
setting and, since my own classroom setting was similar to hers, with similar numbers of students in a chemistry class, I thought it would be important to continue the study that she performed and see if any significant learning differences could be demonstrated.
Materials and Methods

For this study, permission was obtained from the Louisiana State University Institutional Review Board (IRB# E8882, Appendix A), and since the students were all minors, they were asked to sign a student assent form (Appendix B) as well as have their parents sign a permission form (Appendix C).

Population

This study was performed at Episcopal High School of Baton Rouge. Episcopal is an independent school and students entering their tenth grade year who have completed Biology are placed in either honors Chemistry or non-honors Chemistry. The students involved in this study were all non-honors Chemistry students. There were 45 students involved in the study of which 14 made up a class that was designated the control group. Of those 14 students in the control group, 11 were male, 3 were female, and all were in the 10th grade. The test group consisted of 31 students in 2 separate classes, of which 17 were male and 14 were female. 29 students in the test group were in the 10th grade while 2 were in the 11th grade. None of the students in either group were repeating Chemistry and none of the students were designated as special education. The racial and gender makeup of the school, test, and control groups is described in Table 1.

Episcopal high school has a 7 period, rotating schedule. Over the course of a school day, students attend 6 academic periods averaging 55 minutes each and 1 academic period rotates out of the schedule. Each successive day will start with a different academic period with 1 period rotating out of the schedule. Every 7 days the rotation starts over. Over the course of 1 school week, students in a given chemistry class would spend a maximum of 275 minutes in class with the instructor, or 220 minutes if that particular class rotated out of the schedule for a day.
Table 1: Racial and Gender Makeup of Episcopal High School and Study Population

<table>
<thead>
<tr>
<th></th>
<th>Whole School</th>
<th>Test Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>81.53%</td>
<td>77.40%</td>
<td>92.90%</td>
</tr>
<tr>
<td>African American</td>
<td>12.32%</td>
<td>19.40%</td>
<td>0%</td>
</tr>
<tr>
<td>Asian</td>
<td>5.90%</td>
<td>3.20%</td>
<td>7.10%</td>
</tr>
<tr>
<td>Mix</td>
<td>0.25%</td>
<td>0.00%</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>406</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>Male</td>
<td>46.31%</td>
<td>54.84%</td>
<td>78.57%</td>
</tr>
<tr>
<td>Female</td>
<td>53.69%</td>
<td>45.16%</td>
<td>21.43%</td>
</tr>
</tbody>
</table>

In addition to the regular class period, each school day students have the option of getting help during the tutorial period, a 25 minute period after lunch during which students can get individual help from the instructor. Although some of the chemistry students took advantage of this extra time outside of class, think-pair-share was only used during regular class time, and only in the classes designated as the test groups.

Content covered for Study

Non-honors chemistry is taught at Episcopal High School using “Chemistry”, a textbook published by Pearson-Prentice Hall (Wilbraham et al. 2008). The study focused on three main topics that were covered in class: “Atomic Structure”, covered in chapters 4 and 5, “Chemical Quantities”, covered in chapter 10, and “Chemical Reactions”, covered in chapter 11. In the unit on “Atomic Structure and Electrons in Atoms”, students learned about the history behind our knowledge of the basic structure of the atom, varying models of the atom, and how electrons are arranged around the nucleus. In the “Chemical Quantities” unit, students learned about measuring matter using the concept of the mole and relating moles to mass and volume. Lastly, in the “Chemical Reactions” unit, students learned how to describe the various types of chemical reactions and write chemical equations using the proper chemical symbols and formulas (Wilbraham et al. 2008). These three units were chosen because of the balance of concepts and
calculation-type instruction involved in each. Also, since chapters 4 and 5 were not the first
chapters covered, this gave me time to get to know the students and allowed me to pair the
students in the test group effectively so that I felt they would get the maximum benefit from the
Think-Pair-Share activity.

Traditional Instruction and Integration of Think-Pair-Share

For all three units of the study, the control group was taught using the traditional
instruction techniques of lecture and individual practice. Units in my chemistry class are
normally introduced through lecture with the assistance of a power point presentation. Students
are not usually given immediate access to the power point and are instructed to take notes as I
point out important items within the presentation or expand on a concept that is mentioned in the
presentation, but not explained thoroughly. Students are encouraged to pay attention and speak
up when they are not able to follow or are in need of further explanation. Punctuated throughout
the lesson, students are asked, as a class, a general question about the topic at hand designed to
see if they are paying attention as well as to check comprehension. The students are not allowed,
at this point, to discuss the question, but are expected to answer individually if called on. After
the initial introduction of a topic, problems or scenarios are worked for the class to demonstrate
the concept or problem solving technique necessary for that particular unit. After the
demonstration, students are given a practice problem that must be worked individually after
which, as a class, the answer would be discussed and students would have an opportunity to ask
questions and clear up any uncertainties. Once the initial individual practice is complete and I am
satisfied that all of the students have been properly introduced to the topic, I will usually give the
students multiple problems or questions to answer and will allow students to assist each other, if
necessary. For the purpose of the study, the students in the control group were kept separate and
were not allowed to pair up and discuss the answers to questions or practice problems being worked in class during the initial phase of practice as a class. However, students were not explicitly instructed to refrain from helping each other outside of class time, or when time was allotted in class to work on groups of practice problems that had been given as homework.

In addition to traditional techniques, the test groups used the peer instruction technique think-pair-share as described by Kagan (1989) and Butler et al. (2001). During the initial phase of introduction, demonstration, and practice as a class, students in the test groups were given a variety of questions for which they would first be required to answer individually and, in some cases, reveal their initial answer choice through a show of hands. Immediately afterwards they were instructed to pair up and discuss their answer choices with their partner for up to one minute. After one minute, the students were asked to share their answers with the class either through open discussion or with a show of hands. Depending on the material being covered on a given day, the process of think-pair-share may have been used once or as many as three times in a 55 minute period.

Assessment Methodology

For the purpose of measuring students’ learning gains for each section, students in both the control group and the test groups were given a pre-test prior to instruction on the unit, and a post-test after instruction on the unit was completed. There were twenty questions on both the pre-test and post-test (samples in Appendix D) and the questions used on the pre-test were identical to the questions on the post-test. All questions were multiple-choice and were chosen from a test bank that is part of the ancillary materials used with the Chemistry textbook that we used in class (Wilbraham et al. 2008). Individual questions were chosen and ordered according to
increasing complexity. Answers were not discussed until all students had completed the post-test.

Students were encouraged to do their best on the pre-test even though they had not been exposed to the material covered on the test. They were instructed that their pre-test score would not have an effect on their grade for Episcopal, but that they were part of a study that could potentially have an effect on the way science was taught in high school classrooms in the future.

Results from the post-tests were compared to the pre-test scores and normalized learning gains were calculated by dividing the learning gain achieved by the total learning gain possible for each student in both the test groups and the control group (Weber, 2009). Then the normalized learning gains were calculated for each student and an average taken for the combined test groups as well as the control group. The normalized learning gains for the test group and the control group were compared with a paired t-test using the statistics software Graphpad (Instat, version 3.10, 2009). This process was performed for the results of each individual unit taught separately, and then again for the results of all three units added together in order to increase the sample sizes for each group.

A subsequent analysis was performed on the higher order questions for each unit by isolating 10 of the pre-test questions that corresponded to skills specified in the top three tiers of Bloom’s Taxonomy (Forehand, 2010). These 10 higher order questions required students to analyze, evaluate, or create as opposed to just recalling a quick answer from memory. Questions 2, 3, 6, 7, 8, 9, 10, 12, 13, and 17 are examples of higher order questions on the Atomic Structure unit pre-test. Questions 2, 4, 7, 8, 13, 14, 16, 18, 19, and 20 are examples of higher order questions on the Chemical Quantities unit pre-test. Questions 2, 4, 5, 8, 10, 12, 15, 16, 17,
18 are examples of higher order questions on the Chemical Reactions unit pre-test (see Appendix D). For each analysis, information for students who did not complete both the pre and post-test was left out.

As a final step, students were given a survey to evaluate their general feelings about using Think-Pair-Share as opposed to working alone to solve problems in class. 10 questions were developed, 5 that asked specifically about their feelings about pairing up with other students, and five that inquired about their feelings toward working alone or in a group. The students could respond using a 5 step Likert scale (Lovelace et al., 2013) starting with “Completely Disagree” and ending with “Completely Agree” (see Appendix E). The average number of responses was calculated for each question and the results were graphed.
Results

The purpose of this study was to find out if using the active learning technique think-pair-share would be more effective than using the traditional techniques of lecture and demonstration in a tenth grade high school chemistry classroom. Students from three separate sections were designated as control and test groups. The control group consisted of 14 students from one section and the other two sections were combined to form the test group which consisted of 31 students. Three units from the textbook “Chemistry” were used for the study: Chapters 4 and 5 covered “Atomic Structure”, Chapter 10 covered “Chemical Quantities”, and Chapter 11 covered “Chemical Reactions” (Wilbraham et al. 2008).

Prior to starting each unit, a 20 question pre-test was given to the students in both the test and the control groups to test prior knowledge about the topic, and also to establish a baseline in order to determine the learning gains for each student. For each pre-test, the students earned a score of the number correct out of a possible 20. The answers to the pre-test questions were not discussed with the students until after the students had completed the post-test for each unit. The post-test contained the same 20 questions that were on the pre-test, but the questions from the pre-test were mixed in with other questions pertaining to the unit. For each post-test, the students earned a score of the number correct out of a possible 20. As illustrated in figures 1-6 the raw scores of the pre and post-tests for each unit revealed that the majority of the students from both the control group and the test group had scored higher on the post-tests than they had on the pre-tests.
Figure 1: Control Group Pre and Post-test scores for The Unit: Atomic Structure

Figure 2: Test Group Pre and Post-test scores for The Unit: Atomic Structure.
Figure 3: Control Group Pre and Post-test scores for The Unit: Chemical Quantities.

Figure 4: Test Group Pre and Post-test scores for The Unit: Chemical Quantities.
Figure 5: Control Group Pre and Post-test scores for The Unit: Chemical Reactions.

Figure 6: Test Group Pre and Post-test scores for The Unit: Chemical Reactions.
The normalized learning gains were calculated for each unit in order to better illustrate the amount that each student’s understanding of the information in that unit had improved between taking the pre-test and the post-test. T-tests were performed on the means of the normalized learning gains and the results were graphed along with the standard error of the mean for both the control and test group for each unit.

For the first unit, “Atomic Structure”, a Mann-Whitney test was performed, the results of which are shown in Table 2. The mean normalized learning gain for both groups was very similar, 0.726 +/- 0.048 for the control group and 0.708 +/- 0.04 for the test group. The P value was calculated to be 0.833, indicating that there was no significant difference between the mean normalized learning gains for the control group and the test group, as illustrated in Figure 7.

<table>
<thead>
<tr>
<th>Table 2: Mann-Whitney Test Results for the Unit: Atomic Structure</th>
</tr>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Mean Normalized Learning Gain</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Size</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
</tr>
<tr>
<td>P Value</td>
</tr>
</tbody>
</table>

For the second unit, “Chemical Quantities”, two of the students in the test group were unable to take the pre-test and could not be included in the analysis. A Mann-Whitney test was performed, the results of which are shown in Table 3. Again, the mean normalized learning gain for both groups was very similar, 0.513 +/- 0.074 for the control group and 0.496 +/- 0.037 for the test group. The P value was calculated to be 0.9235, indicating that there was no significant
difference between the mean normalized learning gains for either group, as the graph in Figure 8 shows.

![Chart showing mean normalized learning gains for Control and Test groups.](chart.png)

**Figure 7**: Mean Normalized Learning Gains +/- SEM for the Unit: Atomic Structure.

**Table 3**: Mann-Whitney Test Results for Unit: Chemical Quantities

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized Learning Gain</td>
<td>0.513</td>
<td>0.496</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.276</td>
<td>0.200</td>
</tr>
<tr>
<td>Sample Size</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>0.074</td>
<td>0.037</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.9235</td>
</tr>
</tbody>
</table>
Figure 8: Mean Normalized Learning Gains +/- SEM for the Unit: Chemical Quantities.

For the third unit, “Chemical Reactions”, one student from the control group and one from the test group did not complete the pre-test and could not be included in the analysis. A third student, from the test group, was transferred from the class during the unit and could not be included. A Mann-Whitney test was performed, the results of which are shown in Table 4. Again, the mean normalized learning gain for both groups was very similar, 0.502 +/- 0.085 for the control group and 0.514 +/- 0.043 for the test group. The P value was calculated to be 0.9945, indicating that there was no significant difference between the mean normalized learning gains for either group, as the graph in Figure 9 shows.

Table 4: Mann-Whitney Test Results for the Unit: Chemical Reactions

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized Learning Gain</td>
<td>0.502</td>
<td>0.514</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.306</td>
<td>0.229</td>
</tr>
<tr>
<td>Sample Size</td>
<td>13</td>
<td>28</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>0.085</td>
<td>0.043</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.9945</td>
</tr>
</tbody>
</table>
The normalized learning gains from all three units were added together for both groups in an attempt to increase the sample sizes and see if that would reveal some significant differences. This boosted the sample sizes to 41 for the control group and 88 for the test group. When the results of all three units were combined for each group and a Mann-Whitney test performed, the means of the normalized learning gains were almost identical as shown in Table 5. The control group mean was 0.569 +/- 0.044 and the mean for the test group was 0.56 +/- 0.026. The P value for the combined units was 0.825, indicating that the difference between the groups is not significant. These results are illustrated by the graph in Figure 10.

Table 5: Mann-Whitney Test Results for Combination of All Three Units

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized Learning Gain</td>
<td>0.569</td>
<td>0.560</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.283</td>
<td>0.245</td>
</tr>
<tr>
<td>Sample Size</td>
<td>41</td>
<td>88</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>0.044</td>
<td>0.026</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.825</td>
</tr>
</tbody>
</table>
Since the initial results indicated that there was no significant difference in learning gains between the two groups, a second round of tests were run to see if by classifying the test questions according Bloom’s Taxonomy (Forehand, 2010) and only analyzing the questions that required a higher order level of thinking, a significant difference in the mean normalized learning gains might be revealed. For each unit, the 20 test questions were classified according to their level of complexity and the 10 questions that required the highest order of thought to answer were isolated. Only questions from the top three tiers of Bloom’s Taxonomy that required the students to analyze, evaluate, and create (Forehand, 2010) were included in the analysis. The normalized learning gains for only those 10 questions were calculated for each group.

For the first unit on atomic structure, a Mann-Whitney test was performed resulting in a mean of 0.633 +/- 0.073 for the control group and 0.606 +/- 0.054 for the test group. The P value for this test was 0.99 indicating that there was no significant difference in the two means, as
shown in Table 6. A graph of the mean learning gains for the “Atomic Structure” unit is illustrated in Figure 11.

Table 6: Mann-Whitney Test Results for Higher-Order Questions for the Unit: Atomic Structure.

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized Learning Gain</td>
<td>0.633</td>
<td>0.606</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.273</td>
<td>0.303</td>
</tr>
<tr>
<td>Sample Size</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>0.073</td>
<td>0.054</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.99</td>
</tr>
</tbody>
</table>

Figure 11: Mean Normalized Learning Gains +/- SEM for Higher-Order Questions for the Unit: Atomic Structure.

For the second unit on chemical quantities, a Mann-Whitney test was performed resulting in a mean normalized learning gain of 0.561 +/- 0.061 for the control group and 0.451 +/- 0.047 for the test group. The P value for this test was 0.225, which is lower than the P value for the previous unit, but still not low enough to indicate any significant difference in the two means, as shown in Table 7. A graph of the mean learning gains for the “Chemical Quantities” unit is illustrated in Figure 12.
Table 7: Mann-Whitney Test Results for Higher-Order Questions for the Unit: Chemical Quantities.

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized Learning Gain</td>
<td>0.561</td>
<td>0.451</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.221</td>
<td>0.256</td>
</tr>
<tr>
<td>Sample Size</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>0.061</td>
<td>0.047</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.225</td>
</tr>
</tbody>
</table>

Figure 12: Mean Normalized Learning Gains +/- SEM for Higher-Order Questions for the Unit: Chemical Quantities.

The third unit on chemical reactions revealed results much like the first unit with a Mann-Whitney test resulting in a mean normalized learning gain of 0.523 +/- 0.086 for the control group and 0.480 +/- 0.053 for the test group. The P value for this test was 0.584 indicating that there was no significant difference in the two means, as shown in Table 8. A graph of the mean learning gains for the “Chemical Reactions” unit is illustrated in Figure 13.
For the last test, the results from the three units were combined by adding the data from all three units together, again to increase the sample sizes as was done in the first set of tests. A Mann-Whitney test was performed which resulted in mean normalized learning gains of 0.574 +/- 0.042 for the control group and 0.515 +/- 0.031 for the test group. The P value for this test was 0.286, indicating that there was no significance in the difference between the two means.
as shown in Table 9. A graph of the mean learning gains for the combination of all three units is illustrated in Figure 14.

Table 9: Mann-Whitney Test Results for Higher-Order Questions for Combination of All Three Units.

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Normalized</td>
<td>0.574</td>
<td>0.515</td>
</tr>
<tr>
<td>Learning Gain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.268</td>
<td>0.286</td>
</tr>
<tr>
<td>Sample Size</td>
<td>41</td>
<td>88</td>
</tr>
<tr>
<td>Standard Error of the</td>
<td>0.042</td>
<td>0.031</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>0.286</td>
</tr>
</tbody>
</table>

Figure 14: Mean Normalized Learning Gains +/- SEM for Higher-Order Questions for All Three Units Combined.

At the end of the study, students were asked to take a 10 question survey designed to determine whether or not they felt that using think-pair-share was a positive experience or not. The questions asked directly about pairing up with other students (questions 1-5, Appendix E) and indirectly about their feelings toward working alone or as part of a group (questions 6-9, Appendix E). The results of the survey, as illustrated in Figure 15, indicate that the students had a positive attitude when responding to questions 1 through 5 about pairing up with other
students, but, as indicated by the responses to questions 6 and 9, students were slightly more hesitant about getting their instruction from other students rather than from the teacher (see Appendix E).

Figure 15: Results from the Survey of Student Attitudes on the Use of Think-Pair-Share.

When the mean number of responses from questions 1 through 5 (3.87 +/- 0.094) are compared to the mean number of responses from questions 6 through 10 (3.11 +/- 0.195), the difference is significant as indicated in Figure 16. This test resulted in a p value of 0.016.

Figure 16: Attitude Survey mean responses from questions 1-5 compared to the mean responses from question 6-10 (+/- SEM).
Discussion

This study was designed to compare the active learning technique Think-Pair-Share to my own traditional techniques that I use when teaching chemistry to tenth graders. Of the three sections that I taught, two of them were combined as the test group which was taught using think-pair-share in addition to the techniques that I normally use. One of the sections was designated the control group which was taught the same material as the test group but did not use Think-Pair-Share as an instruction method. The test group used the Think-Pair-Share technique during instruction for three of the chemistry units and the results from pre and post-tests were analyzed from the control group and the test group. Analysis of the results did not show a significant difference in the learning gains between the test group and the control group indicating that Think-Pair-Share and my own traditional teaching methods were equally effective.

Initial analysis of the data from the pre and post-tests for all three units taught indicated an increase in the students’ knowledge at varying levels for almost all of the students, with the exception of a few of the students who did not show any learning gains from pre-test to post-test. However, when the learning gains were compared between the control group and the test group, it became clear that the students that were taught using Think-Pair-Share did not fare any better than those taught using my own traditional methods. To look into the results further, I decided to see if, by isolating the learning gains from only the higher order questions on the pre and post-tests, significant differences in the learning gains might be revealed. There is evidence from a prior study (Linton, et. al., 2014) that using active learning strategies like Think-Pair-Share will result in higher learning gains for questions that require a higher level of thought than questions that only draw from rote-memorization. The test questions were classified according to their
difficulty and the amount of higher order thinking required to arrive at an answer and the top 10 questions were isolated from the rest. Bloom’s Taxonomy categorizes the ways that students answer questions with a hierarchy of skills divided into categories that progressively become more complex. The lowest categories only require a quick response from memory, like a definition or an identity. The highest categories require a student to reason and evaluate information that they have learned, often referencing multiple concepts at once, ultimately leading to an answer that can be defended. These 10 questions were chosen because they required the students to compare and analyze information, design ideas, or evaluate facts, all part of higher-order thinking according to Bloom’s Taxonomy (Forehand, 2010). The results from these 10 questions were analyzed and again, the differences in the learning gains were not significant.

I believe that there are three main reasons why the results of this study did not show any significant differences between the learning gains of the control and the test groups. First, the majority of the studies that have been done on think-pair-share have been performed at the college level where the numbers of students in the classes were much larger than the number of students that I had to work with, usually in the hundreds. The small sample sizes that I had to work with, just 14 students in my control group and 31 in my test group, prevented me from overcoming the lack of statistical power resulting from the small sample size. This issue was exacerbated by the problem of absences on test days and 1 of the students being transferred mid-year into a different section. A third student left after the first unit pre-test was completed and never returned to the school. To explore this issue, a power analysis was performed on the data from the combined results for both the initial set of tests and the combined results from the higher-order test results using the statistics software Graphpad (Statmate, version 2.00, 2004).
The power analysis helps by showing the chances of getting significant differences in the results if the tests were to be run a large number of times with the same sample sizes.

Figure 17: Results of power analysis for combined data from all three units. The delta is the difference in the mean normalized learning gains.

Figure 17 indicates that with a delta of only 0.009, the chances of getting significant differences in the results would be less than 10%, while figure 18 shows that, with a delta of 0.059, the chances of seeing a significant difference with the higher order questions would be slightly less than 20%.
The power analysis indicates that the power of the data is low and therefore would not likely show a significant difference in the results between the two groups, even if the test were run many times. A larger sample size may have increased the power of the results and the chances for seeing a significant difference.

The second reason had to do with the traditional methods of teaching in my classroom that was used as a control. Although I was not very familiar with the term active learning prior to conducting the study, there were many aspects of my own methods that could be considered active learning techniques. I always encourage participation in my class and am always on the lookout for students who may not be paying attention or are distracted when I’m teaching. I try
my best to keep students on task and engaged in the lesson. As described earlier, as a normal practice, I encourage students to discuss solutions to problem sets that I give them for practice and I always encourage students to study together when studying for a quiz or a test. While previous studies often compared Think-Pair-Share to lecture alone, this study compared Think-Pair-Share to what could be considered other active learning techniques. Think-Pair-Share is a type of active learning known as peer instruction, and a study on peer instruction (Smith et al., 2009) found that greater learning gains were achieved when peer instruction was combined with instructor explanation than when either technique were used alone. This study suggests that even with active learning techniques like peer instruction, the teacher is still a very important part of the process and still has a large influence on learning outcomes. A subsequent study by Linton et al., in 2014 sought to find out if peer interaction was necessary, or if it was more important for students to be focused and on task to see significant learning gains. This study found that although time on task was important, the addition of peer interaction did improve learning gains, but most often on questions that required a higher level of thinking and a more extensive response than a multiple choice question (Linton et al., 2014).

The third and final reason that my results did not show a significant difference may have been that the format of the questions that I used on my pre and post-tests, multiple choice, may not have been the right format for revealing the difference in learning gains that may have present as a result of the higher order questions that were asked. In my final analysis, I isolated what I considered to be the 10 questions from the pre and post-tests that required the highest order of thinking to answer. The results still did not show a significant difference in learning gains. In fact, in the analysis of the three different sections as well as the combined analysis, the mean learning gain from the control group was slightly higher than for the test group. If I could
perform the experiment again, I would use questions that required a more extensive response than multiple choice questions as prior studies suggest that increases in learning gains may only be revealed when higher order questions are used in the assessments.

The demographics of the study groups presented a unique challenge to the analysis of the results. The control group consisted of one Asian student and the rest of the class was white. The test group was almost all white as well, with only 6 of 31 students being African American and 1 Asian student. Only 3 of the students in the control group were female. It is possible that the lack of diversity in my groups could have been a factor in preventing any significant differences from being revealed in the analysis. More studies like this one need to be performed to explore this aspect at the high school level.

As shown in the results of the survey given at the end of the study, students responded favorably to questions about interacting with a partner in class, indicating that active learning techniques that encourage peer interaction are preferred by students to techniques that require a student to work alone. The students also indicated that working together as a group helped to reduce the anxiety some students feel when they are in the classroom. Combined, these results indicate that peer instruction techniques like Think-Pair-Share may make students feel more comfortable and promote a more positive attitude in the classroom than an environment where students are prevented from interacting.
A power analysis of the results from the comparison of the means of responses to questions 1-5 vs questions 6-10 on the survey indicate that these results are meaningful in the sense that, as shown in Figure 19, significant differences in the results would be found over 80% of the time if this same test was repeated many times over.

In conclusion, although neither Kathleen Trent’s study nor my own show a significant difference in the learning gains between the control and test groups, the student’s responses to the attitude survey did indicate that using cooperative peer instruction techniques like Think-Pair-Share did create a positive learning environment. By reducing the students’ anxiety about participating in class, techniques like Think-Pair-Share encourage students who would not otherwise do so to participate and improve the overall learning atmosphere in the classroom for all students. As the instructor, I noticed that the general attitude in the classroom became much more positive and conducive to learning when students were allowed to collaborate. This finding, and the results of this study, encourages me to continue using active learning techniques like Think-Pair-Share and to explore other techniques in the future.
References


Trent, Kathleen Sipos. *THE EFFECTS OF THE PEER INSTRUCTION TECHNIQUE THINK-PAIR-SHARE ON STUDENTS’ PERFORMANCE IN CHEMISTRY*. Diss. Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Natural Science In The Interdisciplinary Program in Natural Sciences by Kathleen Sipos Trent BS, Nicholls State University, 2013.


Appendix A
IRB Approval

ACTION ON EXEMPTION APPROVAL REQUEST

TO: John Larkin
   Biological Sciences

FROM: Dennis Landin
      Chair, Institutional Review Board

DATE: August 5, 2014

RE: IRB# E8882

TITLE: Does using the peer instruction technique "Think-Pair-Share" improve student's understanding in high school Chemistry


Review Date: 8/4/2014

Approved X Disapproved

Approval Date: 8/4/2014 Approval Expiration Date: 8/3/2017

Exemption Category/Paragraph: 1

Signed Consent Waived?: No

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable): 

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING – Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
8. SPECIAL NOTE:
   *All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb
Appendix B
Student Assent Form

Student Assent Form

I, _________________________________, agree to be in a study to find ways to help students perform better in high school Chemistry. I will have to do special school work for the teacher in my classroom. Sometimes I will be taught Chemistry using traditional instruction techniques. Other times I may get to work with another student. I have to follow all the classroom rules, even when I am working with other students. I can decide to stop being in the study at any time without getting in trouble.

Student's Signature: ________________________________  Age: ______  Date: ____________________

Witness ________________________________  Date: ____________________
Appendix C
Parent Permission Form

Parental Permission

PROJECT TITLE: Does the use of the peer instruction technique Think-Pair-Share increase students’ understanding in high school Chemistry?

PERFORMANCE SITE: Episcopal High School
3200 Woodland Ridge Blvd
Baton Rouge, LA 70816

INVESTIGATIONS: The following investigators are available for questions about this study,
Monday – Friday 8:00 am – 3:20 p.m.
Mr. Michael Lowe 225-753-3180 x1324
Dr. John C. Larkin 225-578-8552

PURPOSE OF THIS STUDY: The purpose of this study is to determine whether students show greater learning gains in Chemistry when using the peer instruction technique Think-Pair-Share.

INCLUSION CRITERIA: Students in Chemistry classes taught by Mr. Michael Lowe.

DESCRIPTION OF STUDY: Over the course of the 2014-2015 school year, the investigator will use the peer instruction technique Think-Pair-Share in addition to traditional teaching methods to teach several units in high school general chemistry. The teacher will use pre and post tests to measure student understanding of the material. The instructor will compare these test results to results gathered from a control group taught using traditional techniques exclusively.

BENEFITS: It is anticipated that all subjects taught using Think-Pair-Share will show improved academic performance pertaining to students’ abilities to grasp content knowledge and students’ abilities to retain content presented.

RISKS: There are no risks associated with participation within this study.

RIGHT TO REFUSE: While participation in this study is highly suggested and recommended, it is not mandatory that a student subject chose to participate. At any time, either the subject may withdraw from the study or the subject’s parent may withdraw the subject from the study. Non-participation in this study will leave no impact on the student’s final grades or assessments throughout the duration of the school year.

PRIVACY: The records of participants in this study include, but are not limited to test scores and attendance, which may be reviewed by investigators. Also, results of the study may be published, but no names or other identifying information will be disclosed in publication. All subjects’ identities will be kept confidential unless otherwise advised by law.
FINANCIAL INFORMATION: There is no cost for participation in this study, nor is there any compensation to the student subjects and/or their representatives for participation.

SIGNATURES: This study has been discussed with me and all of my questions have been answered. I may direct any additional questions regarding study specifics to the primary and/or co-investigator. If I have any questions about subjects’ rights or other concerns I can contact Dr. Dennis Landin, Chairman of the Institutional Review Board at 225-578-8692, irb@lsu.edu I lsu.edu/irb. I will allow my child to participate in the study described above and acknowledge the investigator’s obligation to provide me with a signed copy of this consent form.

Parent Signature______________________________________________Date___________

IF APPLICABLE: The parent/guardian has indicated to me that he/she is non-English speaking/reading, or unable to read. I certify that I have read and/or translated this consent form to the parent/guardian and explained that by completing the signature above, he/she has given permission for the child to participate in the study.

Signature Reader______________________________________________Date___________
Appendix D
Sample Pre-Tests

Pre-Test: Atomic Structure

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

1. Who was the man who lived from 460B.C.–370B.C. and was among the first to suggest the idea of atoms?
   a. Atoms
   b. Dalton
   c. Democritus
   d. Thomson

2. Which of the following is true about subatomic particles?
   a. Electrons are negatively charged and are the heaviest subatomic particle.
   b. Protons are positively charged and the lightest subatomic particle.
   c. Neutrons have no charge and are the lightest subatomic particle.
   d. The mass of a neutron nearly equals the mass of a proton.

3. All atoms are ______.
   a. positively charged, with the number of protons exceeding the number of electrons
   b. negatively charged, with the number of electrons exceeding the number of protons
   c. neutral, with the number of protons equaling the number of electrons
   d. neutral, with the number of protons equaling the number of electrons, which is equal to the number of neutrons

4. The particles that are found in the nucleus of an atom are ______.
   a. neutrons and electrons
   b. electrons only
   c. protons and neutrons
   d. protons and electrons

5. Isotopes of the same element have different ______.
   a. numbers of neutrons
   b. numbers of protons
   c. numbers of electrons
   d. atomic numbers

6. The mass number of an element is equal to ______.
   a. the total number of electrons in the nucleus
   b. the total number of protons and neutrons in the nucleus
   c. less than twice the atomic number
   d. a constant number for the lighter elements

7. How many protons, electrons, and neutrons does an atom with atomic number 50 and mass number 125 contain?
   a. 50 protons, 50 electrons, 75 neutrons
   b. 75 electrons, 50 protons, 50 neutrons
   c. 120 neutrons, 50 protons, 75 electrons
   d. 70 neutrons, 75 protons, 50 electrons

8. Which of the following statements is NOT true?
   a. Atoms of the same element can have different masses.
   b. Atoms of isotopes of an element have different numbers of protons.
   c. The nucleus of an atom has a positive charge.
   d. Atoms are mostly empty space.

9. If E is the symbol for an element, which two of the following symbols represent isotopes of the same element?
   1. $^{36}_{16}E$
   2. $^{29}_{12}E$
   3. $^{21}_{9}E$
   4. $^{21}_{16}E$

   a. 1 and 2
   b. 3 and 4
   c. 1 and 4
   d. 2 and 3
10. How do the isotopes hydrogen-1 and hydrogen-2 differ?
   a. Hydrogen-2 has one more electron than hydrogen-1.
   b. Hydrogen-2 has one neutron; hydrogen-1 has none.
   c. Hydrogen-2 has two protons; hydrogen-1 has one.
   d. Hydrogen-2 has one proton; hydrogen-1 has none.

11. What unit is used to measure weighted average atomic mass?
   a. amu  
   b. gram  
   c. angstrom
   d. nanogram

12. Which of the following statements is NOT true?
   a. Protons have a positive charge.
   b. Electrons are negatively charged and have a mass of 1 amu.
   c. The nucleus of an atom is positively charged.
   d. Neutrons are located in the nucleus of an atom.

13. How does the energy of an electron change when the electron moves closer to the nucleus?
   a. It decreases.
   b. It increases.
   c. It stays the same.
   d. It doubles.

14. What is the maximum number of electrons in the second energy level?
   a. 2  
   b. 8
   c. 18
   d. 32

15. The letter "p" in the symbol 4p⁴ indicates the ___.
   a. number of electrons
   b. sublevel (orbital) shape
   c. energy level
   d. speed of an electron

16. What is the number of electrons in the outermost energy level of an oxygen atom?
   a. 2
   b. 4
   c. 6
   d. 8

17. What is the electron configuration of potassium?
   a. 1s²2s²2p⁶3s²3p⁴4s¹
   b. 1s²2s²2p⁶3s²3p⁵
   c. 1s²2s²3s²3p⁶3d¹
   d. 1s²2s²2p⁶3s²3p⁴4s¹

18. When an atom’s electron is “excited”, the electron ___.
   a. drops from a higher to a lower energy level
   b. jumps from a lower to a higher energy level
   c. moves within its atomic orbital
   d. falls into the nucleus

19. Which of the following scientists was the first to discover the electron?
   a. Dalton  
   b. Bohr
   c. Rutherford
   d. Thomson

20. Which of the following scientists described the atom as having a positively charged nucleus?
   a. Rutherford  
   b. Newton
   c. Thomson
   d. Millikan
Pretest: Chemical Quantities

Multiple Choice

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

1. What SI unit is used to measure the number of representative particles in a substance?
   a. kilogram
   b. ampere
   c. kelvin
   d. mole

2. How many hydrogen atoms are in 5 molecules of isopropyl alcohol, C₃H₇O?
   a. 5 \times (6.02 \times 10^{23})
   b. 5
   c. 35
   d. 35 \times (6.02 \times 10^{23})

3. Which of the following elements exists as a diatomic molecule?
   a. neon
   b. lithium
   c. nitrogen
   d. sulfur

4. All of the following are equal to Avogadro's number EXCEPT _____.
   a. the number of atoms of bromine in 1 mol Br₂
   b. the number of atoms of gold in 1 mol Au
   c. the number of molecules of nitrogen in 1 mol N₂
   d. the number of molecules of carbon monoxide in 1 mol CO

5. How many moles of tungsten atoms are in 4.8 \times 10^{22} atoms of tungsten?
   a. 8.0 \times 10^{-7} moles
   b. 8.0 \times 10^{-1} moles
   c. 1.3 \times 10^{-1} moles
   d. 1.3 \times 10^{-2} moles

6. How many atoms are in 0.075 mol of titanium?
   a. 1.2 \times 10^{23}
   b. 2.2 \times 10^{24}
   c. 6.4 \times 10^{2}
   d. 4.5 \times 10^{22}

7. How many molecules are in 210 mol CO₂?
   a. 2.53 \times 10^{24} molecules
   b. 3.79 \times 10^{24} molecules
   c. 3.49 \times 10^{-24} molecules
   d. 1.26 \times 10^{24} molecules

8. What is true about the molar mass of chlorine gas?
   a. The molar mass is 35.5 g.
   b. The molar mass is 71.0 g.
   c. The molar mass is equal to the mass of one mole of chlorine atoms.
   d. none of the above

9. What is the molar mass of AuCl₃?
   a. 96 g
   b. 130 g
   c. 232.5 g
   d. 303.6 g
10. What is the number of moles of beryllium atoms in 36 g of Be?
   a. 0.25 mol
   b. 4.0 mol
   c. 45.0 mol
   d. 320 mol

11. What is the mass of silver in 3.4 g AgNO₃?
   a. 0.025 g
   b. 0.64 g
   c. 2.2 g
   d. 3.0 g

12. Which combination of temperature and pressure correctly describes standard temperature and pressure, STP?
   a. 0°C and 101 kPa
   b. 1°C and 0 kPa
   c. 0°C and 22.4 kPa
   d. 100°C and 100 kPa

13. The molar mass of a gas can be determined from which of the following?
   a. the density of the gas at STP
   b. the volume of a mole of the gas
   c. Avogadro’s number
   d. none of the above

14. What is the volume, in liters, of 0.500 mol of C₂H₆ gas at STP?
   a. 0.0335 L
   b. 11.2 L
   c. 16.8 L
   d. 22.4 L

15. What is the number of moles in 9.63 L of H₂S gas at STP?
   a. 0.104 mol
   b. 0.430 mol
   c. 3.54 mol
   d. 14.7 mol

16. What is the density at STP of the gas sulfur hexafluoride, SF₆?
   a. 0.153 g/L
   b. 6.52 g/L
   c. 3270 g/L
   d. 3.93 × 10⁻²⁴ g/L

17. The molar mass of a certain gas is 49 g. What is the density of the gas in g/L at STP?
   a. 3.6 × 10⁻²⁴ g/L
   b. 0.46 g/L
   c. 2.2 g/L
   d. 71 g/L

18. A 22.4-L sample of which of the following substances, at STP, would contain 6.02 × 10²³ representative particles?
   a. oxygen
   b. gold
   c. cesium iodide
   d. sulfur

19. Given 1.00 mole of each of the following gases at STP, which gas would have the greatest volume?
   a. He
   b. O₂
   c. SO₃
   d. All would have the same volume.

20. Which of the following compounds has the highest oxygen content, by weight?
   a. Na₂O
   b. CO₂
   c. BaO
   d. H₂O
Pretest: Chemical Reactions

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

1. Chemical reactions ____.
   a. occur only in living organisms
   b. create and destroy atoms
   c. only occur outside living organisms
   d. produce new substances

2. A skeleton equation does NOT show which of the following?
   a. the correct formulas of the reactants and products
   b. the reactants on the left, the products on the right
   c. an arrow connecting the reactants to the products
   d. the relative amounts of reactants and products

3. A catalyst is ____.
   a. the product of a combustion reaction
   b. not used up in a reaction
   c. one of the reactants in single-replacement reactions
   d. a solid product of a reaction

4. 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. P(s) + O₂(g) → PO₂(g)
   b. P(s) + O(g) → P₂O₂(g)
   c. P(s) + O₂(g) → P₂O₅(s)
   d. P₂O₅(s) → P₂O₃(s) + O₂(g)

5. If you rewrite the following word equation as a balanced chemical equation, what will the coefficient and symbol for fluorine be?
   nitrogen trifluoride → nitrogen + fluorine
   a. 6F₂ c. 6F
   b. F₃ d. 3F₂

6. What are the coefficients that will balance the skeleton equation below?
   AlCl₃ + NaOH → Al(OH)₃ + NaCl
   a. 1, 3, 1, 3 c. 1, 1, 1, 3
   b. 3, 1, 3, 1 d. 1, 3, 3, 1

7. When the equation Fe + Cl₂ → FeCl₃ is balanced, what is the coefficient for Cl₂?
   a. 1 b. 2 c. 3 d. 4

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.

1
9. Chemical equations must be balanced to satisfy ___.
   a. the law of definite proportions  
   b. the law of multiple proportions  
   c. the law of conservation of mass  
   d. Avogadro’s principle

10. The product of a combination reaction is Ba(OH)\(_2\). If one of the reactants is H\(_2\)O, what is the other reactant?
   a. Ba\(_2\)O  
   b. BaO  
   c. BaH  
   d. BaO\(_2\)

11. In order to predict whether or not a single-replacement reaction takes place, you need to consult a chart that shows the ___.
   a. periodic table  
   b. activity series of metals  
   c. common polyatomic ions  
   d. ionic charges of representative elements

12. In order for the reaction 2Al + 6HCl \(\rightarrow\) 2AlCl\(_3\) + 3H\(_2\) 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.

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

14. The products of a combustion reaction do NOT include ___.
   a. water  
   b. carbon dioxide  
   c. carbon monoxide  
   d. hydrogen

15. 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

16. Which of the following statements is NOT correct?
   a. The only way to determine the products of a reaction is to carry out the reaction.  
   b. All chemical reactions can be classified as one of five general types.  
   c. Complete combustion has occurred when all the carbon in the product is in the form of carbon dioxide.  
   d. A single reactant is the identifying characteristic of a decomposition reaction.

17. In a double-replacement reaction, ___.
   a. the reactants are usually a metal and a nonmetal  
   b. one of the reactants is often water  
   c. the reactants are generally two ionic compounds in aqueous solution  
   d. energy in the form of heat and light is often produced
18. The complete combustion of which of the following substances produces carbon dioxide and water?
   a. $C_8H_{18}$
   b. $K_2CO_3$
   c. $CaHCO_3$
   d. NO

19. The reaction $2Fe + 3Cl_2 \rightarrow 2FeCl_3$ is an example of which type of reaction?
   a. combustion reaction
   b. single-replacement reaction
   c. combination reaction
   d. decomposition reaction

20. What is the driving force for the following reaction?

$$Ni(NO_3)_2(aq) + K_2S(aq) \rightarrow NiS(s) + 2KNO_3(aq)$$
   a. A gas is formed.
   b. A precipitate is formed.
   c. Ionic compounds are reactants.
   d. Ionic compounds are products.
Appendix E
Sample Attitude Survey

<table>
<thead>
<tr>
<th>STUDENT SURVEY QUESTIONS</th>
<th>Completely Disagree</th>
<th>Disagree much of the time</th>
<th>Neutral</th>
<th>Agree much of the time</th>
<th>Completely Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I liked pairing up with other students better than traditional lecture-style instruction.</td>
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<td>2. I feel like pairing up and interacting with other students helped me understand the material better.</td>
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<td>3. I feel like pairing up and interacting with other students helped me remember the material longer.</td>
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<td>4. I feel like pairing up and interacting with other students helped me to perform better on tests.</td>
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<td>5. I feel like pairing up and interacting with other students reduced my anxiety about participating in class.</td>
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<td>6. I prefer to be taught by other students rather than by a teacher.</td>
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<td>7.</td>
<td>I feel more comfortable participating if I am part of a group.</td>
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<td>8.</td>
<td>I prefer to learn and work alone.</td>
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<td>9.</td>
<td>I would prefer to ask another student to help, rather than ask the teacher.</td>
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<td>10.</td>
<td>I know more about chemistry than my classmates that were in the control group.</td>
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</tbody>
</table>
Vita

Michael Lowe is married to Ashley Lowe and they have two daughters, Katie and Abigail. After graduation from Redemptorist High School in Baton Rouge, Michael served for six years in the United States Navy and received an honorable discharge in 1995. He earned a Bachelor of Science Degree from Louisiana State University in 2000 and is currently teaching science at Episcopal High School in Baton Rouge.